PANEL ESTIMATION OF THE IMPACT OF UNCERTAINTY ON INVESTMENT IN THE INDUSTRIAL COUNTRIES

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Abstract

There is growing interest in economic uncertainty and its long run impact on investment. In previous work the authors established clear evidence of the negative impact of exchange rate uncertainty on investment in the G7, measured using a GARCH approach, and Pooled Mean Group Panel Estimation. In this paper we assess the impact on investment of temporary and permanent components of exchange rate uncertainty derived using a components GARCH model. For a poolable subsample of EU countries, results suggest that it is the transitory and not the permanent component which adversely affects investment.

Keywords: Investment; Uncertainty; Panel Estimation, Components GARCH.
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1. Introduction

There is growing interest in economic uncertainty and its long run influence on investment. Some early neoclassical models emphasised that there is a positive impact from uncertainty on investment, see Hartman (1972) and Abel (1983). Recently, following the work of Dixit and Pindyck (1994) there has been an emphasis on the deleterious impact of economic and financial volatility on investment.

Generally, empirical work tends to imply a negative impact, although zero or even positive results have also been found for some samples. For example, Goldberg (1993) and Darby et al. (1999) find evidence that exchange rate uncertainty can have significant negative long run effects on investment. Byrne and Davis (2002) found that there is formal statistical evidence of similarities between European countries in the significant negative effect of uncertainty on investment using recent developments in panel econometrics. Their work highlighted the importance of exchange rate and long rate volatility. From a UK perspective, this is interesting because differences between European countries will determine the benefits of a single currency, and the reduction in exchange rate uncertainty is one of the primary benefits of Euro Area membership.

Meanwhile, Chadha and Sarno (2002), using an unobserved-components technique employing Kalman Filtering and maximum likelihood estimation to separate permanent and transitory components of price uncertainty, have uncovered statistical evidence of a differential impact of price uncertainty on investment depending upon whether the uncertainty is long or short run, with short run volatility being most damaging. Equally, theoretical work by Baum et al. (2001) and Nucci and Pozzolo (2001) has highlighted the potential importance of separating permanent from transitory volatility in assessing the real impact of uncertainty. Baum et al. (2001) also highlight the potential for an asymmetry in response depending on the sign of the initial shock.

Developing from these strands of work, we investigate the impact on investment of permanent versus transitory components of exchange rate uncertainty, and of asymmetries in exchange rate uncertainty. We first cover briefly some relevant work on theory of uncertainty effects on investment, investment functions, empirical work on uncertainty and investment, measurement of uncertainty and panel estimation. Against this background, we then proceed to our empirical work, with firstly results for component GARCH and exponential GARCH followed by direct assessment of uncertainty in investment functions.

Our baseline is the Pooled Mean Group Panel results using GARCH exchange rate volatility as in Byrne and Davis (2002). Pooled Mean Group Panel estimations is, we contend, a useful means of conducting our analysis, given panel provides additional information and furnishes us with the ability to test differences across countries. We focus in particular on the behaviour of the UK, France, Italy and Germany and consider the differential impact on investment of temporary and permanent components of exchange rate uncertainty derived using a components GARCH model, as well as possible asymmetric effects of positive and negative shocks using EGARCH.

2 Literature survey

2.1 Uncertainty and investment

The basic intuition of an effect of uncertainty on investment stems from the option characteristics of an investment project, given the option of delaying the project and its irreversibility once begun, together with the uncertainty over future prices that will determine its profitability. The value of the option arises from the fact that delaying the project may give a more accurate view of market conditions. (see Dixit and Pindyck, 1994). The call option implies a difference between the net present value (NPV) of an investment and its current worth to the investor. To lead to expenditure, the NPV has to exceed zero so as to cover the option value of waiting. The expectation is that heightened uncertainty, by leading to delay in projects, would lead to a fall in aggregate investment. There may also be threshold effects, i.e. rates of return below which investment is not undertaken, depending on investors' risk aversion.

This contrasts with the view of Hartman (1972) and Abel (1983) who show, counter to the above, that where there is perfect competition and constant returns to scale as well as symmetric adjustment costs, an increase in uncertainty may also raise the value of a marginal unit of capital and hence the incentive to invest. Lee and Shin (2000) argue that the balance between the positive and negative effects of uncertainty may depend strongly on the labour share of firms' costs.

2.2 Investment functions

To investigate such effects empirically at a macro level requires an appropriate specification for investment. The neoclassical model of investment behaviour from Jorgenson (1963) suggests the capital stock is determined by output and the user cost of capital

$$K^* = \frac{\alpha Y}{C_k^{\sigma}} \tag{1}$$

where K^* is the desired capital stock, α is a constant, Y is the level of output, C_k is the user cost of capital and σ is the elasticity of substitution. Substituting investment for the capital stock, we obtain the following long-run relationship

$$\ln(I_t) = \theta_0 + \theta_1 \ln(Y_t) + \theta_2 \ln(C_t) \tag{2}$$

Equation (2) provides the basis for our approach to modelling investment as developed by Bean (1981) and utilised in work such as Darby et al. (1999). As set out in equation (2), the long run determination of investment is based on a simple accelerator model and presumes costs of adjustment apply to this long run equilibrium. Short run dynamics may be added to form a model in error correction format.

A different approach to the determination of aggregate investment behaviour (Tobin, 1969) argues that investment should be increasing in the ratio of the equity value of the firm to the replacement cost of the capital stock. This ratio is known as Tobin's Q or *average Q*. Consequently the investment function can be represented as

$$I = \beta Q \tag{3}$$

the parameter β is strictly positive. Further investment should be undertaken and the capital stock increased, if Q is greater than one, and vice versa for values of Q less than one. Abel (1980) and others have shown that if there are adjustment costs, then investment is dependent on the level of *marginal Q,* the ratio of the future marginal returns on investment to the current marginal costs of investment. Values of marginal Q above one will provide a stimulus to investment.

Unfortunately marginal Q is unobservable; however Hayashi (1982) demonstrated that when the production and adjustment cost functions adhere to certain homogeneity conditions (implying inter alia that there is no market power) then marginal and average Q are equal. So in practice, empirical researchers have included measures of average Q in their investment equations.[1] Often, as in Ashworth and Davis (2001), the specification chosen is a hybrid adding a term in Q to the basic neoclassical function.

2.3 Empirical work on investment and uncertainty

An extensive survey of the literature on investment and uncertainty is provided in Carruth et al. (2000). Overall, they suggest there is a broad consensus that the effect from proxy measures of uncertainty on aggregate investment is negative. This is for a wide range of model types and various methods of uncertainty proxy.

A number of issues arise in the literature. One is *choosing the variable to measure volatility*. For example, it is argued in Carruth et al. (2000) that use of stock market based measures may reveal cash flow uncertainty for the firm, but are not relevant indicators of future economic shocks and policy changes. Meanwhile macroeconomic proxies are generally partial – the exchange rate is most relevant to an exporting company for example, but less so to a producer of non-traded goods or services. In this context, Byrne and Davis (2002) assess a range of uncertainty measures including measures based on exchange rates, long term interest rates, inflation, share prices and industrial production. Only exchange rates and long rates, to a lesser extent, were found to be significant.

There is then the issue of *how to measure volatility*. Papers that have used ARCH or GARCH measures of macroeconomic variables when modelling investment include Huizinga (1993), Episcopes (1995) and Price (1995). For example, Huizinga (1993) considers volatility of US inflation, real wages and real profits and generally finds a negative effect on investment. Driver and Moreton (1991) model uncertainty using the standard deviation across 12 forecasting teams of the output growth and inflation rate of in the next 12 months. They find a negative long-run effect from output growth on investment but no long-run effect from inflation on investment. Darby et al (1999) employ the Kenen-Rodrick (1986) approach of a moving average of the variance.

A further issue is the *specification of the investment function*. One key empirical finding of Leahy and Whited (1996) is that uncertainty proxies may be irrelevant in the

[1] Cuthbertson and Gasparro (1995) find that although Tobin's Q is important for long run UK manufacturing investment, it is not a sufficient statistic. See also Sensenbrenner (1991) for evidence from 6 OECD countries.

presence of Tobin's Q. Looking specifically at work on *exchange rate uncertainty*, empirical evidence for a negative effect of exchange rate volatility on investment is provided inter alia by Goldberg (1993) for the US (using rolling standard deviations) and Darby et al. (1999) for the G7 estimated country-by-country (using the Kenen-Rodrick method outlined above). In the latter paper, investment in Germany and France was found to be negatively affected by exchange rate uncertainty, whilst there was weaker evidence for Italy and the UK and none for the US. More recent work by Darby et al. (2002) concentrates on the impact of exchange rate misalignment on investment and find evidence of non-linearities and asymmetries. They use a different measure of uncertainty, which extracts the trend component of the real exchange rate before calculating volatility. They find that volatility in the US then has a positive effect. This underlines the fact that the method of extracting volatility is important empirically.

Byrne and Davis (2002) provide evidence for similarities across the G7 in the negative response of investment to uncertainty in the nominal and real exchange rates estimated using GARCH and Pooled Mean Group Panel Estimation. This is also found in poolable subgroups including all four larger EU countries. The authors noted that to the extent EMU favours lower exchange rate and long rate volatility, it is implied to be beneficial to investment. In complementary work, Servin (2002) using GARCH measures of uncertainty, finds a negative and highly significant impact of real exchange rate uncertainty on investment using evidence from the developing countries. The impact is larger at higher levels of uncertainty – in line with analytical literature underscoring 'threshold effects'. Moreover, the investment effect of real exchange rate uncertainty is shaped by the degree of trade openness and financial development: higher openness and weaker financial systems are associated with a more significantly negative uncertainty-investment link.

The literature on exchange rate uncertainty and investment has been extended by recent theoretical studies such as Nucci and Pozzolo (2001) who derive a theoretical model where permanent changes in the exchange rate are important for the level of investment whilst changes in the transitory component are not. Recent theoretical work by Baum et al. (2001) investigates the impact of the permanent and transitory components of exchange rate uncertainty on firms' profits. They suggest that it is difficult to identify the effect of volatility of the exchange rate on *growth* in profits, since the effect of a positive change in exchange rates will be different from a negative change.[2] On the other hand there is an unambiguous result that a rise in volatility of the permanent component will boost profit *volatility* (as firms act to take advantage of permanent shifts in the rate) while a rise in temporary volatility will dampen it (as firms become more conservative under heightened uncertainty).

Empirically, a differential impact from long run and short run uncertainty in *prices* on investment is emphasised by Chadha and Sarno (2002). They find evidence of a clear link between uncertainty in the price level and investment. Moreover, they find that short-run uncertainty is more important in determining real activity than long-run uncertainty. This point was also raised by Ball and Cecchetti (1990) when considering the impact of uncertainty in inflation of the level of inflation itself. In related work, Darby et al. (1999) examined the impact of deviations from equilibrium relationships as important factors underlying the response of investment to exchange rate uncertainty.

2.4 Volatility Measurement

As mentioned in the section above, there are a numbers of ways of modelling the impact of uncertainty on investment. These include simple rolling standard deviations or variance, and time series conditional heteroscedastic methods. Focusing on the latter, Engle (1982) introduced ARCH methodology which has been extended to incorporate lagged dependent variable in the conditional variance (GARCH). This method is presumed to capture risk in each period to a greater extent that simple rolling standard deviations. As noted above, GARCH methods have been used to derive measures of uncertainty and numerous studies have found a relationship between this variable and investment.

As set out in Bollerslev (1986), GARCH (p,q) models are of the form,

$$v_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i v_{t-i} \tag{4}$$

where ε_t is serially uncorrelated with mean zero, but the conditional variance of ε_t equals v_t, which may be changing through time. In most applications, ε_t refers to the innovation in the mean for some other stochastic process, say $\{y_t\}$ where

$$y_t = g(x_{t-1}; \beta) + \varepsilon_t \tag{5}$$

[2] We accommodate this by incorporating income into our regression analysis: any effect of a permanent devaluation should feed through that variable. We also test directly for uncertainty measures with asymmetries via use of EGARCH.

and $g(x_{t-1};\beta)$ denotes a function of x_{t-1} and the parameter vector β, where x_{t-1} is in the time *t-1* information set.

To ensure a well-defined process, all the parameters in the infinite order AR representation must be non-negative, where it is assumed that the roots of the polynomial lie outside the unit circle. For a GARCH(1,1) process this amounts to ensuring that both α_1 and β_1 are non-negative. It follows also that ε_t is covariance stationary if and only if $\alpha_1+\beta_1<1$.

An interesting development of the basic GARCH model is the so-called components GARCH (CGARCH) of Engel and Lee (1999). They set out the GARCH(1,1) model as characterised by reversion to a mean ($\overline{w}$) which is constant through time:

$$\sigma_t^2 = \overline{w} + \alpha\left(\varepsilon_{t-1}^2 - \overline{w}\right) + \beta\left(\sigma_{t-1}^2 - \overline{w}\right) \tag{6}$$

The components model allows mean reversion to a varying level q_t using an autoregressive term ρ, modelled as

$$\sigma_t^2 - q_t = \overline{w} + \alpha\left(\varepsilon_{t-1}^2 - \overline{w}\right) + \beta\left(\sigma_{t-1}^2 - \overline{w}\right) \tag{7}$$

$$q_t = w + \rho\left(q_{t-1} - w\right) + \phi\left(\varepsilon_{t-1}^2 - \sigma_{t-1}^2\right) \tag{8}$$

Equation (7) defines the temporary component ($\sigma_t^2 - q_t$), whilst equation (8) is the permanent equation. This model solves for a GARCH(2,2) specification. When $0<(\alpha+\beta)<1$, short run volatility converges to its mean of 0, while if $0<\rho<1$ the long run component converges to its mean of $w/(1-\rho)$. As the long run volatility is more persistent than the short run, it is also assumed that $0<(\alpha+\beta)<\rho<1$. For negative variance to be ruled out, sufficient conditions are that α, β and w are positive and that $\beta > \varphi > 0$.

An objection to both GARCH and CGARCH is that they assume symmetry between positive and negative shocks in terms of their effect on conditional volatility. For example, it is plausible that a negative shock to exchange rates gives rise to higher uncertainty as it could entail heightened expectations of a speculative attack.

The Exponential GARCH model was introduced by Nelson (1991) with the following specification.

$$\log\sigma_t^2 = w + \beta\log\sigma_{t-1}^2 + \alpha\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} \tag{9}$$

Hence the EGARCH describes the relationship between the past shocks and the log of the conditional variance. Since it is specified in logs, no parameter restrictions have to be imposed to ensure that the conditional variance is non negative. Negative shocks have an impact of $\alpha - \gamma$ on the log of the conditional variance and positive shocks have an effect of $\alpha + \gamma$. Hence there is an asymmetry if $\gamma \neq 0$. For example, if $\gamma < 0$, $0 < \alpha < 1$ and $\alpha + \beta < 1$, negative shocks have a larger effect on conditional variance than positive shocks of the same size.

2.5 Panel Estimation

The impact of uncertainty on investment is usefully captured in a cross-country sample by using Pesaran, Shin and Smith's (1999) Pooled Mean Group Estimator (PMGE) for dynamic heterogeneous panel models. Panel methods have become popular in cross sectional macro data sets, since they provide greater power that individual country studies and hence greater efficiency.

Pesaran et al. emphasise that there are two traditional methods when estimating panel models: averaging and pooling. The former involves running *N* separate regressions and calculating coefficient means (see for example the Mean Group Estimator method suggested by Pesaran and Smith, 1995). A drawback to averaging is that it does not account for the fact that certain parameters may be equal over cross sections. Alternatively, pooling the data typically assumes that the slope coefficients and error variances are identical. This is unlikely to be valid for short-run dynamics and error variances, although it could be appropriate for the long run.

Pesaran et al. (1999) proposed the PMGE method, which is an intermediate case between the averaging and pooling methods of estimation and involves aspects of both. The PMGE method restricts the long-run coefficients to be equal over the cross-section, but allows for the short-run coefficients and error variances to differ across groups on the cross-section. We can obtain, therefore, pooled long-run coefficients and averaged short run dynamics as an indication of mean reversion.

The PMGE is based on an Autoregressive Distributive Lag ARDL(p,q,…,q) model

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \delta'_{ij} \mathbf{x}_{it-j} + \mu_i + \varepsilon_{it} \qquad (10)$$

where $\mathbf{x}_{it}$ (kx1) is the vector of explanatory variables for group i, μ_i represents the fixed effects, the coefficients of the lagged dependent variables (λ_{ij}) are scalars and δ_{ij} are (kx1) coefficient vectors. T must be large enough so that the model can be estimated for each cross section.

Equation (10) can be re-parameterised as:

$$\Delta y_{it} = \phi_i y_{it-1} + \beta_i' \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{it-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*}{}' \Delta \mathbf{x}_{it-j} + \mu_i + \varepsilon_{it} \tag{11}$$

where $\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right)$, $\beta_i = \sum_{j=0}^{q} \delta_{ij}$, $\lambda_{ij}^* = -\sum_{m=j+1}^{p} \lambda_{im}$ and $\delta_{ij}^* = -\sum_{m=j+1}^{q} \delta_{im}$

In addition we assume that the residuals in (11) are *i.i.d.* with zero mean, variance greater than zero and finite fourth moments. Secondly, the roots of equation (11) must lie outside the unit circle. The latter assumption ensures that $\phi_i<0$, and hence that there exist a long-run relationship between y_{it} and $\mathbf{x}_{it}$ defined by

$$y_{it} = -(\beta_i' / \phi_i) \mathbf{x}_{it} + \eta_{it} \tag{12}$$

The long-run homogeneous coefficient is equal to $\theta = \theta_i = -(\beta_i' / \phi_i)$, which is the same across groups. The PMGE uses a maximum likelihood approach to estimate the model and a Newton-Raphson algorithm. The lag length for the model can be determined using, for instance, the Schwarz Bayesian Information Criteria. The estimated coefficients in the model are not dependent upon whether the variables are I(1) or I(0). The key feature of the PMGE is to make the long-run relationships homogenous while allowing for the heterogeneous dynamics and error variances.

2.6 Specification

Drawing on the insights provided in the discussion of Sections 2.1-2.5, we estimated the impact of exchange rate uncertainty in a neoclassical investment function which also allows for the influence of Tobin's Q. Estimation was carried out using Pooled-Mean-Group estimation with exchange-rate uncertainty proxies estimated by CGARCH and EGARCH.

As a baseline we first set out the main result of Byrne and Davis (2002) using a simple GARCH (1,1) approach. This was itself a considerable advance on previous work for adopting the PMGE approach and testing for poolability. We sought to further refine the approach to investment and exchange rate uncertainty adopting the insights of Chadha and Sarno (2002) by decomposing uncertainty into a permanent and transitory component. However, our approach uses the Engle and Lee (1999) approach to modelling GARCH, in contrast to the methods of Chadha and Sarno (2002) who utilise a unobserved components model and maximum likelihood estimation to identify the permanent and temporary aspects of uncertainty. The authors also consider their methods in terms of single equation estimation for each country, and we try to move beyond this with panel estimation. Finally, we focus on exchange rate uncertainty whereas Chadha and Sarno look at price level uncertainty.

Additionally we consider the point raised by Baum et al. (2001) that there are asymmetries from exchange rate uncertainty depending on whether they link to appreciation or depreciation by employing the EGARCH approach, which allows for such asymmetries in conditional volatility generation from positive and negative shocks.

In our estimation, besides using PMGE, we also calculated the Mean Group (MGE) estimator, which is an average of the individual country coefficients. This provides consistent estimates of the mean of the long-run coefficients although they are inefficient if slope homogeneity holds. Under long-run homogeneity, PMG estimates are consistent and efficient. We test for long-run homogeneity using a joint Hausman test based on the null of equivalence between the PMG and MG estimation (see Pesaran, Smith and Im, 1996, for details). If we reject the null (obtain a probability value of less that 0.05), we reject homogeneity of our cross section's long run coefficients. Significant statistical difference between our two estimators would be indicative of panel misspecification. The likelihood ratio test for long run parameter heterogeneity is much more conventional in this setting and has homogeneity as the null hypothesis (see Hsiao, 1986).

3. Results

3.1 Data

The main source of data for the G7 countries is the OECD Business Sector Database. A typical problem with private sector investment data is the distortion caused by transfer of ownership e.g. in privatisations. Our quarterly OECD data set circumvents this problem by incorporating business investment and output irrespective of ownership. Our exchange rate data is obtained from Primark Datastream.

3.2 GARCH estimation

The results for the CGARCH are presented in Table 1 below. It can be seen that the transitory equations are fairly conventional with significant positive ARCH terms of 0.07-0.43. The GARCH terms in the transitory equations are more variable, with those for the UK and Germany being insignificant (implying a simple ARCH is appropriate) and that for Japan being negative. Stability of short run volatility is established (the sum of coefficients being between zero and one) except for Japan. As regards the determinants of the long run component, there is a positive constant, which is significant except for Italy, and a very large autoregressive component, implying slow convergence of permanent volatility on its mean level. The size of the autoregressive component exceeds that of the transitory components, implying slower mean reversion in the long run. The component is below one in all cases, implying the process is stable. Finally the permanent ARCH less GARCH term is significant except in the US and is negative in Canada and France, positive elsewhere, implying potential negative volatility in those countries. The charts appended show the transitory and permanent components of volatility for the G7 countries.

Table 1: Components GARCH estimate for nominal effective exchange rate

	UK	US	Germany	Japan	Canada	France	Italy
Perm: C (w)	**0.00177 (0.0013)**	0.00061 (0.00015)	**0.0001 (1.01E-05)**	**0.00118 (0.00099)**	**0.000112 (1.18E-05)**	**0.0001 (6.97E-06)**	0.0041 (0.0147)
Perm [q-c] (ρ)	**0.998 (0.001)**	**0.997 (0.00059)**	**0.934 (0.033)**	**0.997 (0.0019)**	**0.981 (0.038)**	**0.814 (0.04)**	**0.998 (0.004)**
perm [arch-garch] (φ)	**0.043 (0.017)**	-0.017 (0.019)	**0.027 (0.035)**	**0.022 (0.00018)**	**-0.053 (0.018)**	**-0.192 (0.058)**	**0.243 (0.06)**
Tran [arch-q] (α)	**0.37 (0.06)**	**0.079 (0.03)**	**0.132 (0.054)**	**0.179 (0.048)**	**0.0973 (0.04)**	**0.434 (0.018)**	**0.334 (0.053)**
Tran [garch-q] (β)	0.168 (0.136)	**0.882 (0.04)**	0.417 (0.26)	**-0.27 (0.13)**	**0.725 (0.079)**	**0.217 (0.032)**	**0.402 (0.089)**

Notes: Standard errors in parentheses. Bold indicates significance at 5%

Table 2: EGARCH (asymmetric) estimate for nominal effective exchange rate

	UK	US	Germany	Japan	Canada	France	Italy
Constant (w)	**-1.4 (0.22)**	-0.375 (0.06)	**-2.7 (0.62)**	**-0.14 (0.00055)**	**-0.75 (0.147)**	**-8.7 (1.93)**	**-2.77 (0.245)**
Absolute (res/garch) (-1) (α)	**0.485 (0.06)**	**0.06 (0.026)**	**0.354 (0.049)**	**-0.064 (0.007)**	0.038 (0.05)	**0.39 (0.062)**	**0.998 (0.04)**
res/garch (-1) (γ)	-0.064 (0.042)	-0.005 (0.018)	**0.107 (0.035)**	**-0.057 (0.015)**	**-0.079 (0.033)**	0.064 (0.052)	-0.0089 (0.038)
EGARCH (-1) *(β)*	**0.875 (0.022)**	**0.96 (0.0052)**	**0.74 (0.066)**	**0.974 (0.0006)**	**0.922 (0.013)**	0.086 (0.21)	**0.775 (0.024)**

Notes: Standard errors in parentheses. Bold indicates significance at 5%

The results for the EGARCH are given in Table 2. We noted above that there are no required constraints on signs for avoiding negative volatility since the specification is set out in logs. In fact asymmetric effects are only significant in Germany, Japan and Canada. In Japan and Canada it is negative shocks that give rise to heightened volatility and in Germany it is appreciation (probably a reflection of ERM crises when the DM was under upward pressure).

3.3 Panel Estimation

We now go on to present the results of PMGE and MGE estimation. The Likelihood Ratio (LR) test statistic and the Hausman test statistic (both distributed as χ^2) examine panel heterogeneity. The LR statistic always suggests that homogeneity is not a reasonable assumption in the Pesaran et al. (1999) study of aggregate consumption and, as such, can be considered a much more stringent test for poolability than the Hausman test (which typically accepts poolability in the Pesaran et al. study). We focus largely on the LR test in the following results.

As a baseline, Table 3 replicates the result of Byrne and Davis (2002) using GARCH (1,1). Columns 1 and 2 show the results for PMG and MGE estimation of our basic investment function in the G7 with nominal exchange rate uncertainty effects. We show estimated long run coefficients of business output, ln(YB), the conditional variance of the nominal effective exchange rate, estimated error correction terms, the Likelihood Ratio and Hausman statistics. In the equation, the long run elasticity on output is significant and the estimated coefficient is slightly larger than one in magnitude. Also, the error correction term is significant and gives evidence of mean reversion to a long-run relationship. User cost was omitted as insignificant In terms of the measures of volatility, we find that the measure of nominal exchange rate uncertainty is significant in influencing long-run business investment across the G7 with a PMG estimated elasticity of –8.018. We see from the probability values associated with the Hausman test of equivalence of PMG and MG that it accepts (p-value > 0.05) and hence, according to this test there is parameter homogeneity across the G7 as a whole. However, we cannot accept parameter homogeneity for the LR test for nominal (test statistic $\chi^2\{12\} = 30.72$, whilst the critical value is 21.03). This suggests a need to focus on subgroups, and indeed as shown in columns 4 and 5, the EU-4 of the UK, France, Germany and Italy do allow for pooling as well as having a significant exchange rate effect.

Table 4 shows the results in the G7 of the estimation of separate components of the CGARCH separately and together. The results shows that neither transitory nor permanent volatility has a significant effect on investment. Although, there is some evidence of a negative effect from the transitory component at the 10% significance level. However poolability is not accepted by the LR test.

Table 3: Panel Estimation of Investment and Exchange Rate Uncertainty: G7 and EU-4 Countries

	PMGE	MGE	PMGE	MGE
	G7		**EU4**	
Ln(YB)	**1.346** **(24.944)**	**1.439** **(11.637)**	**1.233** **(21.371)**	**1.202** **(63.534)**
CV(DER)	**-8.018** **(2.887)**	**-25.198** **(2.097)**	**-11.808** **(3.312)**	**-12.670** **(2.852)**
Error Correction	**-0.077** **(5.270)**	**-0.083** **(4.431)**	**-0.094** **(3.855)**	**-0.097** **(4.578)**
Likelihood (Unrestricted)	1652.252 (1667.613)		935.335 (937.006)	
LR Statistic χ^2 {df}	**30.72 {12}** **[p=0.00]**		4.19 {6} [0.65]	
Hausman χ^2 {df}	3.44 {12} [0.18]		Na	

Notes: Dependent variable Business Investment. PMGE is Pooled Mean Group Estimation. MGE is Mean Group Estimation. Sample period 1973Q1 to 1996Q4. T statistics are in parentheses. P-values are in brackets. The lag structure is determined by the Schwarz Bayesian Criteria. The LR Statistic is a likelihood ratio test for the null hypothesis of poolability. Hausman test for poolability is a test for the equivalence of PMGE and MGE. If the null hypothesis is accepted (i.e. p-value greater than 0.05) we can accept homogeneity of cross sectional long run coefficients. CV(.) is the conditional variance from GARCH estimation. DER is the first difference of the nominal effective exchange rate.

Table 4: Panel Estimation of Investment and Exchange Rate Uncertainty: G7 Countries

	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.365 (27.7)**	**1.383 (20.1)**	**1.359 (26.178)**	**2.35 (2.51)**	**1.362 (25.922)**	**2.064 (3.126)**
CV(PERM)	7.776 (0.131)	42.636 (0.666)			-28.105 (0.42)	120.177 (0.892)
CV(TEMP)			-150.5 (1.677)	-6383 (1.166)	-153.812 (1.696)	-4792 (1.237)
Error Correction	**-0.083 (6.503)**	**-0.092 (5.784)**	**-0.08 (5.84)**	**-0.082 (4.23)**	**-0.080 (5.926)**	**-0.082 (4.232)**
Likelihood (Unrestricted)	1648.712 (165.620)		1652.139 (1670.381)		1652.565 (1675.343)	
LR Statistic χ^2 {df}	11.815 [0.46]		**36.484 [0.00]**		**45.56 [0.00]**	
Hausman χ^2 {df}	Na		Na		Na	

Notes: See Table 3, also CV (PERM) represents permanent component from CGARCH, CV (TEMP) the corresponding transitory component. These results are for the G7: the US, Canada, Japan, Italy, France, Germany and the UK.

On the basis of the relevance for EMU, our CGARCH results and also the pooling results above, we then focused our attention on nominal exchange rate volatility in the EU-4 of the UK, Italy, France and Germany. Table 5 shows the results and we see that for the temporary component alone the t-value is significant and also when the temporary and permanent components are entered together. Concerning poolability, this is accepted with the LR test for all results except temporary and permanent together (columns 6 and 7).

Table 5: Panel Estimation of Investment and Exchange Rate Uncertainty: EU-4 Countries

	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.293 (22.844)**	**1.290 (23.551)**	**1.278 (22.414)**	**1.237 (33.833)**	**1.278 (21.850)**	**1.229 (41.423)**
CV(PERM)	23.664 (0.368)	97.149 (1.122)			-44.170 (-0.613)	50.163 (0.353)
CV(TEMP)			**-361.123 (-2.343)**	-614.115 (-1.863)	**-406.621 (-2.415)**	-641.930 (-1.824)
Error Correction	**-0.104 -4.353)**	**-0.104 -4.370)**	**-0.095 (-3.997)**	**-0.098 (-4.574)**	**-0.091 (-3.986)**	**-0.097 (-4.530)**
Likelihood (Unrestricted)	927.582 (930.016)		931.234 (936.887)		931.722 (941.676)	
LR Statistic χ^2 {df}	4.867{6} [0.561]		11.305{6} [0.079]		**13.826 {9} [0.032]**	
Hausman χ^2 {df}	Na		Na		Na	

Notes: See Table 3, also CV (PERM) represents permanent component from CGARCH, CV (TEMP) the corresponding transitory component. These results are for France, Germany, Italy and the UK.

Table 6: Panel Estimation of Investment and Exchange Rate Uncertainty: EU-4 Countries with Tobin's Q

	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.276 (19.373)**	**1.266 (5.884)**	**1.238 (17.715)**	**1.144 (8.558)**	**1.227 (16.223)**	**1.138 (8.860)**
TOBIN'S Q	0.061 (0.511)	-0.268 (-0.950)	0.159 (0.949)	-0.093 (-0.501)	0.186 (1.016)	-0.088 (-0.498)
CV(PERM)	23.722 (0.367)	86.718 (0.969)			-56.452 (-0.762)	40.721 (0.284)
CV(TEMP)			**-453.762 (-2.437)**	-603.640 (-1.848)	**-545.412 (-2.571)**	-637.284 (-1.813)
Error Correction	**-0.103 (-4.41)**	**-0.099 (-4.136)**	**-0.089 (-3.695)**	**-0.096 (-4.742)**	**-0.084 (-3.570)**	**-0.096 (-4.737)**
Likelihood (Unrestricted)	927.730 (932.411)		931.744 (938.559)		932.301 (943.279)	
LR Statistic χ^2 {df}	9.360{9} [0.56]		13.629{9} [0.14]		**21.956 {12} [0.04]**	
Hausman χ^2 {df}	**271.92** {9} **[0.00]**		Na		Na	

Notes: See Table 3, also CV (PERM) represents permanent component from CGARCH, CV (TEMP) the corresponding transitory component. These results are for France, Germany, Italy and the UK.

We then sought to assess a variant on these results including Tobin's Q in the estimation, also to test the empirical finding of Leahy and Whited (1996) that uncertainty proxies may be irrelevant in the presence of Q. In fact the transitory component remains significant, while poolability is again suggested for all but the two-component specification. Tobin's Q itself is not significant, a result which contrasts with the G7 results shown in Byrne and Davis (2002).

In our final set of results we investigated whether the inclusion of the EGARCH results, allowing for asymmetric responses of conditional volatility to change in the exchange rate, made a difference to the results. Table 7 shows results with a without Q. Looking first at the G7, we find that an asymmetric measure of GARCH is significant for the G7 but there is no evidence for poolability

We undertook similar estimation for the EU-4. In the basic case the nominal exchange rate is significant but poolability is not indicated. However, when Tobin's q is added we also accept poolability.

Table 7: Panel Estimation of Investment and Uncertainty: G7 Countries EGARCH

	PMGE	MGE	PMGE	MGE
ln(YB)	**1.465 (21.859)**	**1.239 (6.224)**	**1.310 (22.864)**	**0.962 (3.722)**
TOBIN'S Q			**0.265 (2.998)**	0.616 (1.295)
CV(DER)	**-280.845 (-2.484)**	-131.376 (-0.104)	**-307.296 (-2.771)**	216.84 (0.144)
Error Correction	**-0.069 (-5.979)**	**-0.076 (-3.434)**	**-0.074 (-5.229)**	**-0.081 (-3.558)**
Likelihood (Unrestricted)	1646.136 (1667.913)		1649.387 (1679.189)	
LR Statistic χ^2 {df}	**43.555 {12} [0.00]**		**59.604{18} [0.00]**	
Hausman χ^2 {df}	**7.86 {12} [0.02]**		**18.30 {18} [0.00]**	

Notes: Dependent variable Business Investment. PMGE is Pooled Mean Group Estimation. MGE is Mean Group Estimation. Sample period 1973Q1 to 1996Q4. T statistics are in parentheses. P-values are in brackets. The lag structure is determined by the Schwarz Bayesian Criteria. The LR Statistic is a likelihood ratio test for the null hypothesis of poolability. Hausman test for poolability is a test for the equivalence of PMGE and MGE. If the null hypothesis is accepted (i.e. p-value greater than 0.05) we can accept homogeneity of cross sectional long run coefficients. CV(.) is the conditional variance from EGARCH estimation. DER is the first difference of the nominal effective exchange rate.

Table 8 Panel Estimation of Investment and Uncertainty: EU4 Countries EGARCH

	PMGE	MGE	PMGE	MGE
Ln(YB)	**1.273 (23.296)**	**1.216 (25.579)**	**1.188 (15.552)**	**1.091 (7.547)**
TOBIN'S Q			0.262 (1.193)	-0.034 (-0.195)
ECV(DER)	**-294.348 (-2.213)**	-1070.079 (-1.574)	**-644.395 (-2.287)**	-1096.323 (-1.605)
Error Correction	**-0.097 (-3.582)**	**-0.096 (-4.395)**	**-0.078 (-2.808)**	**-0.092 (-4.685)**
Likelihood (Unrestricted)	931.898 (938.482)		932.046 (940.417)	
LR Statistic χ^2 {df}	**13.168{6} [0.040]**		16.743 {9} [0.053]	
Hausman χ^2	Na		Na	

Notes: Dependent variable Business Investment. PMGE is Pooled Mean Group Estimation. MGE is Mean Group Estimation. Sample period 1973Q1 to 1996Q4. T statistics are in parentheses. P-values are in brackets. The lag structure is determined by the Schwarz Bayesian Criteria. The LR Statistic is a likelihood ratio test for the null hypothesis of poolability. Hausman test for poolability is a test for the equivalence of PMGE and MGE. If the null hypothesis is accepted (i.e. p-value greater than 0.05) we can accept homogeneity of cross sectional long run coefficients. ECV(.) is the conditional variance from EGARCH estimation. DER is the first difference of the nominal effective exchange rate. EU4 represents France, Germany, Italy and the UK.

4. Conclusion

In this paper we deepen earlier analyses of exchange rate uncertainty and its impact on investment by assessing the impact on investment of temporary and permanent components of exchange rate uncertainty derived using a components GARCH model and allowing for asymmetric responses to exchange rate changes using an EGARCH. For a poolable subsample of EU countries, it is the transitory and not the permanent component which adversely affects investment. The results imply that to the extent that EMU favours lower transitory exchange rate volatility, it will also be beneficial to investment. Equally, there is some support for asymmetries in uncertainty in Germany, Japan and Canada, and the results for investment functions suggest that the conditional variances derived are successful in an investment function specification for the EU-4 including Tobin's Q.

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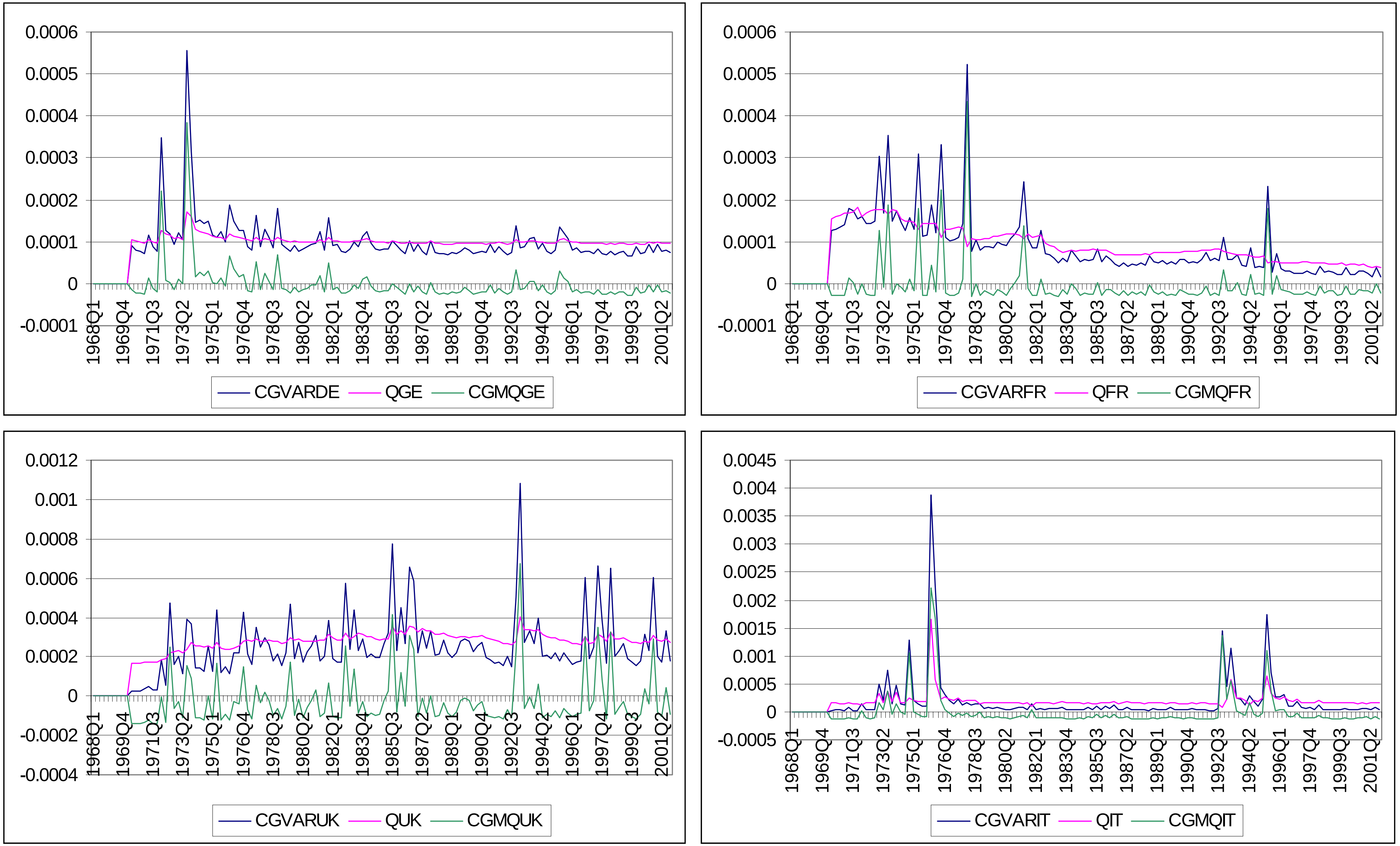
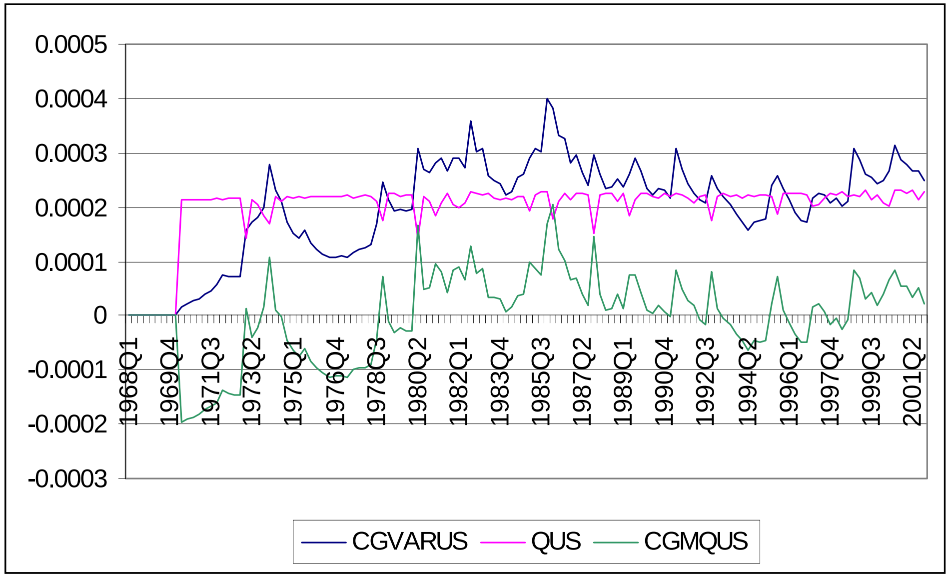
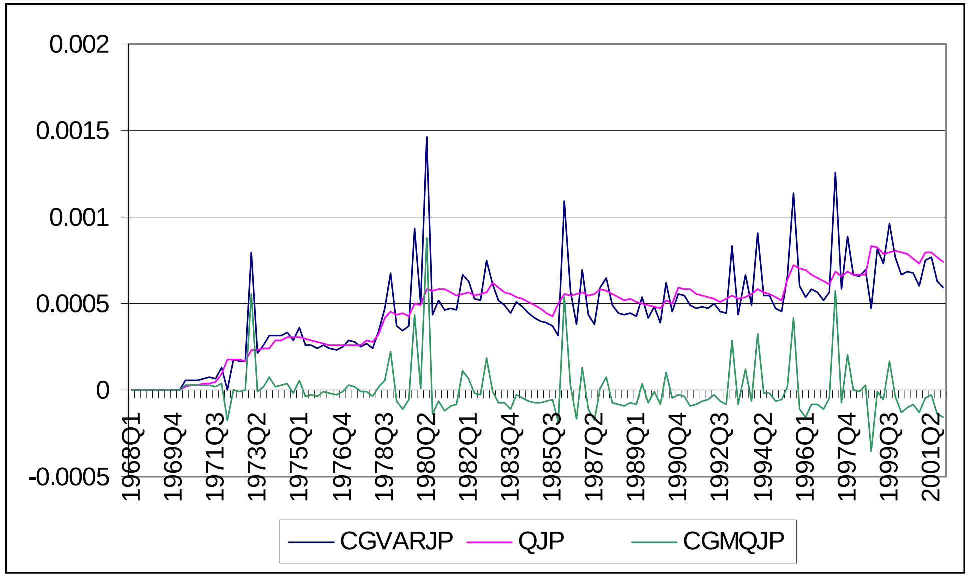
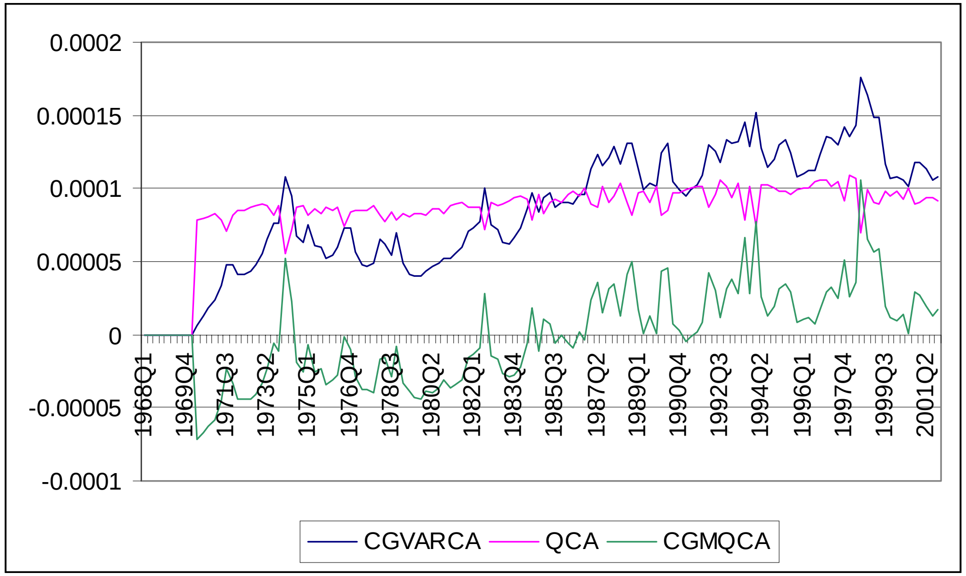


Transitory (CGMQ) and Permanent (Q) component measures of volatility for the Germany, France, UK and Italy.







Transitory (CGMQ) and Permanent (Q) component measures of volatility for the US, Japan and Canada.