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INVESTMENT AND UNCERTAINTY IN THE G7

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Abstract

In this paper we assess the impact of a comprehensive range of macroeconomic and financial measures of uncertainty on business investment in the major industrial countries using Pooled Mean Group Panel Estimation. We discover a significant negative long run effect from both nominal and real exchange rate volatility using a GARCH (1,1) approach on aggregate investment for the G7. This is also found in poolable subgroups including all four larger European countries. Results for an adverse impact of uncertainty on investment are also found for volatility of long rates in recent years but not for inflation, share prices and industrial production. The results imply that to the extent that EMU favours lower exchange rate and long interest rate volatility, it will also be beneficial to investment.

Keywords: Investment; Macroeconomic Uncertainty; Panel Estimation.

JEL Classification Numbers: E22, F31.

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1. Introduction

The benefits of macroeconomic stability are increasingly emphasised by policy makers. This has followed but also underpinned a growing academic interest in economic uncertainty and its effects on macroeconomic variables. For example, there is recent empirical work on the effect of uncertainty on aggregate output growth, with some authors coming to the view that it is generally harmful (Kneller and Young, 2000), although others suggest this depends on the source of the shocks, whether real or nominal (see Blackburn and Pelloni, 2001).

Output growth is crucially dependent upon business investment and the focus of this paper is the relationship between the latter and uncertainty. The two main strands of theoretical literature on this relationship come to different conclusions. The call option approach considers that there is a benefit to await the arrival of new information in an uncertain environment with irreversible investment. Consequently, increased uncertainty requires an investment project to have a greater net present value than would otherwise be the case to justify it (see Dixit and Pindyck, 1994), and increased uncertainty reduces investment. In contrast, Hartman (1972) and Abel (1983) suggest that increased uncertainty raises investment where the marginal product of capital is an increasing function of prices and increases in the variance of prices will increase the expected return.

While there is an extensive empirical literature on uncertainty and investment (see the review in Carruth, Dickerson and Henley 2000b), it is mainly undertaken on the basis of one country or one indicator. Carruth et al. (2000b, page 129) are of the view that the broad consensus is that the relationship is negative and this consensus emerges from a wide range of models and alternative methods of proxying uncertainty. On the other hand, Huizinga (1993) suggests that effects vary depending on the source of uncertainty. To give one example, differing results for exchange rate volatility have been found by authors such as Goldberg (1993) and Darby, Hughes Hallett, Ireland and Piscittelli (1999) depending on the countries studied and the data period used.

Recently, panel econometric methods have become popular in multi-country macroeconomic studies. These methods, which have both a time series and cross sectional dimension, are a means of increasing the efficiency of parameter estimates when testing a particular long run hypothesis. However when adopting this approach it is important to test for cross sectional heterogeneity to ensure that panel estimates are not biased due to unreasonable pooling of countries. Taking account of these factors we conduct a multi-country study of investment and uncertainty using Pesaran, Shin and Smith's (1999) Pooled Mean Group

Estimation (PMGE). We assess long term effects on investment of measures of conditional volatility taking account of heteroscedasticity (estimated errors in a GARCH (1,1) equation), and short term dynamic effects our uncertainty proxies on investment. The indicators used include both financial variables (equity price, interest rates and exchange rates) and macroeconomic variables (e.g. prices and inflation). In an Appendix we also assess simpler measures of volatility (based on moving average standard deviations or variances[1]).

We come to the conclusion that the source of volatility measures typically does matter, as does the way that it is modelled. Besides the general interest in such work, the effect of uncertainty on investment is an important aspect of the benefits of EMU membership for the UK and current incumbents, since EMU is likely to remove part of exchange rate volatility and, possibly, part of long rate volatility also. The empirical approach of this paper is basically to estimate investment functions which are partly common across countries based on PMG panel estimation methods, while paying particular attention to whether country homogeneity is accepted by the data. The paper is structured as follows. First we provide a brief overview of the literature on investment functions, then at somewhat greater length cover the issue of uncertainty and investment. In Section 3 we set out the data, and in Section 4 we consider panel results whilst Section 5 draws conclusions.

2. Literature Survey

2.1 Theory of investment and effects of uncertainty

Modern theories of aggregate investment behaviour in the literature and resultant empirical work have developed from the neo-classical model first proposed by Jorgensen (1963) and the Tobin's Q model originally due to Tobin (1969) and Brainard and Tobin (1968). The neo-classical model is itself an extension of the simple accelerator models, but augmented to include the effects of relative price variables, specifically the user cost of capital. This is computed from the purchase cost of the additional capital, the rates of interest and depreciation and the levels of relevant taxes. Alternatively, the Q-theory of investment argues that the level of investment is determined by the average Q statistic, defined as the financial value of the firm relative to the replacement cost of its capital.[2]

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[1] Note that while measures based on variance and standard deviation are often referred to as unconditional, the fact that the measures usually take rolling averages implies that there is conditionality in these measures also.

[2] Both Chirinko (1993) and Caballero (1999) provide excellent surveys of modern developments in the investment literature.

In the neo-classical model, the firm maximises the discounted flow of all future profits, with adjustment costs assumed to be absent. If we assume that the production function is characterised by a constant elasticity of substitution between capital and other inputs, then we can obtain the following familiar relationship between the desired capital stock, the level of output and the user cost of capital, from the static first order conditions of the firm's maximisation problem

$$K^{*} = \frac{\alpha Y}{C_k^{\sigma}} \qquad (1a)$$

where K^{*} is the desired level of the capital stock, Y is the level of output, C_k is the user cost of capital (otherwise referred to as the rental cost), α is a function of capital and labour and other factors, and σ is the elasticity of substitution parameter between inputs in the production function. The user cost of capital is usually defined as

$$C_k = P_k(r+\delta)\frac{(1-tdep-tcred)}{(1-t)} \qquad (1b)$$

where P_k is the purchase price of a unit of capital, r is the real post-tax financial cost of capital, δ is the depreciation rate of capital (assumed to be geometric), *tcred* is the rate of investment tax credit, *tdep* is the discounted rate of depreciation tax allowances and t is the rate of corporation tax.

By assuming either that net investment is determined as a distributed lag process of changes in the desired capital stock, or that there are explicit costs of adjustment, it is possible to obtain an investment function for empirical estimation that equates the level of investment to lags of the change in the level of output and the user cost of capital. This is illustrated in the following four equations, where equations (2a) and (2b) show the evolution of investment in terms of K, the capital stock, (where δ is the depreciation rate and g is the steady state growth rate), (2c) integrates this into the equation (1a) and (2d) sets out the equation in logarithmic form.

$$I = \delta K + dK \qquad (2a)$$

$$I = (g+\delta)K \qquad (2b)$$

$$I = A(g+\delta)Y / C^{\varepsilon} \qquad (2c)$$

$$\ln(I_t) = \theta_0 + \theta_1 \ln(Y_t) - \varepsilon \ln(C_t) \qquad (2d)$$

An alternative formulation of aggregate investment behaviour, originally developed by Tobin (1969) and Brainard and Tobin (1968) argues that investment should be an increasing function of the ratio of the capitalised financial value of the firm relative to the replacement (purchase) cost of the unit of capital. This ratio is known as Tobin's Q or *average Q*. We can write the investment equation most simply as

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

where β is a strictly positive parameter. If Q is greater than one then the investment should be undertaken and the capital stock increased, whereas for values of Q less than one further investment should not be undertaken and the capital stock should in fact be reduced. Abel (1980), Hayashi (1982) and Lucas and Prescott (1971) have shown that if Tobin's Q is included in the firm's optimisation problem with adjustment costs, then investment is dependent on the level of *marginal Q*. Marginal Q is the ratio of the future marginal returns on investment, relative to the current marginal costs of investment. Values of marginal Q above one will provide a stimulus to investment. Marginal Q is unobservable; however Hayashi 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.[3] Unfortunately the Q model's empirical performance has been generally unsatisfactory and there are additional difficulties in using Q to forecast, centred on the need to project equity prices forward, (for recent work on Q see Cooper and Ejarque, 2001). In our investment specification shown in Section 4 and used as a basis for testing uncertainty we use a basic neoclassical specification and test for Tobin's Q effects based on average Q.

In the context of these structures, 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 stems 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.

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[3] See Cuthbertson and Gasparro (1995) for empirical results on the significance of Tobin's Q in investment decisions in UK manufacturing and Sensenbrenner (1991) for evidence from 6 OECD countries. In particular, Cuthbertson and Gasparro find that although Tobin's Q is important for long run UK investment, it is not a sufficient statistic.

Following the derivation in Pindyck and Solimano (1993), one may consider at what point it is worth paying a sunk cost I for a project whose present value is V, if V evolves according to geometric Brownian motion, where dz is the increment of a Wiener process.

$$dV = \alpha V dt + \sigma V dz \tag{4}$$

The equation implies that the current value of a project is known but future values are lognormally distributed with a variance growing linearly with the time horizon. Even as information arises and V evolves, the future value of the project is always uncertain. The investment rule is to maximise the value of the investment opportunity F(V). The payoff from investing at any given time t is V-I, so the maximand subject to equation (4) is:

$$F(V) = \max E[(V_T - I)e^{-\rho T}] \tag{5}$$

where T is the future time when the investment is made, and ρ is a discount rate. It is assumed α<ρ or the firm would never invest, and we define δ as ρ-α. The solution gives an optimal investment rule in the form of a critical value V^* so it is optimal to invest when $V \geq V^*$ The value of the investment opportunity is:

$$F(V) = \alpha V^{\beta} \tag{6}$$

where β is given by

$$\beta = 1/2 - (\rho - \delta)/\sigma^2 + \sqrt{[(\rho - \delta)/\sigma^2 - 1/2]^2 + 2\rho/\sigma^2} > 1 \tag{7}$$

While V^* and α are:

$$V^* = \frac{\beta}{\beta - 1} I \tag{8}$$

$$a = \frac{V^* - I}{(V^*)^{\beta}} = \frac{(\beta - 1)^{\beta - 1}}{\beta^{\beta} I^{\beta - 1}} \tag{9}$$

As β > 1, V^* > I. So uncertainty and irreversibility together make a wedge between V^* and the cost of investment I. Because δβ/δσ<0, the wedge is larger, the greater is σ, the amount of uncertainty over future values of V. To illustrate, if α = 0 and ρ=δ=0.05, then V^*/I = 1.86 if σ = 0.2 and V^*/I = 3.27 if σ = 0.4.

Abel et al. (1996) extended this theory of irreversibility to show that there could be both a call and put option feature in investment, in terms of options to expand or contract the capital stock in the future. Moreover, it should be noted that Hartman (1972) and Abel (1983) 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.

Given these contrasting theoretical results, as well as ambiguity as to what variable best captures relevant uncertainty at a macro level, empirical work is vital. We now go on to review empirical methods and studies in terms of measures of uncertainty and their use in investment functions, before undertaking our own empirical work.

2.2 Measures of Uncertainty

A choice of measures of volatility is needed in order to proxy for uncertainty in investment functions. In this study our main focus is on conditional-heteroscedastic GARCH measures. This section provides an overview of such measures, referring where appropriate to the past empirical literature on investment and uncertainty, which is surveyed on more detail in the following section. We conclude the section with arguments which favour our focus on GARCH.

Conditional volatility measures take account of an estimated process for generating volatility (see, for example, Mandelbrot, 1963, Westerfield, 1977, Mussa, 1979, and Hsieh, 1988). The basis of such measures is that empirical evidence suggests that short-run asset price and, possibly, inflation movements display distinctive features, being well-characterised by a random-walk model, where changes in prices are statistically independent and uncorrelated. This is in turn consistent with the weak form of the efficient markets hypothesis, where all information is freely available and incorporated in past prices, and hence the current price is the optimal predictor of the future one, subject to a constant "drift" parameter. But price changes also tend not to be characterised by constant volatility over time; instead tranquil periods tend to be followed by volatile ones. The unconditional distributions of price changes tend to be fat tailed or leptokurtic (relatively peaked and fat tailed) rather than normal.

These movements are well suited to modeling by AutoRegressive Conditional Heteroskedastic (ARCH) methods. We firstly introduce Engle's (1983) original ARCH model before considering the more parsimonious Generalised ARCH (GARCH) model introduced by Bollerslev (1986). Following the seminal paper by Engle (1983) we shall refer to all discrete time stochastic processes (ε_t) of the form

$$\varepsilon_t = z_t \sqrt{v_t} \tag{10}$$

$$z_t\ iid, \quad E(z_t) = 0, \quad \mathrm{var}(z_t) = 1, \tag{11}$$

with $\sqrt{v_t}$ a time-varying, positive, measurable function of the time t-1 information set, as an ARCH model. By definition, 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, and in ours, ε_t refers to the innovation in the mean for some other stochastic process, say $\{y_t\}$ where

$$y_t = g(x_{t-1};\beta) + \varepsilon_t \tag{12}$$

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.

Let $f(z_t)$ denote the density function for z_t, and θ be the vector of all the unknown parameters in the model. By the prediction error decomposition, the log-likelihood function for the sample ε_T, $\varepsilon_{T-1}, \ldots, \varepsilon_1$ becomes, apart from the initial conditions,

$$L(\theta) = \sum_{t=1}^{T} \left[\log f(\varepsilon_t v_t^{-1/2}) - \log \sqrt{v_t} \right] \tag{13}$$

The second term in the summation is the Jacobian term arising from the transformation from z_t to ε_t. Note that (13) also defines the sample log-likelihood for y_T, $y_{T-1}, \ldots, y_1$ as given by (12). Given a parametric representation for $f(z_t)$, maximum likelihood estimates for the parameters of interest can be computed directly from (13) by a number of different numerical optimization techniques. In our example we estimated (13) using the maximum likelihood procedure described in Berndt et al. (1974).

As suggested by Engle (1983), one possible parameterisation is to express v_t as a linear function of past squared values of the process

$$v_t = \alpha_o + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-1}^2 \tag{14}$$

where $\alpha_o > 0$ and $\alpha_i \geq 0$. This model is known as the linear ARCH model. With financial and exchange rate data it captures the tendency for volatility clustering.

Hence, to undertake the test, one regresses simultaneously the change in the log of the variable in question (unconditional distribution) on a constant, giving a "conditional mean" equation (12) for the change in the variable, while the variance of the errors of this equation (conditional distribution) is regressed on the lagged squared errors,[4] the "conditional variance" equation (14), with the criterion of maximising a log-likelihood function. Given a coefficient on the lagged squared error in equation (14) greater than zero, volatility will tend to cluster, with large residuals following large ones and vice versa, but of unpredictable sign, while a random, normally-distributed variation in the conditional distribution (error variance) gives the unconditional distribution (error distribution) fatter tails than the normal distribution.

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[4] This, of course, gives all errors the same sign.

In many of the applications with the linear ARCH(q) model, a number of lags are required. An alternative and more flexible lag structure is often provided by the Generalised ARCH or GARCH(p,q) model in Bollerslev (1986),

$$v_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i v_{t-i} \tag{15}$$

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 $\alpha_1+\beta_1<1$. Of course in that situation the GARCH(p,q) model corresponds exactly to an infinite order linear ARCH model with geometrically declining parameters.

Using the coefficient β_1 on the lagged dependent variable and setting the conditional variance constant, GARCH enables a long run response of the conditional variance to shocks to be calculated, as shown in equations (16) and (17). α_0 shows the mean level of volatility. Most of the studies in the literature, for stock returns, the term structure or exchange rates, have found a significant degree of both short and long run shock persistence with high frequency data, thus accounting for the clustering of volatility characteristic of such markets (Bollerslev et al. 1992). Studies of inflation have found similar results (Engel, 1983).

$$(1-\beta_1)h_t = 0 + \alpha_1 \varepsilon_t^2 \tag{16}$$

$$h_t = \alpha_0/(1-\beta_1) + \alpha_1/(1-\beta_1)\varepsilon_t^2 \tag{17}$$

Bollerslev et al. (1992) suggest that in most applications a lag length of p=q=1 will suffice. For example, it has been found by Hsieh (1989a,b) that a simple GARCH(1,1) model did relatively well in describing the returns to five different daily nominal US Dollar rates and this is the model which we utilise in this study.

Further refinements can be made to the specification. When there is autocorrelation in the residuals of a simple conditional mean equation as outlined above (entailing rejection of the random walk hypothesis for the variable), inclusion of lagged dependent variables is a possible way to ensure white noise errors, although it is of course contrary to the efficient markets hypothesis. Meanwhile, dummies can be used to test for seasonal effects (of particular importance in monthly price data), and the lagged variance term enables shocks to have a persistent effect on the variance over time. One could also use dummies for extreme observations, following the argument of Lamoureux and Lastrapes (1990) that otherwise the inclusion of such observations outside the normal sampling range might bias the coefficients.[5] Strictly, in order for the system to be stable, the sum of $\alpha_1+\beta_1$ should be less than one. Some authors impose a constraint to ensure this (the IGARCH model).

GARCH is our preferred approach to estimation of uncertainty effects on inflation. However, we note that there also exist traditional volatility measures used in testing uncertainty and investment which show variability without reference to the underlying process generating the volatility, although as noted they are conditional in the sense of taking recent history of volatility into account (e.g. via moving average processes). One such measure of volatility based on the variance (KR) is taken from Kenen and Rodrick (1986) and Darby et al. (1999)

$$\mathrm{KR} = \left[\frac{1}{8}\sum_{i=1}^{8}(\Delta \ln e_{t-i})^2\right]^{\frac{1}{2}} \tag{18}$$

Volatility can also be derived using an autoregressive moving average model, the proxy being the standard deviation of the model's residuals, as in Goldberg (1993) and subsequent papers:

$$ER_t = \alpha_1 ER_{t-1} + \varepsilon_t + \beta_1 \varepsilon_{t-1} \tag{19}$$

Some authors such as Pindyck and Solimano (1993) also work with the moving average standard deviation (SD) of the relevant time series

$$\mathrm{SD} = \sqrt{\frac{n\sum e^2 - \left(\sum e\right)^2}{n(n-1)}} \tag{20}$$

Justifying our focus on GARCH, we argue that the distinction between GARCH and moving average based volatility is a potentially important one, since heightened average volatility alone may merely reflect a greater incidence of random and independent shocks, i.e. greater *risk*, without a change in underlying perceptions as to the situation on the part of firms considering investment. On the other hand, heightened conditional volatility may indicate greater *uncertainty*[6] on the part of the market regarding the direction of the variable and the intentions of the authorities, including market responses to shocks per se[7] (an increased *tendency* for shocks to have persistent effects on the market) which may be more likely to affect

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[5] In our research, reported below, the subperiods for estimation are chosen to eliminate the main outliers, i.e. ERM realignments; in practice even in the full sample, we found that dummying made little difference in most cases.

[6] In more detail, risk can be defined as the danger that a certain contingency will occur, a measure often related to future events susceptible to being reduced to objective probabilities, and uncertainty is a term applied to expectations of a future event to which probability analysis cannot be applied, such as a change in policy regime or a financial crisis (Shafer 1986). The response of an uncertain market – and the response of investment thereto - may appear out of scale with the proximate causes of a given stimulus, if it leads participants to change the way they form their decisions.

[7] See also Kurz and Motolese (2001).

investment. A similar point is made by Serven (2002), who considers use of GARCH essential to measure exchange rate uncertainty as opposed to "sample variability".

2.3 Modelling Investment and Uncertainty

An extensive survey of the literature on investment and uncertainty is provided in Carruth et al. (2000b). 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. Our intention is not to repeat that survey, but rather to provide a thematic overview giving sufficient background for understanding of our results and possible contrasts with earlier studies, as well as to reference more recent work.

First, there are issues in *choosing the variable to measure volatility*. It is argued in Carruth et al. (2000b) 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. Moreover, stock prices may be vulnerable to bubbles rather than reflecting fundamentals. For these reasons, macro variables such as price, output and exchange rate volatility are often preferred instead. One could query this approach since share prices take into account all information relevant to the future profitability of the firm (or at a macro level the corporate sector). Furthermore, one can argue that investment is discounted by the long rate plus a risk premium, where the latter may be linked to equity market volatility (Davis and Madsen, 2001). 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. Discussion of these issues in the literature is generally cursory.

A further general issue arising across the different measures of volatility is the stationarity properties of the data. Pagan and Ullah (1988) point out that stationarity is a necessary condition to estimate the true variance of some underlying process when using moving averages. As Carruth et al. (2000b) point out, stationarity is not always pre-tested in investment studies; we do so in our work below.

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). Huizinga (1993) considers US inflation, real wages and real profits and generally finds a negative effect on investment. Episcopes (1995) examines US interest rates, stock market index, consumer spending and GDP deflator and again sees a

negative impact on the growth of investment. Price (1995) utilises the conditional variance of the growth rate of GDP, and finds a negative effect on UK manufacturing investment lagged twice.

The question of whether there is a different effect from forward and backward looking measures of uncertainty has been raised by Ferderer (1993). He attempts to produce a forward looking measure based on the risk premium from the term structure. For the US he finds that the effect on investment is negative. 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.

Exchange rate volatility and the impact of related uncertainty on investment has been considered widely, for example in Goldberg (1993), Darby et al. (1999) and Darby et al. (2002). It is also an important focus of our work. Goldberg (1993) and Campa and Goldberg (1995) derived their measure of volatility from the standard errors of the residuals from a moving average representation of the exchange rate using US data. Looking at volatility and investment, Darby et al. (1999) using a model based on Dixit and Pindyck (1994) suggest that there are situations where exchange rate uncertainty will depress investment and situations where it will not.

In the empirical section of their paper Darby et al. (1999) find, using a neoclassical model and Tobin's Q, that exchange rate volatility measured by the Kenen-Rodrick (1986) approach noted above has a significant and negative impact on investment functions for the US, Germany and France. There are additional dynamic effects which are negative for Italy and the UK. There are negative misalignment effects for US, France, Italy and the UK. In contrast, there are short run positive dynamic effects for Germany, Italy and UK from misalignment (France suffers from positive dynamic volatility). On the basis of these results the authors suggest there are no long run benefits to UK and Italian investment from exchange rate stability. 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. Also 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 that the method of extracting volatility is important empirically.

Further exchange rate studies include Nucci and Pozzolo (2001) who derive a theoretical model where permanent changes in the exchange rate are important for investment whilst changes in the transitory component are not. Recent work by Baum et al. (2001) suggest that it is difficult to identify the effect of volatility of the exchange rate on firms' profits, since the effect of a positive change will be different from a negative change. We accommodate this by incorporating income into our regression analysis: any effect of a permanent devaluation should feed through that variable.

Serven (2002) using GARCH measures of uncertainty, finds a negative and highly significant impact of real exchange rate uncertainty on private investment in a sample of developing countries, after controlling for standard investment determinants. 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.

Some disaggregate studies, including Leahy and Whited (1996), Driver et al. (1996), Guiso and Parigi (1999) and Temple et al. (2001) also found negative effects of uncertainty on investment in at least some industries. For example Temple et al. (2001) found that UK industrial survey responses suggested external finance constraints and uncertainty about demand were factors limiting investment, but that the former depended on concentration in the industry.

We suggest that there are a number of lacunae in the existing macro literature, that we shall seek to fill in the following sections. Studies tend to be for a single country, indicator and measurement method. Unlike the studies cited above, we look both across a range of indicators and measures of these indicators and in panels of the G7 countries. We now go on to describe the data and estimation of our own approach to investment and uncertainty.

3. Data

For generating uncertainty proxies, we utilise monthly CPI data, long interest rates data, nominal and real effective exchange rate data, industrial production and the stock market index for the G7 countries over 1968-2001. These are obtained from Datastream.

In terms of macroeconomic data needed for the investment function, we use quarterly data for the G7 countries, namely US, Canada, Japan, UK, Germany, France and Italy. Business investment, business sector output and the business sector capital stock data were taken primarily from the OECD business sector database. A key aspect of these definitions compared with aggregate private investment is that private sector aggregates include housing investment and the stock of housing, which has a different cyclical pattern. Moreover, the use of business sector data overcomes problems of transfer from public ownership by including business sector capital, investment and output regardless of sector of ownership. Data on the stock of equity at market prices in the non-financial corporate sector were constructed using the stock of outstanding assets and liabilities in the financial accounts published by the various national statistical agencies. The capital stock used in Tobin's Q is for the non-financial corporate sector and not the business sector, to ensure consistency with the equity stock.

Details of the construction of all the variables used in the empirical estimation are included in the accompanying data appendix. We also provide more powerful unit root tests than simple OLS Dickey Fuller tests by adopting the strategy developed in Ng and Perron (2001). Extending work by Dufour and King (1991) and Elliot, Rothemborg and Stock (1996), Ng and Perron suggest local GLS detrending to unit root tests yield non-negligible size and power gains. The authors also propose a class of modified information criteria to choose the truncation lag of the tests. Taken together the two steps lead to unit tests with much improved size and power. We apply these methods to: Phillips and Perron's (1988) unit root tests with nonparametric modification to deal with serial correlation of errors; the Elliot, Rothemborg and Stock (1996) approach which derives the asymptotic power envelope for point optimal tests of a unit root; and the Augmented Dickey Fuller test.

Full details of the tests are given in Table B in the Appendix. Business investment, ln(IB) and business output are I(1), as are most of the times series in levels used in traditional specifications for investment. So, more surprisingly, is Tobin's Q over this relatively short sample. The volatility measures are also typically I(1) although there is consistent evidence that equity price and real exchange rate volatility measures are I(0).

4 Results

In this section we consider the long run relationship between uncertainty and investment using Pesaran, Shin and Smith's (1999) Pooled Mean Group Estimator (PMGE) for dynamic heterogeneous panels. We examine our long run estimator in detail, then set out the overall specification chosen for investment. Also, we present our GARCH estimates of uncertainty volatility then go on to give details of our panel results for this variables impact on investment for the G7 countries.

4.1 Pooled Mean Group Estimation of investment functions for the G7

We follow Bean (1981), Driver and Moreton (1991) and Darby et al. (1999) in estimating dynamic error correction models of investment including both short and long-run terms in *average Q* and the real user cost of capital and dynamic terms in output and investment. Consistent with these authors, we also include long-run terms in investment and output and test for homogeneity as implied by the CES production function.

Using this specification, we examine the effects of uncertainty on investment for our cross country sample 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 we could pool the data and assume that the slope coefficients and error variances are identical. Whereas there may be theoretical and empirical reasons to presume that the long-run coefficients are homogenous over the cross-section however there are very few practical cases in which the short-run dynamics and error variances would be homogeneous too.

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. We use the PMGE method to estimate our investment functions. We also examine the estimated long-run adjustment parameters we obtain using the PMGE to consider the speed of adjustment at the panel level.

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

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \delta'_{ij} \mathbf{x}_{it-j} + \mu_i + \varepsilon_{it} \qquad (21)$$

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 (21) can be re-parameterised as:

$$\Delta y_{it} = \phi_i y_{it-1} + \beta'_i \mathbf{x}_{it} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{it-j} + \sum_{j=0}^{q-1} \delta^{*\prime}_{ij} \Delta \mathbf{x}_{it-j} + \mu_i + \varepsilon_{it} \qquad (22)$$

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 (22) are *i.i.d.* with zero mean, variance greater than zero and finite fourth moments. Secondly, the roots of equation (22) 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

$$y_{it} = -(\beta'_i / \phi_i)\mathbf{x}_{it} + \eta_{it} \qquad (23)$$

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.

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).

Table 1: Basic PMGE investment function

	ln(YB)	Tobin's Q	User Cost	Long Interest Rate	ECM	Likelihood (Unrestricted)	LR Statistic	Hausman Statistic
PMGE	**1.247** **(t=26.037)**	**0.169** **(3.243)**	-0.005 (0.013)		**-0.089** **(6.550)**	1650.481 (1678.085)	**55.21** **[p=0.00]**	3.34 [0.34]
MGE	**1.482** **(6.757)**	0.292 (0.375)	0.381 (0.319)		**-0.117** **(7.371)**			
PMGE	**1.346** **(24.047)**		-0.523 (0.931)		**-0.083** **(6.543)**	1644.076 (1651.366)	14.58 [0.28]	1.47 [0.48]
MGE	**1.443** **(15.648)**		0.120 (0.191)		**-0.103** **(7.613)**			
PMGE	**1.258** **(26.526)**	**0.171** **(3.286)**		0.002 (0.468)	**-0.092** **(7.018)**	1653.400 (1673.014)	**39.23** **[0.00]**	Na
MGE	**1.218** **(11.578)**	0.380 (0.968)		0.006 (0.994)	-0.120 **(7.158)**			
PMGE	**1.359** **(24.150)**			-0.002 (0.385)	**-0.082** **(6.608)**	1651.637 (1659.466)	15.66 [0.21]	Na
MGE	**1.359** **(13.857)**			-0.002 (0.253)	**-0.102** **(5.690)**			
PMGE	**1.247** **(29.271)**	**0.166** **(3.233)**			**-0.091** **(6.908)**	1653.317 (1666.087)	**25.54** **[0.01]**	0.20 [0.90]
MGE	**1.250** **(10.998)**	0.388 (0.743)			**-0.103** **(6.043)**			
PMGE	**1.367** **(24.610)**				**-0.082** **(-6.461)**	1648.783 (1653.010)	8.45 [0.21]	0.20 [0.65]
MGE	**1.393** **(18.322)**				**-0.092** **(-5.818)**			
PMGE		**8.948** **(5.554)**			-0.010 (-1.199)	1484.742 (1491.177)	**12.87** **[0.05]**	0.13 [0.71]
MGE		7.446 (1.688)			**-0.033** **(-3.023)**			

Notes: Dependent variable Business Investment. PMGE is Pooled Mean Group Estimation. MGE is Mean Group Estimation. Sample period 1973Q1 to 1996Q4. Lag structure determined by Schwarz Bayesian Criteria. 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. T statistics are in parentheses. P-values in square brackets. Dynamic coefficients are reported in Table A2.

Our basic specification without uncertainty considers the long run equilibrium relationship between business sector investment and output. We also assess the effect of Tobin's Q and the user cost/real long interest rate. Following the discussion above, we also have freely estimated dynamics, which differ markedly across countries. The basic equations are shown in Table 1, and dynamics are reported in Table A2.

From Table 1 the long-run coefficient on income is consistently significant with a t-statistic much larger than 1.96, irrespective of which others variable are included in the specification. Also, the error correction term is always significant and negative. However, the opportunity cost measures of investment - we tried user cost and long term interest rate - are often the wrong sign and are always insignificant (this is consistent with Chirinko, 1993). Tobin's Q is significant and positive in sign using the PMGE. Nevertheless there is a degree of dispersion of country effects since the Likelihood Ratio test rejects long run homogeneity at the 5% significance level which suggests excluding this variable from our analysis.[8] Given that the most simple specification accepts both tests for poolability, in particular the Likelihood Ratio test with a test statistic of 8.45 (p-value = 0.21), and long run coefficients is significant for both estimators we concentrate on the long run equilibrium relationship with income only in our panel study. A sensitivity analysis reintroducing Tobin's Q is noted in Section 4.4 below.

We cannot accept the hypothesis that the coefficient on income is equal to one in our investment function, since the long run income coefficient reported in fourth bottom row is more than two standard errors away from 1.00.[9] Although Carruth et al. (2000a) and Cuthbertson and Gasparro (1995) both find evidence that the null of income homogeneity is accepted, they also report evidence where the estimated elasticity on income is greater than one. In particular, Cuthbertson and Gasparro's preferred specification has an estimated coefficient greater than one. The fact that we have estimated coefficients in excess of one can be viewed as due to our wider sample and hence more efficient estimated statistics. our results are consistent with Jones (1995) who report evidence of increasing investment output ratios for the industrialised countries in the post war period[10] and Davis and Madsen (2001) who note a sharp rise in the capital output ratio. It may also link to an increase in the depreciation rate (where the basic model assumes a constant rate) and increased capital mobility which has made fixed investment more sensitive.

4.2 Deriving uncertainty measures using GARCH

Following the discussion above, to assess conditional volatility we used the Generalised Autoregressive Conditional Heteroskedasticity (GARCH) estimation of the properties of the changes in the log of monthly changes in inflation, equity prices, nominal and real effective exchange rates, industrial production, and differences of long rates as outlined above. The results of GARCH estimation are shown in Tables 2 to 7 below.

Features of note include the following: The dependent variables of the conditional mean equations are all stationary, and the lags are sufficient to remove autocorrelation (using LM tests) at the 95% level, except for Italian inflation and Canadian industrial production. The conditional variance equations are all stable ($\alpha_i+\beta_i<1$) other than the Italian exchange rate and Japanese long rates. All of the specifications are GARCH(1,1) except for the US equity price where a

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[8] The Hausman test statistic suggests poolability when we incorporate only Business Output and Tobin's Q in our long run specification with a test statistic of 0.20 (p-value=0.90). As pointed out by Pesaran et al. (1999) it is often difficult to differentiate between panel specifications on the basis of this test unlike the less easily passed Likelihood Ratio test. Indeed the Mean Group coefficient on Tobin's Q is always insignificant and individual OLS results (available on request) suggest that Tobin's Q is only significant for Canada and Japan. We do not incorporate further results with Tobin's Q in this section of the paper.

[9] Here our estimated equation is equation (24) below, excluding the uncertainty measure.

[10] We note that McGratten (1998) refutes this evidence of non-homogeneity of investment to output using a much longer data period of over one hundred years. Our time series dimension is much shorter.

Table 2: GARCH (1,1) for log-difference of monthly inflation

	UK	US	Germany	Japan	Canada	France	Italy
α_0	0.17E-5 (0.49E-5)	0.23E-6 (0.53E-5)	0.38E-6 (0.76E-5)	0.14E-5 (0.62E-5)	0.53E-6 (0.67E-5)	0.97E-7 (0.13E-4)	0.22E-7 (0.57E-5)
α_1	**0.470** **(0.120)**	**0.275** **(0.110)**	**0.071** **(0.07)**	**0.200** **(0.089)**	**0.290** **(0.150)**	0.031 (0.054)	**0.072** **(0.029)**
β_1	**0.510** **(0.070)**	**0.716** **(0.074)**	**0.864** **(0.064)**	**0.742** **(0.071)**	**0.710** **(0.099)**	**0.950** **(0.050)**	**0.921** **(0.024)**
$\alpha_1+\beta_1$	0.980	0.991	0.935	0.942	1.000	0.981	0.993
$\alpha_1/(1-\beta_1)$	0.959	0.968	0.522	0.775	1.000	0.620	0.911
LM(12) in Con. Mean	13.3 [0.350]	16.1 [0.186]	6.9 [0.861]	19.7 [0.072]	12.8 [0.383]	19.3 [0.082]	43.0 [0.020]
DF of dv	-8.9	-11.8	-13.4	-14.4	-13.6	-8.5	-10.2
ADF of dv	-5.9	-8.5	-10.3	-12.3	-8.2	-5.6	-6.7

Notes: $\alpha_1+\beta_1$ gives an indication of stability and $\alpha_1/(1-\beta_1)$ of long run response. Standard errors are in parentheses. Probability values in square brackets. α_1 is the coefficient on the lagged squared error term whilst β_1 is the coefficient on the conditional variance term. Sample period: 1969M2-2001M11; UK Conditional mean equation includes 12 lags and monthly seasonal dummies. dv = dependent variable.

Table 3 GARCH (1,1) for log-difference of monthly nominal effective exchange rate

	UK	US	Germany	Japan	Canada	France	Italy
α_0	**0.23E-4** **(0.59E-5)**	0.65E-5 (0.66E-5)	**0.34E-4** **(0.54E-5)**	**0.24E-4** **(0.66E-5)**	**0.2E-4** **(0.6E-5)**	0.43E-5 (0.6E-5)	**0.2E-4** **(0.56E-5)**
α_1	**0.326** **(0.071)**	**0.119** **(0.04)**	**0.160** **(0.053)**	**0.108** **(0.034)**	**0.107** **(0.055)**	**0.267** **(0.093)**	**0.808** **(0.180)**
β_1	0.635 (0.432)	**0.863** **(0.032)**	**0.510** **(0.045)**	**0.850** **(0.028)**	**0.684** **(0.054)**	**0.736** **(0.056)**	**0.364** **(0.060)**
$\alpha_1+\beta_1$	0.961	0.982	0.67	0.958	0.791	1.003	1.172
$\alpha_1/(1-\beta_1)$	0.893	0.869	0.327	0.720	0.339	1.011	1.270
LM(12) in Con. Mean	5.8 [0.926]	9.1 [0.698]	11.8 [0.463]	16.1 [0.188]	12.8 [0.385]	14.4 [0.276]	5.6 [0.937]
DF of dv	-14.2	-14.2	-14.8	-14.0	-15.6	-14.5	-13.9
ADF of dv	-12.6	-12.7	-12.4	-12.3	-12.5	-12.2	-12.9

Notes: see Table 2. Sample period 1968M5-2001M11 (1970M5-2001M11 for CA, FR, IT) Conditional mean equation includes 3 lags.

Table 4 GARCH (1,1) for log-difference of monthly share prices

	UK	US	Germany	Japan	Canada	France	Italy
α_0	**0.23E-3** **(0.52E-4)**	**0.36E-3** **(0.82E-4)**	**0.86E-4** **(0.14E-4)**	0.29E-4 (0.4E-4)	**0.58E-3** **(0.17E-3)**	**0.11E-3** **(0.1E-4)**	**0.0011** **(0.4E-3)**
α_1	**0.126** **(0.044)**	**0.195** **(0.059)**	**0.091** **(0.046)**	**0.073** **(0.098)**	**0.110*** **(0.065)**	**0.078** **(0.03)**	**0.17** **(0.072)**
β_1	**0.814** **(0.037)**	**0.650** **(0.063)**	**0.889** **(0.033)**	**0.918** **(0.061)**	**0.648** **(0.099)**	**0.893** **(0.023)**	**0.606** **(0.123)**
$\alpha_1+\beta_1$	0.940	0.845	0.980	0.991	0.758	0.971	0.776
$\alpha_1/(1-\beta_1)$	0.677	0.557	0.820	0.890	0.313	0.729	0.431
LM(12) in Con. Mean	10.1 [0.611]	6.8 [0.870]	14.3 [0.281]	9.7 [0.639]	13.9 [0.306]	19.1 [0.086]	8.4 [0.750]
DF of dv	-19.6	-17.9	-18.8	-18.5	-18.0	-18.3	-18.0
ADF of dv	-14.2	-14.8	-13.7	-12.7	-14.2	-14.4	-13.2

Notes: see Table 2. Sample period 1968M5-2001M11 for France and Germany; 1969M5-2001M12 for Canada, Japan and Italy, 1968M8-2001M11 for the UK and US. Conditional mean equation includes 3 lags (6 lags for US). The US has a GARCH(3,3) specification.

Table 5 GARCH (1,1) for log-difference of monthly industrial production

	UK	US	Germany	Japan	Canada	France	Italy
α_0	**0.67E-4** **(0.58E-5)**	**0.17E-4** **(0.52E-5)**	**0.002** **(0.58E-5)**	**1.314** **(0.238)**	0.025 (0.021)	0.001 (0.008)	0.006 (0.02)
α_1	**0.730** **(0.14)**	**0.398** **(0.13)**	**0.13** **(0.05)**	**0.297** **(0.085)**	**0.060** **(0.028)**	**0.037** **(0.017)**	**0.04** **(0.018)**
β_1	**0.095** **(0.056)**	**0.328** **(0.082)**	n/a	-0.083 (0.111)	**0.917** **(0.036)**	**0.960** **(0.020)**	**0.95** **(0.02)**
$\alpha_1+\beta_1$	0.825	0.726	0.13	0.214	0.977	0.997	0.99
$\alpha_1/(1-\beta_1)$	0.81	0.6	0.13	0.27	0.723	0.925	0.8
LM(12) in Con. Mean	16.4 [0.175]	12.2 [0.428]	6.3 (0.9)	12.6 [0.4]	25.3 [0.013]	17.3 [0.138]	10.9 [0.541]
DF of dv	-23.6	-12.9	-29.4	-24.2	-21.8	-16.4	-29.5
ADF of dv	-16.4	-9.2	-18.6	-12.7	-12.9	-27.2	-18.6

Notes: see Table 2. Conditional mean equation includes Germany 3 lags (sample period 1969M2-2001M6), Japan 4 lags (sample 1969M2 to 2001M6), France 12 lags (sample 1969M2 to 2001M6), Canada 4 lags (sample 1969M2 to 2001M6), Italy 6 lags (Sample 1970M6-2001M12). dv = dependent variable.

Table 6 GARCH (1,1) for difference of long interest rates

	UK	US	Germany	Japan	Canada	France	Italy
α_0	0.0002 (0.0007)	0.003 (0.002)	**0.004** **(0.002)**	**0.003** **(0.001)**	**0.005** **(0.002)**	**0.005** **(0.001)**	0.008 (0.006)
α_1	**0.060** **(0.020)**	**0.123** **(0.036)**	**0.117** **(0.044)**	**0.495** **(0.109)**	**0.231** **(0.064)**	**0.128** **(0.031)**	**0.258** **(0.075)**
β_1	**0.938** **(0.021)**	**0.845** **(0.043)**	**0.795** **(0.066)**	**0.599** **(0.058)**	**0.751** **(0.058)**	**0.841** **(0.028)**	**0.707** **(0.107)**
$\alpha_1+\beta_1$	0.998	0.968	0.912	1.094	0.982	0.969	0.965
$\alpha_1/(1-\beta_1)$	0.968	0.794	0.571	1.234	0.928	0.805	0.881
LM(12) in Con. Mean	4.156 [0.980]	18.969 [0.089]	13.743 [0.317]	17.883 [0.119]	15.717 [0.205]	14.379 [0.277]	14.562 [0.266]
DF of dv	-14.4	-14.2	-12.6	-17.3	-18.4	-18.4	-13.2
ADF of dv	-15.5	-14.6	-11.6	-13.7	-14.1	-12.1	-10.8

Notes: See Table 2 Conditional mean equation includes 3 lags for Italy (sample 1968M4 to 2001M10), Germany (sample 1968M4 to 2001M10), France (sample 1968M5 to 2001M11), Japan 2 lags (sample 1970M1 to 1999M12), Canada 6 lags (sample 1968M7 to 2001M10), UK 6 lags (sample 1968M7 to 2001M10), US 6 lags (sample 1968M7 to 2001M12).

Table 7 GARCH (1,1) for difference of log of real exchange rate

	UK	US	Germany	Japan	Canada	France	Italy
α_0	0.73 (0.335)	0.11 (0.055)	0.20 (0.11)	**0.552** **(0.36)**	**0.36** **(0.31)**	0.33 (0.15)	0.29 (0.095)
α_1	**0.263** **(0.079)**	**0.108** **(0.045)**	**0.119** **(0.047)**	**0.087** **(0.047)**	**0.137** **(0.09)**	**0.438** **(0.165)**	**0.538** **(0.117)**
β_1	**0.522** **(0.136)**	**0.842** **(0.057)**	**0.682** **(0.13)**	**0.814** **(0.088)**	**0.535** **(0.34)**	**0.292** **(0.201)**	**0.39** **(0.103)**
$\alpha_1+\beta_1$	0.785	0.95	0.801	0.901	0.671	0.73	0.928
$\alpha_1/(1-\beta_1)$	0.55	0.683	0.374	0.468	0.292	0.619	0.881
LM(12) in Con. Mean	17.2 [0.14]	17.9 [0.12]	7.0 [0.855]	11.5 [0.486]	10.7 [0.557]	18.3 [0.108]	6.3 [0.898]
DF of dv	-12.8	-14.2	-13.8	-13.4	-16.1	-14.4	-14.1
ADF of dv	-11.7	-11.4	-11.8	-12.3	-12.1	-12.0	-12.8

Notes: See Table 2 Conditional mean equation includes 3 lags except for Japan (also monthly seasonals) and Canada (12 lags). Sample 1970M5-2000M9 except Japan (1971M12-2000M9), Canada (1971M2-2000M9) and UK (1972M5-2000M9).

GARCH(3,3) specification was the simplest acceptable by the data, and German and Japanese industrial production where a simple ARCH with one lag was sufficient.

As noted in the tables, we included monthly seasonals for the log difference of the CPI, given it has a marked seasonal pattern, while for the other series we did not include them. Virtually all of the lagged error α_i and lagged variance β_i terms are significant, with the lagged variance tending to be larger, while the results are more mixed for the baseline level of volatility α_0.

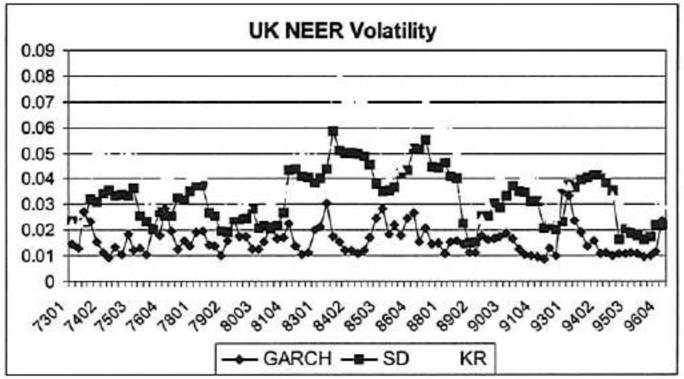
In the inflation equations (In Table 2), the lagged error term is not significant in Germany and France, which particularly for the former may link to long term counter inflation credibility and corresponding action on the part of the central bank. The lagged error term is large in the UK, US and Canada. The baseline level of volatility (constant in the conditional variance equation) is not significant in the price equations.

In the nominal effective exchange rate equations (see Table 3), the lagged variance term is not significant in the UK, although that country has a large lagged error term suggesting short run persistence of volatility. As noted, in Italy the equation has a very large lagged error term and is unstable. The baseline level of volatility is not significant in the exchange rate for the US and France. The long run response to shocks is low in Germany and Canada.

In the equity price equations (see Table 4), the lagged error term in Canada is not significant, nor is the constant for Japan. The equations are generally quite comparable across countries, expect the US where three months lags are taken on the lagged error and lagged variance terms. With the exception of Italy, the long run response to shocks is lower in the US, UK and Canada, perhaps due to their more active and liquid equity markets, than in the Continental countries and Japan.

In the industrial production equations (Table 5), only the simplest form of ARCH estimation was feasible for Germany, while for Japan the lagged variance term is not significantly different from zero, again implying an ARCH type process. Meanwhile. although we also estimated levels equations, we focus on results for differences of long rates (Table 6), given the stationarity tests suggest that within sample a number of the long rates are non stationary, consistent with other research (see Bo and Sterken, 2002).

Figure 1 Measures of Uncertainty for UK NEER



Notes: GARCH is Generalised AutoRegressive Conditional Heteroscedasticity, SD is Standard deviation and KR is Kenen and Rodrick.

Finally the real exchange rate results, which in a sense mix the volatility of inflation and the nominal exchange rate, are all well-behaved and are shown in Table 7. Note that the variable is scaled up by 100 to facilitate convergence in the GARCH.

Besides GARCH results on stationary difference variables (denoted CV), in Appendix C we also report results using the Kenen-Rodrick measure (KR) of variance, and the rolling standard deviation (SD) on differences of the variables, so as to cover the range of specifications used in the literature, see Section 2.2. As noted, these measures do not allow for ARCH effects but instead measure average volatility over a moving window. Figure 1 illustrates the difference between the three measures for UK exchange rate volatility. Although the levels of the measures are not the same their profile through time is very similar, with the major shocks impacting upon each of the measures at the same time. Also, we should note that the GARCH measure exhibits a reasonably constant mean over the entire sample period. Further GARCH measures are shown in the Charts D1-D2 in Appendix D.

4.3 Panel Estimation Results

We turn now to an assessment of uncertainty effects on investment. Table 8 show the results for PMG estimation of our investment functions using conditional volatility of the log-difference of the nominal effective exchange rate (DER), equity prices (DEQ) industrial production (DIP), consumer price (DP) and the long interest rate (DLR), and the real exchange rate (DRER) estimated using GARCH as set out in Section 4.2. In each of the tables we present estimated long run coefficients of business output, ln(YB), estimated error correction terms, the Likelihood Ratio and Hausman statistics.

Table 8 Panel Estimation of Investment and Uncertainty: G7 Countries

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.346** **(24.944)**	**1.439** **(11.637)**	**1.377** **(26.591)**	**1.466** **(13.144)**	**1.363** **(24.610)**	**1.370** **(15.647)**	**1.348** **(27.205)**	**1.413** **(14.931)**	**1.348** **(30.071)**	**1.390** **(18.593)**	**1.371** **(24.720)**	**1.439** **(14.851)**
CV(DER)	**-8.018** **(2.887)**	**-25.198** **(2.097)**										
CV(DEQ)			0.374 (0.585)	-0.758 (0.362)								
CV(DP)					-6.863 (0.787)	-22.596 (1.069)						
CV(DIP)							-0.067 (-1.189)	11.629 (0.817)				
CV(DLR)									0.020 (0.302)	0.076 (0.680)		
CV(DRER)											**-0.094** **(-2.780)**	**-0.256** **(-1.547)**
Error Correction	**-0.077** **(5.270)**	**-0.083** **(4.431)**	**-0.084** **(6.403)**	**-0.095** **(4.926)**	**-0.079** **(6.244)**	**-0.093** **(6.132)**	**-0.083** **(-6.241)**	**-0.095** **(-5.544)**	**-0.086** **(-6.510)**	**-0.112** **(-5.553)**	**-0.078** **(-5.661)**	**-0.081** **(-4.429)**
Likelihood (Unrestricted)	1652.252 (1667.613)		1649.147 (1655.401)		1645.014 (1654.103)		1649.533 (1654.573)		1646.737 (1657.649)		1651.887 (1662.906)	
LR Statistic χ^2 {df}	**30.72 {12}** **[p=0.00]**		18.18 {12} [0.11]		14.38 {12} [0.28]		10.08 {12} [0.61]		**21.83 {12}** **[0.04]**		**30.41{12}** **[0.00]**	
Hausman χ^2 {df}	3.44 {12} [0.18]		1.39 {12} [0.50]		1.47 {12} [0.48]		1.64 {12} [0.44]		0.50 {12} [0.78]		2.18 {12} [0.34]	

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. DEQ the first difference of the stock exchange index. DP is the first difference of the price index. DIP is the first difference of industrial production. DLR is the first difference of the long interest rate. DRER is the first difference of the real effective exchange rate.

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 on the LR test in the following results.

Table 8 presents the estimated long run coefficients and short run error correction term from the following equation:

$$\Delta \ln(IB)_{it} = \phi_i \left(\ln(IB)_{i,t-1} - \theta_{0i} - \theta_1 \ln(YB)_{it} - \theta_2 CV(.)_{it}\right) + \sum_{j=1}^{p} \delta_{ji} \Delta \ln(IB)_{i,t-j} + \sum_{j=0}^{q} \varphi_{ji} \Delta \ln(YB)_{i,t-j} + \sum_{j=0}^{r} \gamma_{ji} \Delta CV(.)_{i,t-j} + \varepsilon_{it} \quad (24)$$

The long run elasticities on output are always significant (t-statistics are greater than 1.96) and the estimated coefficients are again slightly larger than one in magnitude. Also, the error correction terms are significant and give evidence of mean reversion to a long-run relationship. In terms of the measures of volatility, we find for the entire sample period that only the measure of nominal and real exchange rate uncertainty are significant in influencing long-run business investment across the G7 with a PMG estimated elasticity of –8.018 and –0.094 respectively (note that the latter is scaled up by 100 to aid convergence of the GARCH estimates, so the effects are actually comparable in magnitude). The other measures shown in Table 8 (i.e. GARCH measure of the volatility of equity prices, CV(DEQ), industrial production, CV(DIP), and of inflation, CV(DP)) suggest that there is often a negative effect from uncertainty of these variables, although we do not find evidence that this is statistically significant across the G7.

It is emphasised in the panel econometrics literature developed in Pesaran and Smith (1995), Lee et al. (1997) and Pesaran et al. (1999) that it is important to consider whether there is panel heterogeneity. This potential characteristic of our cross section can affect the usefulness of our results. In particular, it may bias our estimated coefficients and reduce the efficiency of the estimated standard errors. We see from the probability values associated with the Hausman test of equivalence of PMG and MG that it always accepts (p-value > 0.05) and hence, according to this test there is parameter homogeneity across the G7 as a whole. This is also true for the LR tests for equity prices, industrial production and inflation. However, we can not accept parameter homogeneity for the LR test for nominal and real exchange rate uncertainty (test statistic $\chi^2\{12\}$ = 30.72 and 30.41, whilst the critical value is 21.03).

At this point we could conclude that there is a difference between the two test statistics on poolability but place greater emphasis on the Hausman test, thus focusing on the G7 result only. Instead, we pursue the issue of poolability of the exchange rate results by splitting our sample. One possible poolable combination for the nominal exchange rate, according to the Joint LR statistic, can be obtained by combining Germany and France with the UK and Italy (Table

Table 9A PMGE Investment and Nominal Exchange Rate Sub Samples

	PMGE	MGE	PMGE	MGE	Individual LR Statistic χ^2 {df}
ln(YB)	**1.346** **(t=24.944)**	**1.439** **(11.637)**	**1.233** **(21.371)**	**1.202** **(63.534)**	0.221 {3} [p=0.97]
CV(DER) G7	**-8.018** **(2.887)**	**-25.198** **(2.097)**			
CV(DER) EU4			**-11.808** **(3.312)**	**-12.670** **(2.852)**	3.826 {3} [0.28]
CV(DER) France					
CV(DER) Germany					
CV(DER) Italy					
CV(DER) UK					
Error Correction	**-0.077** **(5.270)**	**-0.083** **(4.431)**	**-0.094** **(3.855)**	**-0.097** **(4.578)**	
Joint 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]		n.a.		

Notes: EU4 consists of France, Germany, Italy and the UK. Also see Table 8. T-statistics in parentheses. Standard Errors in <>. Probability values in square brackets.

Table 9B PMGE Investment and Real Exchange Rate Sub Samples

	PMGE	MGE	PMGE	MGE	Individual LR Statistic χ^2 {df}
ln(YB)	**1.371** **(24.720)**	**1.439** **(14.851)**	**1.265** **(21.711)**	**1.253** **(35.919)**	0.868 {3} [p=0.83]
CV(DRER) G7	**-0.094** **(2.780)**	-0.256 (1.547)			
CV(DRER) EU4			**-0.134** **(3.232)**	**-0.136** **(-3.522)**	2.132 {3} [0.55]
CV(DRER) France					
CV(DRER) Germany					
CV(DRER) Italy					
CV(DRER) UK					
Error Correction	**-0.078** **(5.661)**	-0.081 (4.429)	n.a.‡	n.a.‡	
Joint LR Statistic χ^2 {df}	**30.41 {12}** **[p=0.00]**		3.343 {6} [0.76]		
Hausman χ^2 {df}	2.18 [0.34]		n.a.		

Notes: EU4 consists of France, Germany, Italy and the UK. Also see Table 8. Standard Errors in <>.
‡ This is due to a problem with an Italian dynamic lag length greater than one. Reducing the maximum lag length to one, reduced the pooled coefficient to –0.142 without changing the individual country results for the other countries.

9A) LR Statistic = 4.19 {d.f.=6} [p-value = 0.65]. Pooling each of the two coefficients individually is accepted by the LR statistic. In this instance the uncertainty coefficient increases as does the significance, to –11.808 (t=3.312). We also find a greater speed of mean reversion to the equilibrium relationship. We also undertook individual country estimates with and without a pooled output coefficient. The UK and Italy are however marginally closer to zero than they are to the pooled estimate on the variability of the nominal effective exchange rate.[11][12]

However, when we examine the results based on the real effective exchange rate (Table 9B) we find that the UK estimated coefficient from a single equation OLS regression or from a panel results from pooling ln (YB), provides interesting results. In this instance the pooled coefficient was equal to –0.134 and, for individual countries, the coefficient for the UK is -0.089 although Italy is only –0.056. Although the UK coefficient is less than two standard errors from zero it is also less that two standard errors from the pooled result and closer to the pooled result. The question arises whether firm investment behaviour is likely to be influenced to a greater extent by the real or nominal exchange rate. Although there are reasons to believe that the nominal exchange rate is important, the consensus opinion emphasises the importance of the real exchange rate for real investment decisions.

4.4 Sensitivity Analysis

To assess the robustness of our results, we considered it important to examine the stability of our estimates across time. We do so by splitting our sample period in the early 1980s, and also estimating the uncertainty coefficient recursively. By this means, we can examine whether the importance of nominal exchange rate volatility has increased or diminished over time or indeed whether other types of volatility have important effects which are submerged in estimation results for the entire sample. In the latter period, hedging was more common. This may be balanced by greater reliance on external as opposed to internal finance for investment in the later period, (although note that the Modigliani-Miller theorem implies that this should be "irrelevant") and possibly greater capital mobility.

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[11] The estimated coefficient on uncertainty measured by the nominal exchange rate for Italy and the UK are –5.573 and –5.120, respectively.

[12] The results for Japanese, Canadian and US nominal exchange rate uncertainty's impact on investment suggest we can not pool this sub-group, with a LR statistic of 15.52 [p-value = 0.00].

Table 10 Panel Estimation of Investment and Uncertainty: G7 Countries Time Split 1: 1973Q1 to 1983Q4.

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	1.412 (-5.164)	1.121 (4.256)	1.446 (10.837)	1.140 (3.378)	1.444 (12.217)	1.473 (6.381)	1.574 (11.845)	1.219 (6.541)	1.436 (10.787)	1.324 (4.874)	1.421 (10.424)	1.252 (4.329)
CV(DER)	-5.164 (-1.803)	-13.144 (-1.325)										
CV(DEQ)			-0.317 (-0.412)	4.300 (0.890)								
CV(DP)					-0.990 (-0.198)	17.526 (1.318)						
CV(DIP)							6.437 (1.994)	35.891 (1.025)				
CV(DLR)									0.108 (0.982)	-0.134 (-0.755)		
CV(DRER)											-0.041 (1.480)	-0.044 (-0.632)
Error Correction	-0.115 (-2.855)	-0.083 (4.431)	-0.120 (-3.034)	-0.197 (-2.285)	-0.079 (6.244)	-0.093 (6.132)	-0.072 (-1.680)	-0.212 (-2.276)	-0.123 (-3.053)	-0.213 (-2.589)	-0.119 (2.939)	-0.210 (2.632)
LR Statistic χ^2 {df}	34.65 {12} [0.00]		29.01 {12} [0.00]		22.88 {12} [0.03]		37.32 {12} [0.00]		23.22 {12} [0.03]		30.224 {12} [0.00]	
Hausman χ^2 {df}	6.88 {12} [0.03]		1.21 {12} [0.55]		2.27 {12} [0.32]		11.77 {12} [0.00]		3.24 {12} [0.20]		0.99 {12} [0.61]	

Table 11 Panel Estimation of Investment and Uncertainty: G7 Countries Time Split 2: 1984Q1 to 1996Q4.

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	1.150 (9.811)	1.562 (2.841)	0.765 (3.953)	1.098 (1.979)	2.227 (7.062)	2.049 (2.398)	0.611 (0.248)	2.382 (1.892)	1.158 (12.919)	2.897 (2.028)	1.131 (8.578)	2.222 (1.739)
CV(DER)	-41.593 (-2.422)	-49.053 (-1.904)										
CV(DEQ)			0.673 (0.499)	-3.271 (-1.195)								
CV(DP)					19.001 (1.032)	41.121 (0.285)						
CV(DIP)							-9.056 (-0.958)	-24.541 (-0.436)				
CV(DLR)									-0.227 (-2.268)	0.359 (0.292)		
CV(DRER)											-0.452 (2.361)	-0.966 (1.330)
Error Correction	-0.084 (6.403)	-0.095 (4.926)	-0.043 (-1.807)	-0.098 (-3.904)	-0.039 (-1.740)	-0.091 (-3.454)	-0.028 (-1.198)	-0.093 (-3.775)	-0.082 (-4.510)	-0.091 (-3.269)	-0.036 (2.535)	-0.078 (3.174)
LR Statistic χ^2 {df}	18.18 {12} [p = 0.11]		34.69 {12} [0.00]		42.73 {12} [0.00]		38.20 {12} [0.00]		45.97{12} [0.00]		33.214 {12} [0.00]	
Hausman χ^2 {df}	1.39 {12} [0.50]		2.78 {12} [0.25]		0.56 {12} [0.76]		7.01 {12} [0.03]		2.79 {12} [0.25]		0.79 {12} [0.67]	

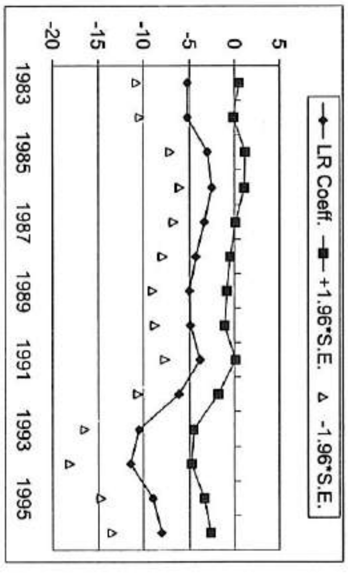

Figure 2: The Long-Run Recursive PMGE Coefficient for Nominal Exchange Rate Uncertainty

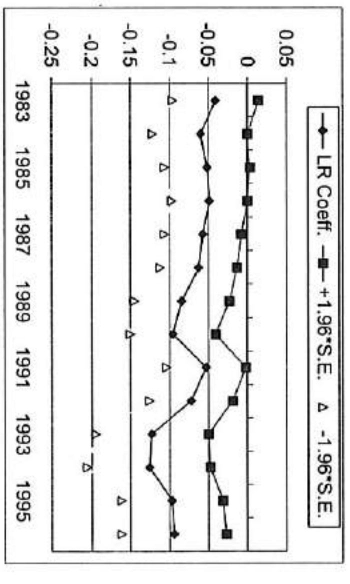

Figure 3: The Long-Run Recursive PMGE Coefficient for Real Exchange Rate Uncertainty

The results from splitting the time series span into two sub samples (Tables 10 and 11) and provide some interesting effects from exchange rate, and to a lesser extent long interest rate, variability. In the earlier sample period, 1973Q1 to 1983Q4, exchange rate volatility only has a significant effect on investment at the 10% significance level: the estimated coefficient is –5.16 (t-statistic = -1.80). However, for the later period the effect from the nominal effective exchange rate increases in both magnitude and significance (the coefficient becomes –41.59, t-statistic = 2.42). There are similar changes in the real rate coefficient. We note also that the income coefficients are closer to 1.0 in the later sample, in the case of exchange rates and long rates.

These results are confirmed by the recursively estimated coefficients (and standard error bands) on the impact of exchange rate volatility in Figure 2 and 3.[13] From the charts we see exchange rate volatility becoming more important when we incorporate more recent data into our sample period. For some of the earlier periods there does not appear to be a strongly negative coefficient. But as we move into the 1990s the coefficient decreases further below zero (approximately by a factor of two).

Another explanation may be that firms are less sensitive to exchange rates when they are in a situation of imperfect competition. In the second half of the sample, financial liberalisation, anti trust policy, privatisation and other forms of market opening have been much more marked. The resulting increased contestability may underlie the shifting coefficient.

Overall, our results suggest that volatility effects are still present, indeed more important in the 1990s than the 1970s; and although this is mainly restricted to the exchange rate it also emerges for the difference of the long rate. Indeed, there is evidence of homogeneity of the long run coefficients for the later period using both the Hausman test and the Likelihood Ratio test when we incorporate exchange rate volatility into our long run specification (Table 11, columns 2 and 3). The industrialised countries' macroeconomic structures with respect to investment, openness and the exchange rate volatility are, this result suggests, becoming increasingly similar. This may again link to increased product market liberalisation, capital mobility and market efficiency. The tests on poolability are time dependent, since the estimated statistic from the recursive sample period often has a probability value greater than 0.05.

The G7 results for the volatility of Industrial Production gives us some indication in the earlier period that there is a significant positive effect on investment in the long run. However, we discount this result here since the estimated coefficient is only marginally significant, the error correction term is insignificant at the 5% level (suggesting the absence of a long run relationship between investment and uncertainty) and there is no evidence of poolability from either the LR or Hausman statistic.

Table 12 Panel estimates for Long Interest Rates: European Countries later Panel

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.158 (12.919)**	**2.897 (2.028)**	**0.876 (5.049)**	1.495 (1.820)	**1.105 (9.487)**	**1.288 (5.286)**	**0.879 (5.033)**	0.767 (1.424)	**1.106 (9.584)**	**2.085 (2.576)**
CV(DLR) G7	**-0.227 (-2.268)**	0.359 (0.292)								
CV(DLR) FR, GN, IT & UK			-0.215 (-1.114)	1.630 (0.969)						
CV(DLR) GN & IT					**-0.473 (-2.026)**	**-0.511 (-4.938)**				
CV(DP) GN, IT & FR							-0.242 (-1.254)	-0.014 (-0.028)		
CV(DP) GN, IT & UK									**-0.452 (-2.023)**	1.847 (0.783)
Error Correction	**-0.082 (-4.510)**	**-0.091 (-3.269)**	**-0.068 (-8.340)**	**-0.078 (-4.268)**	**-0.101 (-4.560)**	**-0.105 (-11.409)**	**-0.076 (-11.701)**	**-0.080 (-3.142)**	**-0.077 (-2.709)**	**-0.093 (-7.332)**
LR Statistic χ^2 {df}	**45.97{12} [0.00]**		**22.00 {6} [0.00]**		1.97 {2} [0.37]		**14.73 {4} [0.01]**		**9.51 {4} [0.05]**	
Hausman χ^2 (df)	2.79 {12} [0.25]		1.25 {12} [0.54]		Na		Na		Na	

Notes: Sample period 1984Q1-1996Q4, see Table 8.

With regards to the long-run interest rate, the estimated coefficient in the later period is significant at the 5% level and negative (-0.227). Although we have a reasonable specification (e.g. a significant error correction term) panel poolability is rejected using the LR test statistic, and only accepted with the less stringent Hausman test. Consequently we consider whether it is possible to split the cross section sample in Table 12.

Germany and Italy appear to behave similarly with regard long-run interest rate volatility. This is shown by the likelihood ratio statistic, which is insignificant by a large margin when we combine these two countries. Our results are somewhat surprising since Italy is typically considered as an economic "outsider" with regard to Monetary Union, see for example the evidence from Darby et al. (1999). In this instance it is clearly exhibiting similar behaviour to the largest European country. We do not find such clear evidence for combined significance and poolability for France or the UK with regards the volatility of long interest rates. But if anything the evidence sides with the UK exhibiting relatively (i.e. compared to France) similar behaviour to Italy and Germany. The LR statistic is borderline significant at the 5% level and uncertainty is having a negative effect, with a coefficient of –0.452.

We seek to calibrate the impact of uncertainty on investment in the context of the successful results highlighted above. These are shown in Table 13. It can be seen that a 10% rise in the level of volatility relative to the average leads to a fall in investment of 1-1.5% except in the case of the later period exchange rate coefficient (5%) and the long rate for the G7 in the later sample (0.7%). Using the standard deviation of volatility as a benchmark, a 1 standard deviation rise in conditional volatility leads to a 2-4% fall in investment for the full sample G7 exchange

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[13] We believe our approach to recursive estimation of PMGE is highly appropriate for testing the stability of coefficients in a panel data study. For recent innovations in testing for structural breaks in panel data see Kao and Chang (2000), in a panel cointegration setting, and Andrews and Lu (2000) using GMM in dynamic panels.

Table 13: Impact of increased uncertainty on investment

Sample	Variable	Average level of C.V.	Coefficient	Base level	10% rise	1 std dev	50% rise
1973-1996	G7 nominal exchange rate	0.013	-8.018	-0.107	-0.011	-0.037	-0.054
1973-1996	EU4 nominal exchange rate	0.012	-11.800	-0.146	-0.015	-0.070	-0.073
1973-1996	G7 real exchange rate	1.41	-0.094	-0.133	-0.013	-0.035	-0.066
1973-1996	EU real exchange rate	1.27	-0.134	-0.171	-0.017	-0.064	-0.085
1984-1996	G7 nominal exchange rate	0.013	-41.600	-0.534	-0.053	-0.202	-0.267
1984-1996	G7 long rate	0.311	-0.227	-0.074	-0.007	-0.021	-0.037
1984-1996	EU3 long rate	0.298	-0.452	-0.144	-0.014	-0.035	-0.072

Notes: base level is equal to the coefficient times the average level of C.V. (GARCH conditional variance) over the sample. Since the investment function is specified in logs, 0.01 is equivalent to a 1% change.

rate and both the long rate estimates. In the case of the EU exchange rate the effect is 7%, and 20% for the G7 exchange rate in the later sample.

Two further experiments were undertaken to test the robustness of the main results. First, we introduced Tobin's Q to the same equations, to test the empirical finding of Leahy and Whited (1996) that uncertainty proxies may be irrelevant in the presence of Q (Appendix E Table E1). Second, we removed the time means from the equations presented in Table 8. This is shown in Appendix Table E2.

Broadly speaking, the results do not controvert our main findings. Q is significant at around 0.16 in all of the PMG estimates. When including Tobin's Q, the nominal and real effective exchange rate remain significant in the PMG estimates. Interestingly, all the other estimates are also negative in all cases, albeit insignificant. As regards the removal of time means, this again does little to the results. The size of coefficients is reduced somewhat but we find evidence that we can pool the G7 countries using the stronger Likelihood Ratio test.

5. Conclusions

The panel results show unequivocally that exchange rate uncertainty as measured by conditional volatility from GARCH estimates, is harmful to investment, both for the G7 and for all subsamples. There is evidence of a growing exchange rate effect over the sample. A long rate effect also emerges for major EU countries other than France over the 1984-96 period. Results for inflation, equity prices and industrial production do not, in contrast, suggest that these variables have a major and consistent negative effect on investment across the G7. As regards the implications for EMU, the panel results suggest it is of benefit for all the large EU countries, including the UK, to reduce exchange rate and long rate volatility. Since it is likely that EMU will reduce trade-weighted exchange rate volatility, EMU is indicated to favour investment. Equally, for some countries EMU may also reduce long rate volatility (given, for example, a deeper and more liquid bond market, lower fiscal deficits and less volatile short rates). This would compound the beneficial effect.

References

Abel, A. (1980) Empirical investment equations: An integrative framework. *Carnegie-Rochester Conference Series on Public Policy* 12, 39-91.

Abel, A. (1983) Optimal investment under uncertainty. *American Economic Review* 73, 228-233.

Abel, A., Dixit, A., Eberly, J.C., Pindyck, R.S. (1996) Options, the value of capital and investment. *Quarterly Journal of Economics* 111, 753-777.

Andrews, D.W.K. and Lu, B. (2000) Consistent Model and Moment Selection Criteria for GMM Estimation with Application to Dynamic Panel Data Models. Yale University, Working Paper No. 1233.

Asteriou, D., Price, S. (2000) Uncertainty, investment and economic growth: evidence from a dynamic panel. City University mimeo.

Baillie R.T., Bollerslev T. (1989) The message in daily exchange rates - a conditional variance tale. *Journal of Business and Economic Statistics*, 297-305.

Baum, C.F., Caglayan, M., Barkoulas, J.T. (2001) Exchange rate uncertainty and firm profitability. *Journal of Macroeconomics 23(4), 565-76.*

Bean, C. (1981) An econometric model of manufacturing investment in the UK. *Economic Journal* 91, 106-121.

Blackburn, K. and Pelloni, A. (2001) On the relationship between growth and volatility in learning-by-doing economics, University of Manchester, mimeo.

Bollerslev, T (1986) Generalized Autoregressive Conditional Heteroskedasticity. *Journal of Econometrics* 31, 307-27.

Bollerslev, T. (1990) Modelling the coherence in short run nominal exchange rates: A multivariate generalised ARCH model, *Review of Economics and Statistics* 72, 498-505.

Bollerslev T., Chou R.Y., Kroner, K. F. (1992) ARCH modelling in finance. *Journal of Econometrics* 52, 5-59.

Brainard, W.C., Tobin, J. (1968) Pitfalls in financial model building. *American Economic Review* 58, 99-122.

Brunner, A.D. (1992) Conditional asymmetries in real GNP: A seminonparametric approach. *Journal of Business Economics and Statistics* 10, 65-72.

Caballero, R. (1999) Aggregate Investment, in *Handbook of Macroeconomics* Vol. 1, Eds. J.B. Taylor and M. Woodford, Elsevier Science.

Campa, J.M., Goldberg, L.S. (1995) Investment in manufacturing, exchange rates and external exposure. *Journal of International Economics* 38, 297-320.

Carruth, A., Dickerson, A., Henley, A. (2000a) Econometric modelling of UK aggregate investment: The role of profits and uncertainty. *The Manchester School* 68, 276-300.

Carruth A., Dickerson A., Henley, A. (2000b) What do we know about investment under uncertainty? *Journal of Economic Surveys* 14, 119-153.

Chirinko, R. (1993) Business fixed investment spending: Modelling strategies, empirical results, and policy implications. *Journal of Economic Literature* XXXI, 1875-1911.

Cooper, R., Ejarque, J. (2001) Exhuming Q: Market power versus capital market imperfections, NBER Working Paper # 8182.

Cuthbertson, K., Gasparro, D. (1995) Fixed investment decisions in UK manufacturing: The importance of Tobin's Q, output and debt. *European Economic Review* 39, 919-941.

Darby, J., Hughes Hallett, A., Ireland, J., Piscatelli, L. (1999) The impact of exchange rate uncertainty on the level of investment. *Economic Journal* 109, C55-C67.

Darby, J., Hughes Hallett, A., Ireland, J., Piscatelli, L. (2002) Exchange rate uncertainty, price misalignments and business sector investment. University of Strathclyde, mimeo.

Davis, E.P., Madsen, J. (2001) Productivity and Equity Returns: A Century of Evidence for 9 OECD Countries. Brunel University Department of Economics and Finance Working Paper No 01-12.

Dixit, A., Pindyck, R.S. (1994) *Investment under Uncertainty.* Princeton University Press.

Driver, C., Moreton, D. (1991) The influence of uncertainty on aggregate spending. *Economic Journal* 101, 1452-59.

Driver, C., Moreton, D. (1992) *Investment, Expectations and Uncertainty.* Oxford, Basil Blackwell.

Driver, C., Yip, P., Dakhil, N. (1996) Large company capital formation and effects of market share turbulence: micro-data evidence from the PIMS database. *Applied Economics* 28, 641-651.

Dufour, J.M., King, M. (1991) Optimal invariant tests for the autocorrelation coefficient in linear regressions with stationary and nonstationary errors. *Journal of Econometrics* 47, 115-143.

Elliott, G., Rothemborg, T.J., Stock, J.H. (1996) Efficient tests for an autoregressive unit root. *Econometrica* 64, 813-836.

Engle, R.F. (1983) Estimates of the variance of US inflation based upon the ARCH model. *Journal of Money Credit and Banking* 15, 286-301.

Episcopes, A. (1995) Evidence on the relationship between uncertainty and aggregate investment. *Quarterly Journal of Economics and Finance* 35, 41-52.

Favero, C.A., Pesaran M-H., Sharma, S. (1994) A duration model of irreversible investment, theory and empirical evidence. *Journal of Applied Econometrics* 9, S95-S112.

Ferderer, J.P. (1993) The impact of uncertainty on aggregate investment spending: an empirical analysis. *Journal of Money Credit and Banking* 25, 30-48.

Goldberg, L.S. (1993) Exchange rates and investment in United States Industry. *Review of Economics and Statistics* 75, 575-589.

Guiso, L., Parigi, G. (1989) Investment and demand uncertainty. *The Quarterly Journal of Economics* 114, 185-227.

Hartman, R. (1972) The effect of price and cost uncertainty on investment. *Journal of Economic Theory* 5, 258-266.

Hayashi, F. (1982) Tobin's marginal Q and average Q: A neo-classical interpretation. *Econometrica* 50, 213-24.

Hsieh, D. A. (1988) The statistical properties of daily exchange rates 1974-1983. *Journal of International Economics* 24, 129-145.

Hsieh, D. A. (1989a) Testing for non-linear dependencies in daily foreign exchange rates. *Journal of Business* 62, 25-43.

Hsieh, D. A. (1989b) Modeling heteroskedasticity in daily foreign exchange rates. *Journal of Business and Economic Statistics* 7, 307-17.

Hsiao, C. (1986) *Analysis of Panel Data*. Cambridge University Press, Cambridge.

Huizinga, H. (1993) Inflation uncertainty, relative price uncertainty and investment in US manufacturing. *Journal of Money, Credit and Banking* 25, 521-554.

Jones, C. (1995) Time series tests of endogenous growth models. *Quarterly Journal of Economics* 110, 495-525.

Jorgensen, D.W. (1963) Capital theory and investment behaviour. *American Economic Review* 53, 247-259.

Kao, C., Chiang, M-H. (2000) Testing for Structural Change of a Cointegrated Regression in Panel Data. Syracuse, mimeo.

Kenen, P., Rodrick, D. (1986) Measuring and analyzing the effects of short-term volatility in real exchange rates. *Review of Economics and Statistics* 68, 311-9.

Kneller, R., Young, G (2000) Business cycle volatility, uncertainty and long-run growth. *The Manchester School*, 69, 534-52.

Kurz, M., Motolese, M. (2001) Endogenous uncertainty and market volatility. *Economic Theory* 17, 497-544.

Lamoureux, C.G., Lastrapes, W.D. (1990) Persistence in variance, structural change and the GARCH model. *Journal of Business and Statistics* 8, 225-234.

Lee, J., Shin, K. (2001) The role of variable input in the relationship between investment and uncertainty. *American Economic Review* 90, 667-680.

Leahy, J., Whited, T. (1996) The effects of uncertainty on investment: Some stylised facts. *Journal of Money, Credit and Banking* 28, 64-83.

Lucas, R.E., Prescott, E.C. (1971) Investment under uncertainty. *Econometrica 39*, 659-81.

McGratten, E. (1998) A defense of AK growth models. *Federal Reserve Bank of Minneapolis Quarterly Review* 22(4), 13-27.

Mandelbrot, B. (1963) The variation of certain speculative prices. *Journal of Business* 36, 394-419.

Mussa, M. (1979) Empirical regularities in the behavior of the exchange rates and theories of the foreign exchange market. *Carnegie Rochester Conference Series on Public Policy* 11, 9-57.

Ng, S., Perron, P. (2001) Lag length selection and the construction of unit root tests with good size and power. *Econometrica* 69, 1519-1554.

Nucci, F., Pozzolo, A.F. (2001) Investment and the exchange rate: An analysis with firm-level panel data. *European Economic Review 45, 259-83.*

Pagan, A., Ullah, A. (1988) The econometric analysis of models with risk terms. *Journal of Applied Econometrics* 3, 87-106.

Perron, P., Ng, S. (1996) Useful modifications to unit root tests with dependent errors and their local asymptotic properties. *Review of Economic Studies* 63, 435-465.

Pesaran, M.H. Shin, Y., Smith, R. (1999) Pooled Mean Group estimation of dynamic heterogeneous Panels. *Journal of American Statistical Association* 94, 621-634.

Pesaran, M.H., Smith, R. (1995) Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics* 68, 79-113.

Pesaran, M.H., Smith, R., Im, K-S. (1996) Dynamic linear models for heterogeneous panels. In L. Matyas and P. Sevestre (eds.) The Econometrics of Panel Data, Kluwer Academic Publishers.

Pindyck, R.S., Solimano, A. (1993) Economic instability and aggregate investment, *NBER Macroeconomics Annual*, 259-303.

Phillips, P.C.B., Perron, P. (1988) Testing for a unit root in time series regression. *Biometrika* 71, 599-607.

Price, S. (1995) Aggregate uncertainty, capacity utilization and manufacturing investment. *Applied Economics* 27, 147-154.

Sensenbrenner, G. (1991) Aggregate investment, the stock market, and the Q model - robust results for six OECD countries. *European Economic Review* 35, 769-825.

Serven, L. (2002) Real exchange rate uncertainty and private investment in developing countries, forthcoming, *Review of Economics and Statistics.*

Shafer, J.R. (1986) Managing crises in the emerging financial landscape. OECD Economic Studies, 8: 56-77.

Temple, P., Urga, G., Driver, C. (2001) The influence of uncertainty on investment in the UK: A macro or micro phenomenon? *Scottish Journal of Political Economy* 48, 361-82.

Tobin, J. (1969) A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking* 1, 15-29.

Westerfield, R (1977) The distribution of common stock price changes: An application of transactions time and subordinated stochastic models. *Journal of Financial and Quantitative Analysis* 12, 743-65.

Appendix A: Results including dynamics

Table A1: G7 Basic Investment Functions: OLS Results

	US^1	Canada^2	France^3	Germany^4	Italy^5	Japan^6	UK^7	MGE
Error Correction	-0.054 (t=-2.101)$_1$	-0.117 (-3.649)$_1$	-0.080 (-3.221)$_1$	-0.148 (-3.549)$_1$	-0.051 (-2.018)$_1$	-0.057 (-2.892)$_1$	-0.140 (-2.899)$_1$	-0.092 (-5.818)
ln(YB)	1.353 (27.491)	1.790 (11.051)	1.449 (9.015)	1.255 (17.210)	1.180 (3.380)	1.447 (12.701)	1.278 (9.139)	1.393 (18.322)
Sigma	0.016	0.034	0.016	0.020	0.019	0.012	0.033	
LL	257.33	185.10	264.55	238.46	241.19	274.91	190.06	
$\overline{R}^2$	0.56	0.19	0.58	0.59	0.54	0.60	0.07	
LM$_4$ Test: $\chi^2(4)$ CV = 9.49	6.13	2.43	1.63	0.02	0.01	0.39	0.45	
Normality: $\chi^2(2)$ CV = 5.99	0.55	0.58	1.85	6.50	15.77	6.49	2.97	
Hetero: $\chi^2(1)$ CV = 3.84	0.56	0.85	0.13	0.01	0.03	0.32	1.35	
ARDL	(3,1)	(3,0)	(1,1)	(1,1)	(2,1)	(2,3)	(1,0)	
Dln(IB)(-1)	0.279 (3.436)	0.181 (1.863)			0.310 (3.997)	0.200 (2.300)		0.139 (2.679)
Dln(IB)(-2)	0.232 (2.873)	0.211 (2.167)						0.063 (1.547)
Dln(YB)	1.081 (6.178)		2.505 (10.241)	1.640 (9.745)	1.453 (6.515)	1.155 (7.448)		1.119 (3.307)
Dln(YB)(-1)						0.099 (0.520)		0.014 (1.000)
Dln(YB)(-2)						0.757 (5.230)		0.108 (1.000)
Inpt	-0.413 (-2.018)	-1.437 (-3.1147)	-0.711 (-3.631)	-0.857 (-2.929)	-0.291 (-1.039)	-0.595 (-3.727)	-0.956 (-2.727)	-0.751 (-5.205)

Notes: Dependent variable is Δlib. T-statistics are presented in parentheses. Subscripts to parentheses are lag length of variables. Probabilities for diagnostic tests are presented in squared brackets. Variable definitions are included in the data appendix. 1. We have a balanced panel data set 1973Q1 to 1996Q4. Max lag length (3,3). Individual lag length is determined by the Schwarz Bayesian Information Criteria. Hausman test on poolability 0.20 [p-value = 0.65]. Likelihood Ratio 8.45 [p-value = 0. 21].

Table A2: G7 Basic Investment Functions: PMGE Results

	US^1	Canada^2	France^3	Germany^4	Italy^5	Japan^6	UK^7	PMGE
Error Correction	-0.053 (t=-2.101)$_1$	-0.078 (-2.939)$_1$	-0.086 (-3.860)$_1$	-0.126 (-3.210)$_1$	-0.041 (-3.005)$_1$	-0.064 (-3.567)$_1$	-0.126 (-2.991)$_1$	-0.082 (-6.461)
ln(yb)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)	1.367 (27.491)
Sigma	0.016	0.035	0.016	0.021	0.019	0.012	0.033	
LL	257.33	182.72	264.55	236.40	239.93	281.88	189.46	
$\overline{R}^2$	0.56	0.15	0.55	0.58	0.53	0.66	0.07	
LM$_4$ Test: $\chi^2(4)$ CV = 9.49	6.13	1.28	1.38	0.04	0.01	0.45	0.58	
Normality: $\chi^2(2)$ CV = 5.99	0.53	0.46	2.33	3.96	14.01	7.14	3.43	
Hetero: $\chi^2(1)$ CV = 3.84	0.55	0.00	0.09	0.11	0.02	0.30	1.01	
ARDL	(3,1)	(3,0)	(1,1)	(1,1)	(2,1)	(2,3)	(1,0)	
Dln(IB)(-1)	0.278 (3.559)	0.182 (1.881)			0.302 (4.118)	0.215 (2.604)		0.140 (2.710)
Dln(IB)(-2)	0.231 (2.983)	0.195 (2.020)						0.061 (1.542)
Dln(YB)	1.084 (6.451)		2.4847 (10.465)	1.633 (9.809)	1.485 (7.224)	1.132 (7.651)		1.117 (3.315)
Dln(YB)(-1)						0.071 (0.393)		0.010 (1.000)
Dln(YB)(-2)						0.750 (5.375)		0.107 (1.000)
Inpt	-0.416 (-2.139)	-0.526 (-2.710)	-0.086 (-3.860)	-0.938 (-3.284)	-0.401 (-3.039)	-0.565 (-3.736)	-1.008 (-3.003)	-0.644 (-7.058)

Notes: Dependent variable is Δlib. T-statistics are in parentheses. Subscripts to parentheses are lag length of variables. Probabilities for diagnostic tests are presented in squared brackets. Variable definitions are included in the data appendix. 1. We have a balanced panel data set 1973Q1 to 1996Q4. Max lag length (3,3). Individual lag length is determined by the Schwarz Bayesian Information Criteria. Hausman test on poolability 0.20 [p-value = 0.65]. Likelihood Ratio 8.45 [p-value = 0. 21].

Appendix B: Data Appendix

Unit Root Tests

It is well know that Dickey Fuller unit root type tests have low power, hence Phillips and Perron (1988) propose a nonparametric modification to deal with serial correlation of errors in these tests, required to produce consistent estimation of the equation variance. In Phillips Perron large negative test statistics reject the null hypothesis of unit root. However, Schwert (1989) suggests that there may be substantial size distortions in finite samples when the data generation process has a predominance of negative autocorrelations in first difference.

ADF tests may require a substantial lag to deal with moving average errors, hence have low degrees of freedom and low power. Perron and Ng (1996), following Stock (1990, unpublished), suggest three modified tests to deal with size distortions when the residuals have negative serial correlation. Perron and Ng utilise an autoregressive spectral density estimator. They use local asymptotic analysis to explain why other estimators yield no improvement. Perron and Ng show that their test maintains good power whilst correcting for the moving average errors encountered in most macroeconomic series.

Furthermore Ng and Perron (2001) suggest utilising GLS detrending to their modified tests estimating the spectral density at frequency zero, yielding non-negligible size and power gains.

Elliot, Rothemborg and Stock (1996) derive the asymptotic power envelope for point optimal tests of a unit root. Tests are second best when uniformly point optimal tests do not exist. Pt(0.5) has a power function tangential to the power envelope at one point and never too far below the envelope. DF-GLS is one that has the limiting power function close to that of the Pt(0.5) test. Dufour and King (1991) suggest that local detrending using GLS yields substantial power gains.

Throughout we utilise the Ng and Perron (2001) method for choosing the lag length. BIC and AIC are not sufficiently flexible for unit root tests. In particular, a modified AIC approach produces unit root tests with much improved size and power. MAIC with GLS and M class have good size and power. The MAIC is also useful for DF-GLS. However Phillips and Perron (GLS) still has high size distortions even when using MAIC.

Table B: Unit Root Tests Summary

	US	CN	FR	GE	IT	JP	UK
ln(IB)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
ln(IB)*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
ln(YB)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
ln(YB)*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Tobin's Q	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Tobin's Q*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
User Cost	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
User Cost*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
Long Rate	I(1)	I(1)	I(1)	I(0)	I(1)	I(1)	I(1)
Long Rate*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
CV(NEER)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)
CV(NEER)*	I(1)	I(0)	I(0)	I(1)	I(1)	I(1)	I(0)
CV(Inflation)	I(1)	I(1)	I(1)	I(0)	I(1)	I(1)	I(1)
CV(Inflation)*	I(0)	I(0)	I(1)	I(1)	I(1)	I(1)	I(1)
CV(Equity Prices)	I(0)	I(1)	I(0)	I(0)	I(0)	I(0)	I(0)
CV(Equity Prices)*	I(0)	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)
CV(Industrial Prod)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(0)
CV(Industrial Prod)*	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)	I(1)
CV(REER)	I(0)	I(0)	I(1)	I(0)	I(1)	I(1)	I(0)
CV(REER)*	I(1)	I(0)	I(1)	I(1)	I(1)	I(1)	I(0)
CV(Long Rate)	I(0)	I(0)	I(1)	I(0)	I(1)	I(1)	I(1)
CV(Long Rate)*	I(1)	I(1)	I(1)	I(0)	I(0)	I(0)	I(1)

Notes: Sample period 1973Q1 to 1996Q4. Asterisk (*) indicates trend in unit root specification. CV(.) is the conditional variance from GARCH estimation.

Table B1 Canada Unit Root Tests Trend Included

	k	Alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	2	0.943	-10.374	-2.260	0.218	9.921	8.869	-2.194
ln(YB)	1	0.945	-9.864	-2.198	0.223	9.917	9.341	-2.210
Q	4	0.948	-10.069	-2.239	0.222	10.809	9.075	-2.065
User Cost	0	0.936	-5.639	-1.675	0.297	19.664	16.152	-1.812
Long Rate	1	0.960	-5.108	-1.467	0.287	19.417	17.291	-1.422
CV(DP)	0	0.588	**-31.060**	**-3.940**	**0.127**	**2.934**	**2.937**	**-4.966**
CV(DER)	0	0.463	**-37.212**	**-4.295**	**0.115**	**2.694**	**2.553**	**-5.884**
CV(DEQ)	9	0.637	-5.456	-1.649	0.302	17.671	16.695	-2.222
CV(DIP)	0	0.873	-11.259	-2.363	0.210	8.379	8.142	-2.537
CV(DLR)	0	0.879	-10.737	-2.309	0.215	8.800	8.529	-2.471
CV(RER)	4	0.422	**-26.382**	**-3.631**	**0.138**	**3.442**	**3.461**	**-3.448**
SD(DP)	0	0.867	-11.756	-2.422	0.206	7.626	7.763	-2.595
SD(DER)	9	0.853	-9.766	-2.208	0.226	10.094	9.337	-2.145
SD(DEQ)	8	0.891	-10.359	-2.222	0.215	9.455	9.056	-2.016
SD(DLR)	1	0.932	-8.686	-2.059	0.237	11.046	10.585	-2.087
V(DP)	8	0.960	-3.510	-1.322	0.377	27.965	25.920	-1.287
V(DER)	8	0.882	-8.520	-2.062	0.242	11.461	10.703	-2.064
V(DEQ)	8	0.921	-6.492	-1.743	0.268	14.739	14.056	-1.805
V(DLR)	9	0.939	**-44.530**	**-4.705**	**0.106**	**2.167**	**2.117**	-2.375
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Table B2 Table Canada Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	3	1.006	0.819	0.685	0.836	68.204	49.147	0.874
ln(YB)	3	1.005	1.267	1.371	1.082	114.525	84.843	1.346
Q	4	0.963	-6.715	-1.816	0.270	3.824	3.707	-1.762
User Cost	0	0.985	-1.405	-0.696	0.496	14.503	14.181	-0.708
Long Rate	1	0.970	-3.780	-1.353	0.358	7.674	6.495	-1.332
CV(DP)	11	0.898	-1.833	-0.858	0.468	14.343	12.099	-0.984
CV(DER)	7	0.861	-2.502	-1.108	0.443	12.042	9.737	-1.470
CV(DEQ)	9	0.731	-3.325	-1.259	0.379	8.153	7.348	-1.977
CV(DIP)	0	0.959	-3.753	-1.162	0.310	7.346	6.641	-1.201
CV(DLR)	0	0.907	**-8.393**	-2.037	0.243	3.460	**2.963**	**-2.151**
CV(RER)	6	0.597	**-11.775**	**-2.419**	**0.205**	**2.241**	**2.110**	**-2.508**
SD(DP)	0	0.896	**-9.300**	**-2.092**	**0.225**	3.190	**2.889**	**-2.215**
SD(DER)	9	0.933	-3.561	-1.274	0.358	8.760	6.884	-1.287
SD(DEQ)	8	0.912	-7.369	-1.884	0.256	3.571	3.458	-1.874
SD(DLR)	1	0.947	-6.687	-1.827	0.273	4.242	3.668	-1.850
V(DP)	9	0.990	-1.264	-0.610	0.482	19.531	14.252	-0.545
V(DER)	8	0.950	-3.261	-1.211	0.371	9.492	7.454	-1.168
V(DEQ)	8	0.938	-4.717	-1.517	0.322	5.621	5.236	-1.688
V(DLR)	9	0.953	**-21.706**	**-3.294**	**0.152**	**1.234**	1.130	**-2.113**
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS for both the statistic and spectral density. Estimated statistics in bold indicate stationarity. MZa and MZt are Modified Phillips-Perron tests. MSB is Modified Sargan-Bhargava test. ERS Pt is the Elliot, Rothemberg and Stock feasible point optimal test. M Pt is the modified point optimal test. DF-GLS is the Augmented Dickey Fuller test.

Table B3 France Unit Root Tests Trend Included

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	0	0.965	-3.161	-1.238	0.392	30.981	28.389	-1.309
ln(YB)	2	0.942	-11.029	-2.231	0.202	9.347	8.855	-2.003
Q	6	0.980	-1.227	-0.641	0.523	64.417	54.514	-0.708
User Cost	0	0.924	-6.777	-1.753	0.259	14.986	13.530	-1.866
Long Rate	1	0.972	-5.403	-1.553	0.288	19.084	16.598	-1.495
CV(DP)	11	0.868	-2.993	-1.123	0.375	27.622	27.912	-1.466
CV(DER)	0	0.547	**-33.260**	**-4.075**	**0.123**	**2.717**	**2.755**	**-5.269**
CV(DEQ)	0	0.838	-14.063	-2.599	0.185	7.172	6.788	-2.848
CV(DIP)	3	0.967	-3.333	-1.276	0.383	36.283	27.030	-1.230
CV(DLR)	4	0.868	-7.132	-1.861	0.261	14.655	12.823	-1.898
CV(RER)	11	0.582	-2.357	-1.085	0.461	39.778	38.660	-1.679
SD(DP)	0	0.870	-11.298	-2.377	0.210	9.614	8.066	-2.594
SD(DER)	8	0.895	-5.685	-1.681	0.296	18.757	16.020	-2.048
SD(DEQ)	8	0.836	-14.857	-2.673	0.180	6.657	6.448	-2.063
SD(DLR)	1	0.913	**-19.279**	**-3.090**	**0.160**	**5.167**	**4.817**	**-3.118**
V(DP)	8	0.932	-1.390	-0.829	0.597	83.631	65.015	-2.108
V(DER)	8	0.926	-4.157	-1.441	0.347	25.602	21.920	-1.697
V(DEQ)	8	0.919	-5.940	-1.632	0.275	15.560	15.238	-1.609
V(DLR)	12	0.941	-3.857	-1.259	0.326	23.838	21.969	-1.244
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Table B4 France Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	7	0.993	-0.912	-0.464	0.509	18.863	16.343	-0.618
ln(YB)	12	1.002	0.884	0.777	0.879	72.892	54.207	0.623
Q	11	1.008	1.132	0.701	0.619	35.481	31.705	0.483
User Cost	0	0.945	-5.003	-1.575	0.315	5.861	4.915	-1.639
Long Rate	1	0.979	-4.103	-1.348	0.328	6.337	6.080	-1.266
CV(DP)	10	1.014	0.215	0.215	0.999	72.450	58.790	0.491
CV(DER)	5	0.812	-6.592	-1.698	0.258	4.490	4.120	**-2.034**
CV(DEQ)	0	0.862	**-12.152**	**-2.439**	**0.201**	**2.231**	**2.119**	**-2.624**
CV(DIP)	3	0.983	-1.477	-0.756	0.512	14.331	14.395	-0.834
CV(DLR)	4	0.939	-3.312	-1.256	0.379	9.962	7.375	-1.255
CV(RER)	5	0.895	-1.489	-0.693	0.466	16.721	13.077	-0.965
SD(DP)	0	0.903	**-8.755**	**-2.092**	0.239	**3.027**	2.799	**-2.206**
SD(DER)	10	0.916	-2.387	-1.020	0.427	9.675	9.835	**-2.166**
SD(DEQ)	8	0.882	**-8.499**	**-2.038**	0.240	3.139	2.973	-1.822
SD(DLR)	1	0.941	**-12.951**	**-2.539**	**0.196**	**2.351**	**1.914**	**-2.542**
V(DP)	8	0.954	-0.731	-0.571	0.781	39.836	30.657	-1.893
V(DER)	8	0.953	-2.241	-1.015	0.453	10.456	10.607	-1.415
V(DEQ)	8	0.943	-4.027	-1.394	0.346	6.545	6.113	-1.440
V(DLR)	8	0.957	-5.328	-1.632	0.306	5.701	4.600	-1.478
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Table B5 Germany Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	1	1.002	0.357	0.250	0.702	36.968	33.507	0.166
ln(YB)	4	1.006	1.333	1.112	0.834	67.288	53.910	0.940
Q	2	0.983	-1.397	-0.724	0.519	17.760	14.904	-0.727
User Cost	1	0.964	-3.905	-1.257	0.322	7.143	6.398	-1.419
Long Rate	1	0.939	**-9.802**	**-2.061**	**0.210**	3.460	**3.091**	**-2.083**
CV(DP)	2	0.869	**-9.694**	**-2.077**	**0.214**	3.469	**3.011**	**-2.075**
CV(DER)	9	0.682	-0.470	-0.406	0.864	38.347	38.647	-1.949
CV(DEQ)	0	0.884	**-10.345**	**-2.270**	**0.219**	**2.492**	**2.384**	**-2.414**
CV(DIP)	11	0.498	-0.580	-0.513	0.885	39.150	38.992	-1.721
CV(DLR)	3	0.841	**-9.457**	**-2.171**	**0.230**	**2.838**	**2.604**	**-2.226**
CV(RER)	0	0.460	**-37.435**	**-4.321**	**0.115**	**0.665**	**0.670**	**-5.919**
SD(DP)	10	0.906	-1.177	-0.454	0.386	12.903	11.790	-1.378
SD(DER)	9	0.932	-2.852	-1.193	0.418	9.413	8.587	-1.864
SD(DEQ)	8	0.900	-4.144	-1.362	0.329	6.161	6.018	-1.399
SD(DLR)	10	0.957	-1.865	-0.938	0.503	15.989	12.790	-1.225
V(DP)	8	0.953	-1.372	-0.544	0.396	13.699	11.639	-1.223
V(DER)	8	0.983	-0.974	-0.677	0.695	30.323	24.080	-0.888
V(DEQ)	8	0.950	-3.189	-1.173	0.368	8.764	7.580	-1.209
V(DLR)	8	0.944	-5.228	-1.610	0.308	5.157	4.706	-1.662
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Table B6 Germany Unit Root Tests Trend Included

	K	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	0	0.964	-3.147	-1.251	0.398	34.608	28.895	-1.373
ln(YB)	0	0.970	-2.685	-1.126	0.419	35.442	32.837	-1.192
Q	2	0.988	-0.898	-0.332	0.370	40.762	35.741	-0.350
User Cost	0	0.901	-8.870	-2.104	0.237	10.726	10.281	-2.231
Long Rate	1	0.898	-16.541	-2.861	0.173	5.505	5.603	**-2.940**
CV(DP)	2	0.830	-12.628	-2.492	0.197	7.327	7.333	-2.528
CV(DER)	9	0.352	-1.341	-0.818	0.610	67.341	67.784	-2.653
CV(DEQ)	0	0.864	-12.038	-2.410	0.200	7.722	7.807	-2.589
CV(DIP)	11	0.045	-1.317	-0.763	0.580	62.448	62.883	-2.342
CV(DLR)	3	0.800	-12.130	-2.432	0.200	7.973	7.683	-2.473
CV(RER)	0	0.416	**-39.241**	**-4.427**	**0.113**	**2.400**	**2.337**	**-6.263**
SD(DP)	0	0.818	-15.679	-2.756	0.176	6.000	6.076	**-3.034**
SD(DER)	9	0.873	-6.048	-1.635	0.270	14.694	14.984	-2.326
SD(DEQ)	8	0.895	-4.418	-1.426	0.323	20.325	20.129	-1.454
SD(DLR)	10	0.928	-3.354	-1.289	0.384	31.016	27.063	-1.605
V(DP)	0	0.888	-10.011	-2.216	0.221	9.015	9.202	-2.347
V(DER)	8	0.963	-1.826	-0.768	0.421	37.914	37.331	-1.134
V(DEQ)	8	0.937	-4.341	-1.454	0.335	22.211	20.815	-1.441
V(DLR)	8	0.926	-7.656	-1.934	0.253	13.346	11.957	-1.865
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Table B7 Italy Unit Root Tests

	k	Alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	2	0.994	-1.000	-0.416	0.415	15.734	12.993	-0.378
ln(YB)	11	1.001	0.206	0.131	0.633	38.025	27.687	0.275
Q	7	0.972	-2.455	-1.062	0.433	11.129	9.732	-1.022
User Cost	0	0.993	-0.563	-0.352	0.626	31.762	23.087	-0.436
Long Rate	1	0.980	-4.028	-1.415	0.351	7.824	6.087	-1.394
CV(DP)	1	0.984	-1.745	-0.778	0.446	13.169	11.857	-0.814
CV(DER)	9	0.904	-0.771	-0.492	0.637	26.616	22.497	-0.919
CV(DEQ)	2	0.540	**-23.676**	**-3.434**	**0.145**	**1.112**	**1.056**	**-4.225**
CV(DIP)	1	1.000	0.175	0.136	0.774	57.018	37.769	-0.016
CV(DLR)	9	0.861	-2.984	-1.162	0.389	9.830	8.088	-1.263
CV(RER)	9	0.866	-0.702	-0.448	0.638	25.985	22.902	-1.066
SD(DP)	0	0.949	-4.705	-1.533	0.326	5.443	5.208	-1.580
SD(DER)	8	0.972	-1.252	-0.537	0.429	14.497	12.750	-0.649
SD(DEQ)	0	0.901	**-8.884**	**-2.089**	0.235	3.231	**2.831**	**-2.209**
SD(DLR)	4	0.939	**-8.420**	-1.990	0.236	4.105	**3.148**	-1.880
V(DP)	8	0.962	-1.789	-0.936	0.523	14.053	13.557	**-2.072**
V(DER)	8	0.968	-2.238	-0.893	0.399	10.915	9.790	-0.962
V(DEQ)	8	0.935	-3.316	-1.259	0.380	8.586	7.368	-1.556
V(DLR)	12	0.950	-3.702	-1.346	0.364	8.202	6.625	-1.169
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Table B8 Italy Unit Root Tests Trend Included

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	2	0.923	-11.713	-2.409	0.206	7.761	7.840	-2.754
ln(YB)	1	0.946	-10.410	-2.165	0.208	11.009	9.310	-2.067
Q	1	0.917	-10.735	-2.290	0.213	8.448	8.623	-2.318
User Cost	0	0.908	-8.257	-1.923	0.233	11.944	11.382	-2.039
Long Rate	1	0.970	-6.757	-1.705	0.252	15.765	13.606	-1.531
CV(DP)	8	0.939	-5.851	-1.691	0.289	17.184	15.548	-1.578
CV(DER)	9	0.820	-2.019	-1.004	0.498	45.854	45.127	-1.188
CV(DEQ)	0	0.477	**-36.663**	**-4.281**	**0.117**	**2.527**	**2.487**	**-5.805**
CV(DIP)	1	0.951	-4.129	-1.401	0.339	28.954	21.696	-1.592
CV(DLR)	0	0.504	**-35.409**	**-4.205**	**0.119**	**2.633**	**2.590**	**-5.599**
CV(RER)	9	0.816	-1.593	-0.882	0.554	56.610	56.204	-1.119
SD(DP)	0	0.922	-6.812	-1.842	0.270	16.704	13.381	-2.000
SD(DER)	8	0.949	-2.578	-1.043	0.404	32.531	32.057	-1.213
SD(DEQ)	0	0.866	-11.699	-2.345	0.200	9.171	8.181	-2.553
SD(DLR)	4	0.886	**-18.016**	**-3.001**	**0.167**	5.534	**5.058**	-2.741
V(DP)	8	0.949	-2.839	-1.191	0.420	39.258	32.097	-2.162
V(DER)	10	0.934	-12.570	-2.478	0.197	7.568	7.415	-2.007
V(DEQ)	0	0.896	-9.144	-2.049	0.224	11.835	10.323	-2.212
V(DLR)	0	0.907	-8.300	-2.012	0.242	11.722	11.062	-2.134
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Table B9 Japan Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	3	1.003	0.449	0.278	0.620	34.134	28.154	0.627
ln(YB)	4	1.001	-0.028	-0.015	0.537	27.053	20.927	0.305
Q	4	0.974	-4.613	-1.519	0.329	5.229	5.311	-1.518
User Cost	6	0.985	-1.470	-0.857	0.583	21.642	16.659	-1.071
Long Rate	0	0.982	-1.720	-0.600	0.349	10.150	9.994	-0.610
CV(DP)	1	0.984	-1.745	-0.778	0.446	13.169	11.857	-0.814
CV(DER)	9	0.904	-0.771	-0.492	0.637	26.616	22.497	-0.919
CV(DEQ)	2	0.540	**-23.676**	**-3.434**	**0.145**	**1.112**	**1.056**	**-4.225**
CV(DIP)	1	1.000	0.175	0.136	0.774	57.018	37.769	-0.016
CV(DLR)	9	0.861	-2.984	-1.162	0.389	9.830	8.088	-1.263
CV(RER)	9	0.866	-0.702	-0.448	0.638	25.985	22.902	-1.066
SD(DP)	12	0.874	-1.364	-0.725	0.531	15.294	15.426	**-2.725**
SD(DER)	0	0.906	**-8.447**	-1.792	**0.212**	4.335	3.865	-1.895
SD(DEQ)	8	0.943	-3.786	-1.358	0.359	6.353	6.483	-1.309
SD(DLR)	5	0.953	-3.806	-1.339	0.352	8.546	6.466	-1.306
V(DP)	8	0.957	-1.328	-0.646	0.486	15.270	14.163	-1.458
V(DER)	0	0.934	-6.031	-1.331	**0.221**	5.431	5.244	-1.383
V(DEQ)	8	0.954	-3.424	-1.308	0.382	7.008	7.155	-1.282
V(DLR)	8	0.982	-1.365	-0.799	0.585	22.783	17.223	-0.701
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Table B10 Japan Unit Root Tests Trend Included

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	2	0.961	-10.768	-2.319	0.215	9.390	8.472	-2.464
ln(YB)	3	0.942	-11.152	-2.341	0.210	8.764	8.280	-2.100
Q	4	0.970	-5.664	-1.671	0.295	16.945	16.063	-1.572
User Cost	6	0.979	-2.150	-0.923	0.429	44.393	36.588	-1.053
Long Rate	0	0.922	-6.871	-1.745	0.254	15.599	13.386	-1.879
CV(DP)	8	0.939	-5.851	-1.691	0.289	17.184	15.548	-1.578
CV(DER)	9	0.820	-2.019	-1.004	0.498	45.854	45.127	-1.188
CV(DEQ)	0	0.477	**-36.663**	**-4.281**	**0.117**	**2.527**	**2.487**	**-5.805**
CV(DIP)	1	0.951	-4.129	-1.401	0.339	28.954	21.696	-1.592
CV(DLR)	0	0.504	**-35.409**	**-4.205**	**0.119**	**2.633**	**2.590**	**-5.599**
CV(RER)	9	0.816	-1.593	-0.882	0.554	56.610	56.204	-1.119
SD(DP)	0	0.848	-13.157	-2.565	0.195	7.776	6.927	-2.809
SD(DER)	0	0.881	-10.650	-2.222	0.209	8.843	8.978	-2.364
SD(DEQ)	8	0.932	-4.595	-1.516	0.330	20.078	19.829	-1.445
SD(DLR)	5	0.881	-10.705	-2.287	0.214	9.282	8.643	-2.168
V(DP)	0	0.889	-9.878	-2.222	0.225	9.553	9.226	-2.367
V(DER)	0	0.923	-7.000	-1.636	0.234	13.101	13.331	-1.702
V(DEQ)	8	0.945	-4.040	-1.406	0.348	22.430	22.375	-1.375
V(DLR)	8	0.937	-4.004	-1.276	0.319	22.429	21.189	-1.279
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Table B11 UK Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	4	1.001	-0.469	-0.210	0.448	18.005	15.457	0.041
ln(YB)	4	1.005	1.459	1.108	0.759	56.244	46.814	0.787
Q	2	0.983	-1.562	-0.708	0.453	12.373	12.544	-0.706
User Cost	0	0.955	-4.076	-0.450	**0.110**	7.062	6.836	-0.472
Long Rate	5	0.958	-2.381	-1.003	0.421	10.157	9.767	-1.258
CV(DP)	9	0.590	-2.324	-1.056	0.454	10.477	10.392	**-3.419**
CV(DER)	0	0.488	**-36.157**	**-4.193**	**0.116**	**0.863**	**0.849**	**-5.636**
CV(DEQ)	0	0.817	**-15.759**	**-2.763**	**0.175**	**1.708**	**1.721**	**-3.041**
CV(DIP)	3	0.420	**-12.175**	**-2.460**	**0.202**	**2.002**	**2.043**	**-3.281**
CV(DLR)	0	0.983	-1.593	-0.804	0.505	14.718	13.788	-0.825
CV(RER)	0	0.379	**-40.653**	**-4.440**	**0.109**	**0.827**	**0.792**	**-6.443**
SD(DP)	0	0.913	-7.929	-1.954	0.246	3.236	3.233	**-2.045**
SD(DER)	8	0.927	-3.264	-1.263	0.387	8.122	7.493	-1.330
SD(DEQ)	8	0.911	-6.157	-1.691	0.275	4.214	4.190	-1.588
SD(DLR)	9	0.895	-2.903	-1.137	0.392	8.441	8.274	**-2.498**
V(DP)	12	0.912	-1.730	-0.845	0.488	12.889	12.900	**-2.445**
V(DER)	8	0.967	-1.653	-0.909	0.550	18.325	14.821	-1.050
V(DEQ)	9	0.929	-2.407	-0.974	0.405	9.693	9.490	**-2.529**
V(DLR)	8	0.946	-3.189	-1.206	0.378	8.049	7.615	-1.415
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Table B12 UK Unit Root Tests Trend Included

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	0	0.947	-4.786	-1.516	0.317	20.619	18.854	-1.601
ln(YB)	3	0.963	-7.096	-1.810	0.255	15.751	12.957	-1.624
Q	2	0.955	-4.162	-1.393	0.335	27.892	21.385	-1.385
User Cost	0	0.896	-9.328	-1.383	**0.148**	12.492	12.470	-1.471
Long Rate	5	0.938	-4.153	-1.384	0.333	27.332	21.351	-1.458
CV(DP)	9	0.496	-3.604	-1.330	0.369	26.534	25.077	**-3.492**
CV(DER)	0	0.502	**-35.522**	**-4.179**	**0.118**	**2.719**	**2.763**	**-5.565**
CV(DEQ)	0	0.774	**-18.991**	**-3.076**	**0.162**	**4.923**	**4.830**	**-3.476**
CV(DIP)	3	0.317	-14.637	-2.705	0.185	6.180	6.230	**-3.648**
CV(DLR)	0	0.967	-2.670	-1.080	0.405	41.678	31.636	-1.264
CV(RER)	0	0.391	**-40.224**	**-4.453**	**0.111**	**2.402**	**2.436**	**-6.402**
SD(DP)	0	0.883	-10.313	-2.257	0.219	10.097	8.903	-2.439
SD(DER)	8	0.895	-4.597	-1.440	0.313	19.837	19.284	-1.515
SD(DEQ)	8	0.878	-9.539	-2.142	0.225	10.613	9.736	-1.885
SD(DLR)	9	0.863	-5.104	-1.554	0.304	19.974	17.665	-2.632
V(DP)	0	0.928	-6.407	-1.765	0.275	15.902	14.225	-1.877
V(DER)	8	0.947	-2.526	-1.035	0.410	36.338	32.776	-1.174
V(DEQ)	8	0.924	-5.343	-1.537	0.288	18.574	16.743	-1.554
V(DLR)	8	0.922	-5.161	-1.552	0.301	20.676	17.437	-1.626
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Notes: *K* is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Table B13 US Unit Root Tests

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	2	1.007	1.489	1.014	0.681	50.527	39.217	1.067
ln(YB)	9	1.003	0.619	0.377	0.609	36.351	28.302	0.579
Q	0	0.992	-0.719	-0.450	0.625	25.957	22.201	-0.489
User Cost	2	0.984	-1.935	-0.881	0.455	11.341	11.520	-0.859
Long Rate	1	0.965	-4.494	-1.488	0.331	6.083	5.474	-1.479
CV(DP)	6	0.741	-5.894	-1.625	0.276	4.496	4.444	**-2.880**
CV(DER)	5	0.862	-7.410	-1.786	0.241	3.813	3.810	-1.901
CV(DEQ)	1	0.679	**-22.588**	**-3.361**	**0.149**	**1.133**	**1.085**	**-3.690**
CV(DIP)	7	0.609	-3.138	-1.239	0.395	7.647	7.788	-2.260
CV(DLR)	8	0.939	**-9.640**	**-2.195**	0.228	**2.807**	**2.545**	-1.744
CV(RER)	2	0.852	**-9.698**	**-2.037**	**0.210**	3.392	**3.162**	**-2.100**
SD(DP)	0	0.952	-4.378	-1.460	0.334	6.309	5.632	-1.509
SD(DER)	8	0.962	-1.733	-0.884	0.510	17.564	13.427	-0.974
SD(DEQ)	8	0.929	-4.962	-1.566	0.316	5.617	4.961	-1.588
SD(DLR)	2	0.952	-5.647	-1.672	0.296	5.204	4.363	-1.647
V(DP)	8	0.956	-4.062	-1.354	0.333	6.050	6.119	-1.295
V(DER)	8	0.991	-0.363	-0.288	0.792	49.265	34.523	-0.411
V(DEQ)	8	0.960	-2.620	-1.135	0.433	10.703	9.312	-1.436
V(DLR)	9	0.959	**-9.113**	**-2.134**	0.234	**2.880**	**2.689**	-1.704
5% Critical Values			*-8.1*	*-1.98*	*0.233*	*3.17*	*3.17*	*-1.98*

Table B14 US Unit Root Tests Trend Included

	k	alpha-hat	MZa	MZt	MSB	ERS Pt	M Pt	DF-GLS
ln(IB)	1	0.925	-14.966	-2.651	0.177	6.534	6.592	-2.647
ln(YB)	1	0.919	-11.717	-2.411	0.206	8.528	7.830	-2.465
Q	0	0.990	-0.507	-0.237	0.468	65.784	51.038	-0.451
User Cost	1	0.971	-2.435	-1.089	0.447	45.496	36.837	-1.187
Long Rate	1	0.958	-5.471	-1.603	0.293	18.079	16.517	-1.604
CV(DP)	0	0.538	**-33.683**	**-4.100**	**0.122**	**2.781**	**2.725**	**-5.338**
CV(DER)	5	0.868	-7.229	-1.799	0.249	12.547	12.788	-1.890
CV(DEQ)	1	0.646	**-24.797**	**-3.519**	**0.142**	**3.753**	**3.687**	**-3.900**
CV(DIP)	7	0.467	-4.660	-1.526	0.328	19.431	19.553	-2.598
CV(DLR)	2	0.933	-6.784	-1.831	0.270	13.961	13.443	-1.832
CV(RER)	2	0.838	-10.801	-2.266	0.210	8.575	8.726	-2.328
SD(DP)	0	0.932	-5.975	-1.689	0.283	18.628	15.212	-1.833
SD(DER)	0	0.836	-14.207	-2.613	0.184	6.985	6.720	-2.861
SD(DEQ)	8	0.899	-8.147	-1.980	0.243	12.807	11.303	-1.797
SD(DLR)	2	0.931	-8.173	-1.997	0.244	11.647	11.225	-1.953
V(DP)	8	0.946	-5.194	-1.572	0.303	18.230	17.391	-1.477
V(DER)	8	0.884	-5.331	-1.547	0.290	19.084	16.814	-1.988
V(DEQ)	8	0.948	-3.723	-1.305	0.350	26.764	23.610	-1.481
V(DLR)	9	0.951	-12.446	-2.481	0.199	7.430	7.398	-1.847
5% Critical Values			*-17.3*	*-2.91*	*0.168*	*5.48*	*5.48*	*-2.901*

Notes: ***K*** is the lag length determined by MAIC. Sample period 1973Q1 1996Q1. Alpha-hat is the estimated autoregressive coefficient. All variables have been detrended by GLS. Estimated statistics in bold indicate stationarity.

Appendix C: Tests using other Measures of Uncertainty

As mentioned in the text, our focus on GARCH measures of uncertainty is justified by the fact that heightened average volatility alone may merely reflect a greater incidence of random and independent shocks, i.e. greater *risk*, without a change in underlying perceptions as to the situation on the part of firms considering investment. On the other hand, heightened conditional volatility may indicate greater *uncertainty* on the part of the market regarding the direction of the variable and the intentions of the authorities, which may be more likely to affect investment.

Nevertheless, for completeness, in this appendix we assess the Kenen and Rodrick and rolling standard deviation measures for selected indicators of uncertainty and their impact on investment using the panel estimation framework. The results are presented in Table C1.

Whereas the GARCH approach estimates the autocorrelated volatility of our time series and provides negative effects from uncertainty, the volatility of the raw exchange rate, or total volatility, series does not provide substantial results in favour of a negative effect from moving-average measures of exchange rate volatility on investment. None of the PMG coefficients in Table C1 suggest a significant negative effect (only the mean group estimator – which may be susceptible to country outliers – gives an indication of negative effect from volatility). Indeed the first difference of Kenen's measure of volatility suggests that there is a positive effect (although in this case the LR statistics for pooling fails). As argued there are economic reasons for preferring the GARCH, as it highlights periods of concentrated volatility which might be expected to maximise uncertainty and the option value of waiting to undertake investment, while the rolling measures could just be capturing background volatility with occasional outliers that firms learn to live with.

From the other variables considered, there is some indication of a negative effect from inflation in Table C2 and this is irrespective of whether we use Kenen and Rodrick's measure of volatility or the standard deviation. The implications for monetary policy reactions may be a reason why it is moving average and not GARCH measures of inflation volatility that come to the fore. Short, and long interest rates and the equity price series provide scant evidence of any effect in Table C3. We find that the standard deviation of the equity series has a positive effect although there is no evidence of poolability using the LR statistic (Table C4).

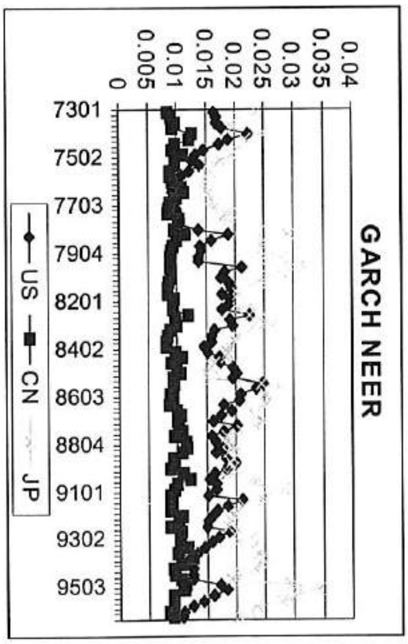
Table C1 Panel Estimation of investment: Whole Sample Period G7 Exchange Rate, Inflation, Long Rate and Equity Prices

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
LYB	**1.408** **(24.204)**	**1.441** **(18.147)**	**1.425** **(23.237)**	**1.421** **(18.928)**	**1.285** **(22.750)**	**1.356** **(20.518)**	**1.272** **(23.434)**	**1.288** **(17.926)**	**1.379** **(26.702)**	**1.372** **(14.886)**	**1.382** **(27.001)**	**1.378** **(17.926)**	**1.324** **(31.984)**	**1.343** **(16.351)**	**1.339** **(30.682)**	**1.350** **(18.163)**
SD(DER)	1.266 (1.288)	-1.487 (-0.639)														
KR(DER)			**1.651** **(2.112)**	-0.191 (-0.139)												
SD(DP)					**-8.865** **(-2.002)**	-7.196 (-1.055)										
KR(DP)							**-8.331** **(-2.406)**	-9.150 (-1.927)								
SD(LR)									0.025 (1.013)	0.025 (0.901)						
KR(LR)											0.056 (1.692)	0.042 (1.393)				
SD(DEQ)													0.283 (1.399)	0.027 (0.109)		
KR(DEQ)															0.126 (0.816)	-0.087 (-0.488)
Error Correction	**-0.077** **(-6.204)**	**-0.090** **(-5.704)**	**-0.075** **(-6.152)**	**-0.094** **(-6.021)**	**-0.082** **(-4.912)**	**-0.099** **(-6.308)**	**-0.084** **(-4.904)**	**-0.101** **(-5.586)**	**-0.081** **(-7.068)**	**-0.102** **(-5.219)**	**-0.085** **(-6.932)**	**-0.109** **(-4.871)**	**-0.091** **(-5.597)**	**-0.107** **(-6.904)**	**-0.090** **(-6.215)**	**-0.106** **(-6.902)**
LR Statistic χ^2 [p–value]	**32.41 (12)** [0.00]		**26.86 (12)** [0.01]		**26.52 (12)** [0.01]		**22.47 (12)** [0.03]		16.81 (12) [0.16]		16.87 (12) [0.15]		13.86 (12) [0.31]		14.32 (12) [0.28]	
Hausman χ^2 [p–value]	1.76 [0.42]		3.25 [0.20]		-5.14 [0.08]		0.12 [0.94]		0.92 [0.97]		n.a.		4.91 [0.09]		5.86 [0.05]	

Notes: SD(.) is the standard deviation. KR(.) is the Kenen Rodrick measure of volatility. See Table 8.

APPENDIX D:

Chart D1: Nominal Exchange Rate Volatility measured by GARCH



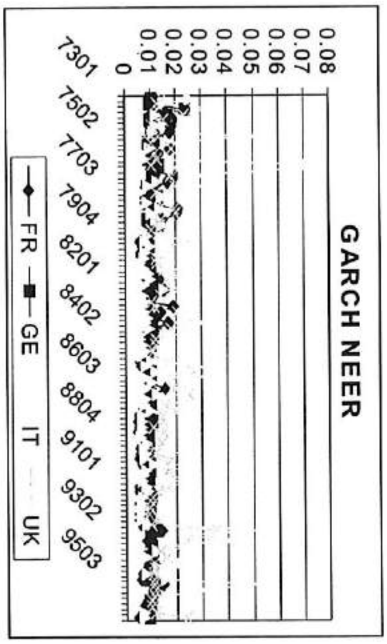
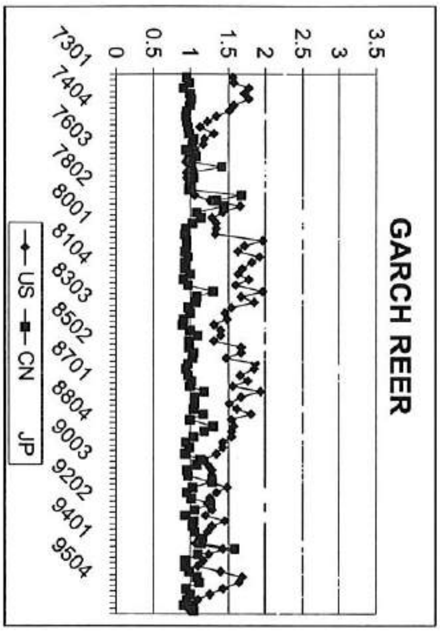
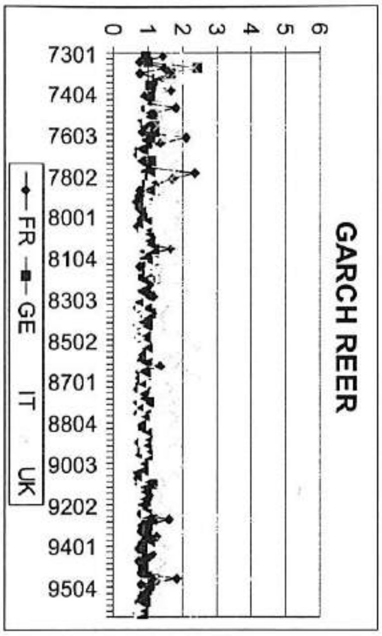


Chart D2: Real Exchange Rate Volatility measured by GARCH





Appendix E

Table E1 Panel Estimation of Investment and Uncertainty

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.247** **(29.271)**	**1.250** **(10.998)**	**1.282** **(22.641)**	**1.245** **(10.272)**	**1.236** **(25.336)**	**1.198** **(12.887)**	**1.255** **(27.397)**	**1.284** **(12.029)**	**1.243** **(28.968)**	**1.248** **(12.774)**	1.236 **(30.469)**	**1.261** **(12.909)**	**1.259** **(28.733)**	**1.240** **(12.577)**
Q	**0.166** **(3.233)**	0.388 (0.743)	**0.210** **(2.218)**	0.487 (1.059)	**0.166** **(3.031)**	0.360 (0.662)	**0.227** **(4.325)**	0.338 (0.842)	**0.164** **(3.155)**	0.375 (0.720)	**0.173** **(3.665)**	0.335 (0.871)	**0.165** **(2.992)**	0.506 (1.024)
CV(DER)			**-7.135** **(-2.717)**	**-23.609** **(-2.154)**										
CV(DP)					-4.143 (-0.643)	-40.500 (-1.360)								
CV(DEQ)							-0.679 (-1.099)	0.238 (0.086)						
CV(DIP)									-0.047 (-1.203)	13.584 (0.838)				
CV(DLR)											-0.049 (-1.092)	0.134 (1.045)		
CV(DRER)													**-0.076** **(-3.096)**	-0.252 (-1.672)
Error Correction	**-0.091** **(-6.908)**	**-0.103** **(-6.043)**	**-0.079** **(-5.542)**	**-0.030** **(-2.153)**	**-0.089** **(-7.036)**	**-0.100** **(-5.822)**	**-0.085** **(-7.007)**	**-0.112** **(-4.870)**	**-0.091** **(-6.953)**	**-0.103** **(-5.991)**	**-0.090** **(-6.630)**	**-0.117** **(-6.097)**	**-0.089** **(-6.252)**	**-0.093** **(-4.809)**
Likelihood (Unrestricted)	1653.32 (1666.09)		1654.2597 (1678.1378)		1653.5399 (1668.2952)		1650.51 (1675.51)		1654.07 (1667.37)		1653.72 (1673.95)		1660.75 (1677.56)	
LR Statistic χ^2 [p–value]	**25.54 {18}** **[0.01]**		47.76 {18} [0.00]		**29.51 {18}** **[0.04]**		**50.00 {18}** **[0.00]**		26.59 {18} [0.09]		**40.46 {18}** **[0.00]**		**33.62 {18}** **[0.01]**	
Hausman χ^2 [p–value]	Y Q Joint 0.20{18} [0.90]		Y Q DER Joint **11.15{18} [0.01]**		Y Q DER Joint **5.81{18}** [0.12]		Y Q DER Joint **0.16**{18} **[0.98]**		Y Q DER Joint **1.01**{18} **[0.80]**		Y Q DER Joint 2.51{18} [0.47]		Y Q DER Joint 2.24 {18} [0.52]	

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. Lag structure determined by Schwarz Bayesian Criteria. 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.

Table E2 Panel Estimation of Investment and Uncertainty Time means removed

	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE	PMGE	MGE
ln(YB)	**1.371** **(8.521)**	1.037 (3.437)	1.439 (9.423)	0.988 (2.496)	1.379 (8.438)	1.166 (3.310)	**1.314** **(7.454)**	0.996 (4.267)	1.461 (8.374)	1.006 (2.772)	1.421 (9.153)	1.104 (3.872)	1.431 (9.610)	**1.046** **(3.329)**
CV(DER)			-4.130 (-2.029)	-4.161 (-3.368)										
CV(DP)					0.953 (0.166)	1.007 (0.097)								
CV(DEQ)							0.636 (0.961)	0.798 (0.418)						
CV(DIP)									-0.066 (-1.343)	-0.095 (-1.114)				
CV(DLR)											-0.108 (-1.527)	-0.045 (-0.692)		
CV(DRER)													**-0.064** **(-2.421)**	**-0.061** **(-3.543)**
Error Correction	-0.097 (-4.985)	-0.096 (-4.787)	-0.097 (-5.079)	-0.094 (-5.060)	-0.098 (-5.009)	-0.102 (-5.001)	-0.098 (-4.988)	-0.099 (-5.010)	-0.097 (-5.038)	-0.094 (-4.974)	-0.095 (-5.137)	-0.095 (-5.299)	-0.097 (-4.854)	-0.095 (-4.926)
Likelihood (Unrestricted)	1673.4572 (1674.4052)		1675.6086 (1677.4316)		1673.4684 (1676.9917)		1673.8259 (1679.4363)		1674.4523 (1676.4638)		1676.8560 (1679.0231)		1676.5130 (1678.7986)	
LR Statistic χ^2 [p–value]	1.90 {6} [0.93]		3.645 {12} [0.99]		7.046 {12} [0.85]		11.22 {12} [0.51]		4.02 {12} [0.98]		4.33 {12} [0.98]		4.57 {12} [0.97]	
Hausman χ^2 [p–value]	Y 1.71 [0.19]		Y DER Joint na		Y 0.46 [0.50] DP 0.00 [0.99] Joint 1.17 [0.56]		Y 4.33 [0.04] DEQ 0.01 [0.93] Joint na		Y 2.04 [0.15] DIP 0.18 [0.67] Joint 2.04 [0.36]		Y 2.08 [0.15] DLR 1.08 [0.30] Joint 6.69 [0.04]		Y DRER Joint 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. Lag structure determined by Schwarz Bayesian Criteria. 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.

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