Microeconometric Evidence on Uncertainty and Investment

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Abstract

We use a range of uncertainty measures for individual UK companies to explore the relationship between uncertainty and firm-level investment behaviour. We use a panel of 655 quoted non-financial UK firms, in the period 1987-2000, for which information on analysts' earnings forecasts is available on the I/B/E/S database. The measures of uncertainty that we consider are: volatility in daily share prices; volatility in monthly consensus earnings forecasts; and the variance of forecast errors for the consensus forecasts. For a sub-sample of firms tracked by two or more analysts, we also consider the dispersion in earnings forecasts across individual analysts.

We find significant negative effects on investment from each of these measures of uncertainty individually. When we consider them jointly, both volatility measures appear to be informative, and to provide distinct information that helps to explain firm-level investment spending. These effects are robust to including a range of additional controls, including Tobin's Q, a measure of the level of expected profitability constructed from the analysts' earnings forecasts, cash flow and cash stock variables, and real sales growth. Our preferred specifications suggest that a 10% increase in uncertainty implies a 4.4% reduction in investment rates in the short run, and would imply an 8.6% reduction in the capital stock in the long run if the higher level of uncertainty was sustained. We do not find any significant differences in the impact effect of sales growth on investment between firms facing different levels of uncertainty.

Key words: Investment, panel data, uncertainty

JEL classification: D80, D92, E22, G31

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Summary

Economists and policymakers have a keen interest in understanding investment. Business investment accounts for around 10% of UK national income. In the short term, investment is a volatile component of demand, and has proved difficult to forecast. In the longer term, capital accumulation is a key determinant of the growth of potential output.

There is considerable debate about the effects of uncertainty on investment. Interest in this topic has been stimulated recently by theoretical advances, such as the development of ‘real options’ theory, which stresses the value of the option to delay investment decisions until more information has accumulated, and for example by concerns about the effect of an uncertain economic slowdown. Does an increase in uncertainty cause firms to postpone investment projects in the short run ? Would a permanently higher level of uncertainty induce firms to choose less capital intensive technologies in the long run? More subtly, does an increase in uncertainty affect the sensitivity of investment to policy interventions, perhaps weakening the impact of interest rates on investment spending ?

This paper contributes to a growing empirical literature that uses data on the investment spending of individual firms to investigate these issues. We use data for a sample of 655 quoted UK non-financial companies in the period 1987-2000, for which we can obtain both accounting data from Datastream and data on analysts’ earnings forecasts from I/B/E/S. This allows us to address two of the major challenges in this empirical literature - to construct firm-level measures of uncertainty, and to control for other important determinants of firms’ investment decisions, notably expectations of future profitability.

For policy purposes, it is important to distinguish between an effect of uncertainty on investment that holds at a given level of expected future profitability, and effects that may be observed because changes in uncertainty directly affect expectations of future profitability, or tend to be associated with changes in expected profitability. For example, if the aim of policy is to raise investment, will anything be achieved simply by promoting a more stable environment, or should the focus be on raising expected future returns?

Consider, for example, the semiconductor industry during an economic slowdown of uncertain

duration and following the bursting of the dot-com bubble. Investment may have fallen for at least two distinct reasons: forecasts of demand for semiconductors being revised downwards; or the uncertainty surrounding these forecasts being greater. Our aim is to isolate the latter effect of uncertainty *per se*, by controlling for the influence of expected profitability on investment decisions. Earlier research at the Bank of England, and elsewhere, has shown that informative measures of expected profitability for individual firms can be constructed using data on analysts' earnings forecasts.

We consider four measures of uncertainty, based on: i) within-year volatility of the firm's share price; ii) within-year volatility of the average or 'consensus' forecasts of the firm's future earnings; iii) dispersion across individual analysts in their forecasts of the firm's future earnings; and iv) the variance of the forecast errors observed *ex post* for the consensus earnings forecasts. Perhaps due to the nature of our sample, we find the first two of these measures to be the most informative for explaining company investment spending. That is, we have a relatively small sample of firms that are tracked by more than one analyst, and a relatively short time period over which to measure variation in the forecast error variance.

In line with similar research using data for quoted US companies, we find that higher uncertainty reduces investment in the short term, and our findings indicate that a persistent rise in uncertainty would be associated with lower capital accumulation in the long term. Our results suggest that these effects are large, with a 10% rise in uncertainty reducing investment rates by around 4.4% in the short run, and reducing capital stocks by around 8.6% in the long run. Unlike some previous research, however, we do not find any effect of measured uncertainty on the sensitivity of investment to demand shocks.

These findings suggest that the effects of uncertainty on business investment are large enough to be taken into consideration when considering the outlook for the economy, and to motivate further research to develop a better understanding of the reasons why uncertainty matters for investment decisions.

1 Introduction

The impact of uncertainty on business investment is an important open question in economics. Despite much recent interest, convincing empirical evidence remains quite scarce. This issue is certainly relevant for policy makers. As well as being an important component of demand, capital accumulation is also a key determinant of the growth of potential output. It is therefore useful to study investment behaviour in order to understand both business cycle fluctutations and long-run trends. Moreover, investment has tended to be more volatile than other components of demand, and has proved difficult to forecast (see Bernanke (2003)). Understanding the impact of uncertainty on investment may help in understanding investment fluctuations.

Theoretical analyses have suggested a variety of mechanisms through which uncertainty may affect investment behaviour. Real options theory (see Dixit and Pindyck (1994)) states that when investment is (at least partly) irreversible, then an increase in uncertainty may cause the firm to postpone investment, even at an unchanged level of expected future profitability. In these models, firms invest if the net present value of the investment project exceeds the value of the option to postpone. At higher levels of uncertainty, the option to wait may become more valuable, making the firm less likely to invest. However, as shown in Abel and Eberly (1999) and Caballero (1999), the impact on the level of the capital stock in the long run is more ambiguous. Firms may invest less in response to positive demand shocks, but they may also be stuck with more capital than they desire following negative demand shocks. Hence, whether firms operate with higher or lower capital stocks on average at higher levels of uncertainty will depend on which of these effects dominates. As Bloom, Bond and Van Reenen (2001) note, the more robust prediction of the real options literature is that the impact effect of demand shocks on investment should be weaker at higher levels of uncertainty. In other words, uncertainty should have an impact on investment dynamics rather than necessarily on long run capital accumulation.

A different channel through which higher uncertainty may reduce both investment and desired capital stocks operates through risk aversion. Traditionally finance theory has emphasised that the relevant component of risk is the part that cannot be eliminated by holding a diversified portfolio of shares in many companies, rather than uncertainty about the firm's own future profitability *per se*. However recent contributions have noted that performance-related incentive contracts increase managers' exposure to firm-specific risks, so that the rate of return they require from investment projects may depend on diversifiable as well as undiversifiable components of risk.[1]

An older strand of the literature identifies a different mechanism relating uncertainty and investment and predicts a positive relationship between the two variables. Hartman (1972) and Abel (1983) show that under the assumption of risk neutral, competitive firms with constant returns to scale technology, expected profits are a convex function of future prices. If then there is a mean preserving spread in the distribution of future prices, such an increase in uncertainty will lead to a higher expected level of future profits. For risk neutral firms, the increase in expected future profits will increase the range of possible investment projects with positive net present values and thus lead the firm to undertake additional investment. This will hold more generally if the risk premium in the firm's required rate of return is given, or responds sufficiently little to the increase in future price uncertainty. However Caballero (1991) noted that these results are dependent on the assumptions of perfect competition and constant returns to scale technology. The convexity of the profit function can be overturned by introducing a sufficient degree of imperfect competition or decreasing returns to scale, suggesting that the sign of this effect of uncertainty is dependent on market conditions and the technology with which the firm operates. It should also be noted that this effect of uncertainty operates through the level of expected profits and would not be detected in empirical models where an adequate control for expected future profitability is included.

The policy implications of distinguishing between effects of uncertainty on investment that operate through the level of expected profitability, and through other channels, are potentially important. If the objective is to raise business investment, an important question is whether anything will be achieved simply by reducing the level of uncertainty faced by firms, or whether the focus should be on raising expected returns. Also, if the 'real options' channel is particularly important, the impact of monetary policy on investment may become weaker at high levels of uncertainty.

As this brief review indicates, the theoretical literature leaves open the sign and persistence of any relationship between investment and uncertainty. This ambiguity has spurred a large empirical literature on the issue, with papers examining the investment-uncertainty relationship both at the aggregate and the firm level.

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(1) See, for example, Himmelberg, Hubbard and Love (2002).

The analysis by Leahy and Whited (1996) is one of the earliest papers of the latter kind. The authors investigate the impact of uncertainty on the investment of 600 US manufacturing firms. Although they find evidence of a negative relationship between their measure of uncertainty (based on the within-year variance of the daily share returns of each company) and investment, this result disappears once Tobin's Q is added to the model and remains unimportant when the effects of output and cash flow are controlled for. Given these results and the strong negative correlation between Q and the measure of uncertainty, the authors conclude that the impact of uncertainty on investment operates through its effect on Tobin's Q.

More recent papers have reached a different conclusion. Bond and Cummins (2004) use data on 946 publicly traded US firms. In addition to the volatility of stock returns, the authors construct measures of uncertainty using I/B/E/S data on analysts' forecasts of firms' future profits. These measures include the dispersion of individual analysts' forecasts of earnings per share for the same firm, and the variance of consensus forecast errors. The authors also include measures of average Q in their specification in order to control for the effect of expected future profitability. Their estimates suggest three main results: i) the uncertainty measures have a significant negative effect on investment; ii) this impact is robust to the inclusion of the Q variables; and iii) the estimates support the prediction of the real options literature that investment responds less to demand shocks at higher levels of uncertainty.

Similar results are reported in Bulan (2003), who uses a panel of 2722 US firms. The uncertainty measure (based on the volatility of stock returns) is decomposed into its firm, industry and market level components. The author's results strongly support a negative relationship between firm-specific uncertainty and investment, not captured by Tobin's Q or cash flow. The analysis also indicates that the effect of uncertainty may be stronger for firms that are large or less competitive. Also, industry-specific uncertainty is found to be important when considering firms that engage in irreversible investment.

For the United Kingdom, recent work has focused on industry level data. Examples include Driver et al. (2002) and Hallett et al. (2003). Both papers present evidence in favour of a significant negative relationship between investment and uncertainty and also indicate that this relationship varies substantially across industries. UK evidence at the firm level is provided in Bloom, Bond and Van Reenen (2001).[(2)] Using a panel of 672 UK manufacturing firms, the authors test the prediction of the real options literature that investment responds less to demand shocks when the firm's environment is more uncertain. Estimates of their investment equations provide support for this non-linear affect. An interaction term between their uncertainty measure (also based on the volatility of stock returns) and real sales growth has a significant negative coefficient, indicating a weaker impact effect of sales growth at higher levels of uncertainty. The authors also find that if their uncertainty measure is decomposed into macroeconomic and firm-specific factors, only the firm-specific components are informative in this context. This, they argue, suggest that it may be difficult to identify the effects of uncertainty by using aggregate data.[(3)]

One shortcoming of Bloom, Bond and Van Reenen (2001) is that their approach does not include forward-looking controls for the influence of expected future profitability. This is a potentially important caveat, as any measure of uncertainty may pick up the effects of expected future returns on current investment that are not accounted for by the empirical model. As noted above, whether or not uncertainty affects investment only through an effect on the level of expected profitability has important implications for policy analysis.

The aim of the current paper is to use UK firm-level data to investigate whether uncertainty affects investment even when expected future profitability is controlled for. We follow Bond and Cummins (2004) in using I/B/E/S data on analysts' earnings forecasts to construct controls for expected profitability. An earlier paper (Bond et al. 2004) has shown that analysts' forecasts of future profitability have considerable explanatory power for company investment, using a similar sample of UK firms.[(4)] In addition, we use the I/B/E/S data to construct novel measures of uncertainty for individual firms.

The main aim of this paper is not to test between different theoretical explanations, but rather to provide evidence on the more basic question of whether uncertainty has any influence on firms' investment decisions, at a given level of expected future profitability. Our analysis will however

(2) Other recent papers have examined the uncertainty-investment relationship for a variety of different countries and have, in general, concluded in favour of a negative relationship. For Japan, see Ogawa and Suzuki (2003). Evidence for Belgium is provided in Butzen et.al. (2002) and Fuss and Vermeulen (2004). The investigation by Guiso and Parigi (1999) deals with the case of Italy, while Sterken et. al. (2002) present findings for a panel of Dutch firms.
(3) Bond and Lombardi (2004a) show that aggregation problems may also make it difficult to detect effects of uncertainty on investment using macro data. A large body of the empirical literature has used aggregate data to investigate the relationship between uncertainty and investment. See Carruth et.al. (2000) for an extensive survey.
(4) See also Cummins, Hassett and Oliner (1999) and Bond and Cummins (2001) for earlier studies using US samples.

shed some light on the possible mechanisms by distinguishing between short-run effects on investment and long-run effects on capital accumulation, and by considering whether uncertainty affects the impact effect of demand shocks on current investment.

The rest of the paper is organised as follows. Section 2 discusses our econometric specifications. The dataset and construction of the key variables is described in Section 3. Section 4 presents the estimation results and discusses their implications. Section 5 concludes.

2 Empirical investment equation

The q-model of investment implies the following basic relationship:

$$\frac{I_t}{K_t} = a + \frac{1}{b}(q_t - 1) + \epsilon_t \qquad \textbf{(1)}$$

where q_t denotes marginal q, I_t is gross investment in period t, K_t is the net capital stock and ε_t is an additive shock to marginal adjustment costs.[5] The parameters a and b are structural parameters of the adjustment cost function. Equation **(1)** implies more generally that expectations of future profitability matter for firms' investment decisions, since marginal q summarises the value of an additional unit of capital in terms of its expected contribution to the firm's current and future profits.

In our empirical implementation, we augment this relationship with measures of firm level uncertainty and estimate regressions of the following form:

$$\frac{I_t}{K_t} = \alpha + \beta(q_t - 1) + \gamma_0\sigma_t + \gamma_1\sigma_{t-1} + \epsilon_t \qquad \textbf{(2)}$$

where σ_t is a measure of uncertainty.

The addition of the uncertainty terms is motivated by the theoretical and empirical literature, discussed in the introduction, suggesting that uncertainty may affect firms' investment decisions in ways that are not fully captured by available measures of average q. Since there is no consensus in the theoretical literature on the sign or persistence of the effect of uncertainty on investment, it is of interest to estimate the effect empirically for UK firms, using a range of different proxies for the

(5) See Hayashi (1982) for the formal derivation, or Bond and Van Reenen (2003) for a recent exposition.

level of uncertainty faced by individual firms. As we discuss further in Section 4, equation **(2)** allows an increase in uncertainty to affect investment rates temporarily ($\gamma_0 \neq 0$; $\gamma_0 + \gamma_1 = 0$) or to have a long-run effect on the capital stock ($\gamma_0 + \gamma_1 \neq 0$). The measures of average q, expected profitability and uncertainty considered in this paper are described below.

3 Data and empirical measures

In this paper, we use the data constructed in Bond et al. (2004) for all variables other than the uncertainty measures. These are described briefly below (see Bond et al. (2004) for more details). The construction of the uncertainty measures is described in Section 3.3.

3.1 Average q measure

Since marginal q in equation **(2)** is not observable, it is necessary to find an observable proxy. For a value-maximising firm with a single capital good, Hayashi (1982) has shown that under certain restrictions on the profit function,(6) marginal q equals average q, defined as

$$q_t \equiv \frac{V_t}{p_t^I(1-\delta)K_{t-1}}. \quad \textbf{(3)}$$

Here V_t is the (maximised) net present value of the firm's expected future profits (possibly adjusted for debt and taxes) and the denominator is the replacement cost at time t of the capital stock inherited from the previous period. Here p_t^I denotes the price of investment goods and δ is the rate of depreciation (assumed to be 8% per annum for all firms). In this paper we use a measure of average q based on equation **(3)**, which allows for debt-financing,

$$q_t^E \equiv \frac{V_t^E + H_t}{p_t^I(1-\delta)K_{t-1}}, \quad \textbf{(4)}$$

where V_t^E is the firm's stock market valuation, H_t is a measure of the stock of debt, and we define $Q_t^E = q_t^E - 1$. More details are provided in Bond et al. (2004).

(6) The necessary condition is linear homogeneity of the profit function in (K_t, I_t). Sufficient conditions for this to hold are perfect competition in output and input markets, and constant returns to scale in both production and adjustment cost technologies.

3.2 *Measure of expected profitability*

Several recent papers have argued that measures of average q based on stock market valuations contain significant measurement error; see, for example, Erickson and Whited (2000) and Bond and Cummins (2001). This may be because share prices are influenced by many factors other than the present discounted value of expected future dividends,(7) whilst investment depends predominantly on factors that influence the firm's longer term or 'fundamental' value.(8) For whatever reason, alternative measures of average q that replace stock market values by fundamental valuations, estimated using analysts' earning forecasts, have been shown to be more informative in the context of econometric investment equations; see Cummins, Hassett and Oliner (1999) and Bond and Cummins (2000, 2001). Bond et al. (2004) present similar findings for UK firms, using a very simple measure of expected future profitability constructed from I/B/E/S data on analysts' earnings forecasts.

Approved securities analysts are asked by I/B/E/S to provide forecasts of earnings per share for the current year t, as well as forecasts for one and two years ahead. They are also asked to provide a forecast of 'long-term' growth in 'trend earnings'. We consider a sample of UK companies for which forecasts of earnings per share for the current year, and for one year ahead, are available at the start of the current year. In cases where several analysts provide forecasts for the same firm, we abstract here from heterogeneity across analysts by using the unweighted means of the individual forecasts, which I/B/E/S term the consensus forecasts. To calculate forecasts of total profits for firm i in year s ($\widehat{\prod}_{is}$) from the reported forecasts of earnings per share, we multiply the earnings per share forecast by the number of shares outstanding at the time the forecast was made. Following Bond et al. (2004), we then use the available data to construct a measure of expected profitability,

$$E\prod_{it} = \frac{\widehat{\prod}_{it} + \beta_{t+1}\widehat{\prod}_{i,t+1}}{p_t^K(1-\delta)K_{i,t-1}} \qquad \textbf{(5)}$$

The discount factor β_t is calculated as the inverse of $1 + r_t + \zeta$, where r_t is the nominal yield on 20-year UK government bonds, and ζ is a constant risk premium, which we set equal to 0.08. $E\prod_{it}$ thus provides an *ex-ante* measure of discounted expected profitability of the firm in the current year and the following year, which we include in our empirical investment equation as an

(7) See, for example, Shiller (1981, 2000) and Summers (1986).
(8) See Bond and Cummins (2001) and Abel and Eberly (2002).

alternative control to the usual measure of average q.

3.3 Uncertainty measures

In this paper uncertainty is proxied by the within-year volatility of firms' daily stock market returns, and by measures constructed using the I/B/E/S data on analysts' earnings forecasts. The measure of share price volatility, Vol_t, is the standard deviation of daily stock returns during the firm's current accounting period, as in Bloom, Bond and Van Reenen (2001). These authors show that there is a monotonic relationship between the variance of demand shocks and the variance of the firm's fundamental value, in a simple model of investment with partial irreversibility. However an obvious concern with this type of measure is that high frequency fluctuations in share prices may be contaminated by non-fundamental influences.(9) We therefore consider alternative measures of uncertainty based on analysts' earnings forecasts for individual firms.

The first measures we use are based on the availability of monthly observations on the consensus forecasts of earnings per share for the current year. So far as we are aware, this is the first paper to consider within-year volatility in these monthly forecasts as a measure of firm-level uncertainty, as least in the context of microeconometric investment equations. The formal justification for relating this to the uncertainty in the firm's environment is based on the monotonicity result in Bloom, Bond and Van Reenen (2001), noting that volatility in expected future profits will be the main determinant of volatility in the firm's fundamental value in the class of models they consider. Less formally, we expect complete certainty about the firm's prospects to be associated with stable forecasts, whilst greater uncertainty is likely to be associated with more significant revisions as new information accrues.

We construct two measures based on these within-year revisions to analysts' forecasts. The first measure, Rev_t, is the coefficient of variation across all the monthly consensus forecasts of earnings per share for the firm's current accounting period issued during the period. The second measure, $Range_t$, is the difference between the highest and lowest of these consensus forecasts, divided by the absolute value of the mean of all the monthly consensus forecasts issued during the period.

Following Bond and Cummins (2004), we consider two further indicators of uncertainty based on

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(9) Shiller's (1981) term 'excess volatility' captures precisely this concern.

the analysts' forecasts. One is based on the errors in the consensus earnings forecasts. Specifically, Err_t, is the square of the difference between the ex ante consensus forecast of earnings per share at the start of the current accounting period and the ex post realized level of earnings per share for that period, as reported by I/B/E/S. Current and lagged values of these squared forecast errors are indicative of the forecast error variance, which is expected to be positively related to the level of uncertainty in the firm's environment. We thus include a distributed lag of these squared forecast errors in our empirical models to control for this forecast error variance without imposing a priori weights.

Our final measure is only available for a sub-sample of firms for which two or more analysts issue earnings forecasts. For this sub-sample, we construct a measure of dispersion in the individual forecasts. Specifically, $Disp_t$, is the coefficient of variation across different analysts' forecasts of earnings per share for the firm's current accounting period, calculated for the earliest month in which at least two analysts issue a forecast. The motivation for this measure is that disagreement among analysts is likely to be lower when a firm's future profits are more certain.

After cleaning the data as in Bond et al. (2004), and in addition removing the top and bottom percentiles of the uncertainty measures in order to reduce the impact of outliers, we obtain a data set of 655 firms, for which we have at least four consecutive annual observations between 1987 and 2000.(10) The dispersion measure, $Disp_t$, can be calculated for a sub-sample of 498 firms. Descriptive statistics for the variables in our full sample of firms are given in Table 1.

3.4 Behaviour of uncertainty measures

It is interesting to compare the time series variation in our uncertainty measures with time series of other uncertainty measures and cyclical indicators. Chart 1 shows the annual average level for the firms in our sample of our measure based on within-year revisions to earnings forecasts, Rev_t, This is compared with a survey measure of perceived uncertainty from the CBI's Quarterly Industrial Trends survey, and with a survey measure of capacity utilization from the same CBI survey, which indicates the state of the business cycle.(11) Table 2 summarises the correlations

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(10) See Appendix C in Bond et.al. (2004). We drop extreme values of q^E and $E\prod$, i.e. values that are negative or lie in the top decile of the empirical distribution. Simlar outlier deletion methods were applied to $\frac{I}{K}$ and $\frac{CF}{K}$.

(11) The uncertainty measure from the CBI's Quarterly Industrial Trends survey is the percentage of firms reporting that 'uncertainty about demand' is likely to limit capital expenditure authorisations. The survey measure of capacity utilization from the CBI's Quarterly Industrial Trends survey is defined as the percentage of firms reporting that they

between these three time series. We can see that from 1987 to 2000, the average level of our uncertainty measure has a high positive correlation (0.84) with the aggregate CBI survey measure of uncertainty, and a similarly high negative correlation (-0.85) with the CBI measure of capacity utilization. This suggests that perceptions of uncertainty vary counter-cyclically, and this is reflected in our measure based on the volatility of earnings forecasts.

By contrast, a measure of aggregate stock market volatility, calculated using daily returns on the FTSE 100 index, is weakly negatively correlated (-0.25) with the aggregate uncertainty measure based on the CBI survey, and almost uncorrelated (0.04) with the aggregate cyclical measure considered here. As shown in Chart 2, fluctuations in aggregate stock market volatility are dominated by events like the October 1987 crash and the ICT bubble in the late 1990s, which are not major influences on uncertainty perceived by firms responding to the CBI survey, or closely related to business cycle developments (compare Chart 1).

Tables 3 and 4 report the cross-sectional correlations between our main measures of uncertainty for individual firms. Table 3, using data on the individual firm-year observations, shows that there are statistically significant positive correlations between volatility in daily stock returns and volatility in monthly earnings forecasts. Table 4, based on average levels for individual firms, shows slightly higher correlations between these measures, and further indicates a significant positive correlation between volatility in monthly earnings forecasts and the forecast error variation. However most of these correlations are well below one, suggesting that these different measures may reflect different aspects of the uncertainties facing these firms.

4 Empirical results

We estimate a range of empirical investment equations, starting with very simple specifications that relate investment only to measures of uncertainty, then adding Tobin's Q and other controls for expected profitability, and finally considering whether measured uncertainty influences the impact effect of real sales growth on current investment. All models are estimated in first-differences to eliminate any unobserved permanent firm-specific effects, and year dummies are included to control for any unobserved common time-specific effects. All explanatory variables are treated as endogenous, using the sequential moment conditions for large cross

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operate at full capacity. Shown are annual averages.

section, short time series panels outlined by, for example, Arellano and Bond (1991).[12] The reported results use a common set of instruments for all specifications, comprising levels of the investment rate, the ratio of cash flow to capital, and real sales growth, each dated t-2, t-3, t-4 and t-5. Broadly similar findings were obtained using a wide range of alternative instrument sets. We report one-step GMM results with heteroskedasticity-robust standard errors, computed using DPD98 for Gauss (see Arellano and Bond, 1998).

Table 5 reports results from simple specifications relating just investment and the uncertainty measures without any other controls. We find significant negative coefficients on current and lagged values of each of our four main measures of firm-level uncertainty, using our full sample of 655 firms. Higher volatility in both the firm's daily stock returns (Vol_t) and in monthly analysts' earnings forecasts (Rev_t and $Range_t$) is associated with lower investment rates. The similarity of the coefficients obtained on the first and second lags of the squared forecast errors (Err_{t-s}) suggests that investment also tends to be lower for firms and periods with less predictable earnings.

Table 6 adds a standard measure of Tobin's Q (Q_t^E) to each of these four specifications. As is commonly found, the coefficient on Tobin's Q is small, positive and statistically significant. However the volatility in daily stock returns (particularly the first lag of this measure) and monthly earnings forecasts (particularly the current values of these variables) continue to provide highly significant additional information. We thus find that the effects of these uncertainty measures on company investment do not operate entirely through effects on (measured) average q. This finding for UK firms is consistent with that reported recently for US firms by Bond and Cummins (2004) and by Bulan (2003), although not with that reported originally by Leahy and Whited (1996). The significance of the squared forecast error terms is however weakened considerably when we control for Tobin's Q.

Table 7 adds an alternative control for the effect of expected future profitability ($E\prod_t$) on current investment decisions, using the consensus forecasts for the firm's earnings in the current and following periods, as described in section 3.2. Consistent with the results for a similar sample of UK companies reported in Bond et al (2004), this measure of expected profitability is a highly significant explanatory variable in our empirical investment equations, whilst Tobin's Q is marginally significant at best when we control for analysts' earnings forecasts. The squared

(12) Bond (2002) provides an introduction to these Generalised Method of Moments (GMM) estimators for panel data.

forecast error terms become completely insignificant when we control for the effect of the level of expected profitability in this way (column 3). However current volatility in monthly earnings forecasts (columns 5 and 7) and lagged volatility in daily stock returns (column 2) continue to be significant explanatory variables even when we include this more informative control for expected profitability.

Table 8 considers the robustness of this finding to a set of additional control variables. Consistent with the main finding in Bond et al (2004), we find no significant sensitivity of investment to fluctuations in cash flow ($\frac{CF}{K}$) when analysts' earnings forecasts are used to control for the influence of expected future profitability (columns 1 and 4).[13] We do find a strongly significant effect of current real sales growth (y), and a weakly significant effect of a stock measure of liquidity ($\frac{CS}{K}$). The inclusion of these variables weakens but does not eliminate the significance of our measures of the volatility of monthly earnings forecasts (columns 2 and 5). The exclusion of the insignificant Tobin's Q and lagged investment variables from our preferred parsimonious specifications leads to more significant estimated coefficients on our measure of daily share price volatility (columns 3 and 6).

Table 9 explores the prediction emphasized by Bloom, Bond and Van Reenen (2001) that, in the presence of partial irreversibility, the impact effect of demand shocks on current investment should be lower for firms that are subject to a higher level of uncertainty. In contrast to their empirical results, we find no significant heterogeneity in the coefficient on current sales growth across firms with different levels of any of our uncertainty measures, although we do continue to find significant coefficients on our basic uncertainty terms when these interactions are included in the models. This difference appears to be due mainly to differences in the samples used.[14] For our sample we were unable to detect any significant heterogeneity in the impact effect of sales growth, even if we exclude the linear uncertainty terms or our control for expected profitability, or if we use the kind of sales-accelerator error correction specification used by Bloom, Bond and Van Reenen (2001). We note that our sample seems to be unusual in this respect. Significantly lower coefficients on current sales growth for firms facing higher measured uncertainty have also been reported by Bond and Cummins (2004) for US firms, Bond and Lombardi (2004b) for Italian

(13) Similar findings are reported for US companies in Cummins, Hassett and Oliner (1999) and Bond and Cummins (2001).
(14) Bloom, Bond and Van Reenen (2001) used a sample of 672 quoted UK manufacturing companies (including firms not necessarily covered in the I/B/E/S database) over the period 1972-91.

firms, and by Malik (2004) for South Korean firms.

Table 10 considers the measure of uncertainty based on dispersion in earnings forecasts ($Disp_t$), across different analysts covering the same firm at the same time, as used by Bond and Cummins (2004). The construction of this measure requires the availability of earnings forecasts for a minimum of two analysts, and reduces the available sample with at least four consecutive observations from 655 to 498 firms. As reported by Bond and Cummins (2004) for US firms, we find significantly lower investment rates for firms where there is greater disagreement between analysts about their future earnings (column 1), and this effect is robust to the inclusion of Tobin's Q (column 3). Unlike Bond and Cummins (2004), we find that this effect is not robust to the inclusion of a more informative control for the level of expected future profitability, constructed from the consensus earnings forecasts (columns 5 and 6). However our alternative measure of uncertainty, based on the volatility of the monthly consensus earnings forecasts, is found to be informative for this sub-sample, even when we control for the level of expected profitability (columns 7 and 8). At least for this sample, the time series volatility measure seems to provide a more informative indicator of uncertainty than does the cross-section dispersion measure.

We have considered results for our empirical specifications using sub-samples of smaller and larger firms. We find broadly similar effects of volatility in earnings forecasts on investment for both sub-samples, although larger firms seem to respond to an increase in volatility with a lag of one year. We find more heterogeneity in the effects of share price volatility on investment, with statistically significant effects being identified only for smaller firms, in specifications where we control for the level of expected profitability.

Finally, for illustrative purposes, we consider the magnitude of the effects of uncertainty on company investment suggested by our preferred empirical specifications. These estimates should be interpreted with great caution. They are derived from a reduced form empirical specification that was designed to test the null hypothesis that measures of uncertainty have no effect on investment after controlling for expected profitability, sales growth and liquidity. The model was not designed to quantify the effects of measured uncertainty correctly under the alternative, and the coefficients on our uncertainty measures have no clear structural interpretation.

The specification in column 3 of Table 8 has the form

$$\left(\frac{I}{K}\right)_{it} = \alpha + \beta E\prod_{it} + \gamma_1 VOL_{i,t-1} + \gamma_2 REV_{it} + \theta y_{it} + \lambda \left(\frac{CS}{K}\right)_{i,t-1} + \varepsilon_{it}.$$

The partial elasticity of investment rates with respect to (last period's) share price volatility is thus given by

$$\eta^{I/K}_{VOL} = \gamma_1 \left(\frac{VOL_{i,t-1}}{(I/K)_{it}}\right)$$

and the partial elasticity of investment rates with respect to (current) volatility in earnings forecasts is given by

$$\eta^{I/K}_{REV} = \gamma_2 \left(\frac{REV_{it}}{(I/K)_{it}}\right).$$

Evaluated at our sample means, these elasticities are -0.36 and -0.08 respectively. A 10% increase in uncertainty that was (immediately) reflected in both these indicators would thus be expected to reduce investment rates by around 4.4%.

To consider the longer run effect of a permanent increase in uncertainty on the level of the capital stock, we note from equation **(5)** that our expected profitability term $E\prod_{it}$ can be interpreted as a non-linear error correction term that relates the level of discounted expected profits $\pi^e_{it} = \widehat{\prod}_{it} + \beta_{t+1}\widehat{\prod}_{i,t+1}$ to a measure of the level of the capital stock $\kappa_{it} = p^K_t(1-\delta)K_{i,t-1}$. The investment rate $(I/K)_{it}$ can be expressed approximately as the growth rate of the capital stock (g) plus the rate of depreciation (δ). If we then consider a steady state in which real sales and capital are growing at some rate g_i, π^e_{it} grows at the same rate such that $E\prod_{it}$ is constant, both uncertainty measures are constant at VOL_i and REV_i respectively, and similarly the cash stock variable takes the constant value $(CS/K)_i$, we obtain

$$g_i + \delta = \alpha + \beta \left(\frac{\pi^e}{\kappa}\right)_i + \gamma_1 VOL_i + \gamma_2 REV_i + \theta g_i + \lambda \left(\frac{CS}{K}\right)_i.$$

Solving for the level of the capital stock κ_i as a function of the level of discounted expected profits π^e_i, the uncertainty measures and the liquidity variable, we obtain

$$\kappa_i = f\left(VOL_i, REV_i, \left(\frac{CS}{K}\right)_i\right).\pi^e_i$$

where

$$f(.) = \left[\left(\frac{1}{\beta}\right)\left(g_i + \delta - \alpha - \gamma_1 VOL_i - \gamma_2 REV_i - \theta g_i - \lambda \left(\frac{CS}{K}\right)_i\right)\right]^{-1}.$$

Holding constant the level of discounted expected profits, we can calculate the steady state partial elasticity of the capital stock with respect to each uncertainty measure as

$$\eta^{\kappa}_{VOL} = \left(\frac{VOL_i}{\kappa_i}\right).\frac{\partial \kappa_i}{\partial VOL_i}|_{\pi^e_i} = \left(\frac{\pi^e}{\kappa}\right)_i.\left(\frac{\partial f(.)}{\partial VOL_i}\right).VOL_i$$

and

$$\eta^{\kappa}_{REV} = \left(\frac{REV_i}{\kappa_i}\right) . \frac{\partial \kappa_i}{\partial REV_i}|_{\pi^e_i} = \left(\frac{\pi^e}{\kappa}\right)_i . \left(\frac{\partial f(.)}{\partial REV_i}\right) .REV_i$$

Evaluated at our sample means, these steady state partial elasticities are -0.70 and -0.16 respectively. At a given level of discounted expected future profits, a permanent 10% increase in the level of uncertainty that was reflected in both our measures would thus be expected to reduce capital stocks by around 8.6% in the long run.

5 Conclusions

We have considered a range of uncertainty measures in our analysis. Our results indicate that measures of uncertainty have statistically significant effects on the investment behaviour of quoted UK companies. Higher volatility of both daily share prices and monthly analysts' earnings forecasts are associated with lower investment rates in the short run. Permanent increases in these uncertainty measures would be associated with lower capital stock levels in the long run. These effects are robust to controlling for the level of expected profitability (as measured by analysts' earnings forecasts), sales growth, Tobin's Q, and cash flow and cash stock variables. Although our empirical specifications are not structural, they suggest that the magnitude of these uncertainty effects are not trivially small. However, for this sample of large quoted UK companies, we do not find evidence that higher uncertainty is associated with a weaker impact effect of demand shocks on current investment, as predicted by real options models in which a higher level of uncertainty induces a more cautious response of investment to new information.

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Chart 1: Time series of averages over firm-level uncertainty measure (Rev), in comparison with aggregate uncertainty and cyclical measures based on CBI survey

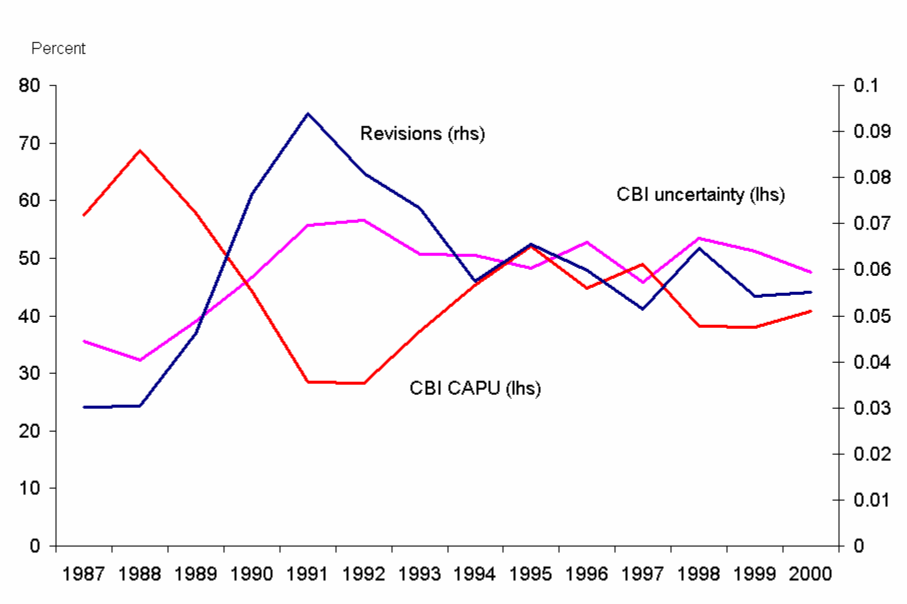

Chart 2: Aggregate stock market volatility measure (FTSE 100 equity index)

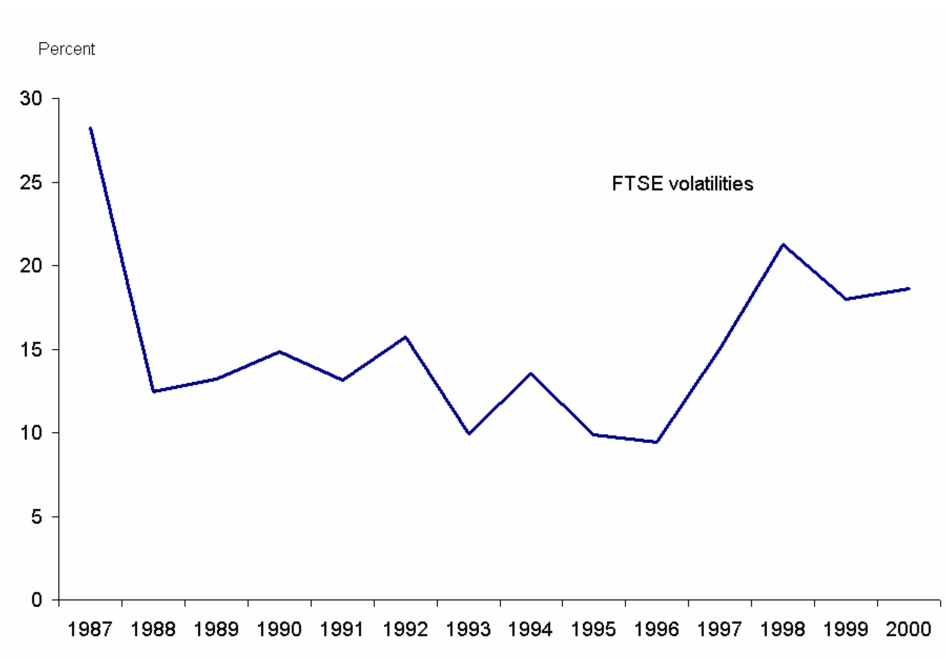

Table 1: Descriptive statistics of full sample (4908 observations, 655 firms, 1987-2000)

	mean	std. dev.	min	max
Q^E	2.65	2.03	0.11	17.76
I/K	0.15	0.13	-0.95	0.73
EΠ	0.44	0.32	0	3.14
CF/K	0.26	0.15	-0.93	1.37
CS/K	0.26	0.36	0	4.78
y	0.07	0.19	-0.64	1.82
Vol	1.53	0.66	0.45	4.36
Rev	0.06	0.10	0	1.14
Range	0.16	0.25	0	3.06
Err	0.33	1.14	0	17.30
Disp	0.09	0.42	0	19.83

Note: Q^E is Tobin's average Q, I/K is the investment rate, EΠ is expected profitability, CF/K is the ratio of cash flow (post-tax profits plus depreciation) to capital, CS/K is the ratio of the cash stock (cash and marketable securities) to capital, and y is the real growth rate of sales. For further details about the construction of these variables, see Bond et al. (2004). The uncertainty measures Vol, Err, Rev, Range and Disp are described in Section 3.3.

Table 2: Correlations between uncertainty and cyclical indicators, 1987-2000.

	Rev	CBI uncertainty	CBI CAPU
Rev	1		
CBI uncertainty	0.84	1	
CBI CAPU	-0.85	-0.93	1

Note: Rev is the annual average level of our uncertainty measure for the firms present in each year of our sample. This uses 4908 observations on 655 firms.

Table 3: Cross-sectional correlations of uncertainty measures: firm-year observations*

	Vol	Rev	Range
Vol	1		
Rev	0.333	1	
Range	-0.336	0.987	1

*All correlation coefficients are significant at the 1 %-level.

Table 4: Cross-sectional correlations of uncertainty measures: firm averages*

	Vol	Rev	Range	Err
Vol	1			
Rev	0.441	1		
Range	0.435	0.990	1	
Err	0.073	0.415	0.418	1

* All correlation coefficients are significant at the 1 %-level, except for the correlation between Vol and Err, which is significant at the 10 %-level.

Table 5. Uncertainty Measures

	1	2	3	4
VOL_t	-0.048 (0.016)			
VOL_{t-1}	-0.075 (0.020)			
ERR_{t-1}		-0.028 (0.011)		
ERR_{t-2}		-0.026 (0.011)		
REV_t			-0.539 (0.139)	
REV_{t-1}			-0.294 (0.108)	
$RANGE_t$				-0.222 (0.056)
$RANGE_{t-1}$				-0.124 (0.043)
$(I/K)_{t-1}$	0.061 (0.036)	0.037 (0.045)	0.083 (0.035)	0.081 (0.035)
m1	-9.853	-7.607	-8.179	-8.161
m2	-0.519	-1.407	-0.348	-0.494
Sargan	0.312	0.571	0.651	0.695
Joint significance: uncertainty measures	0.000	0.016	0.000	0.000

Notes:
(s.e.)
Column 2: 655 firms, 2943 observations; 1990-2000;
All others: 655 firms, 3598 observations, 1989-2000

Table 6. Uncertainty Measures and Tobin's Q

	1	2	3	4
VOL_t	-0.032 (0.016)			
VOL_{t-1}	-0.051 (0.021)			
ERR_{t-1}		-0.019 (0.010)		
ERR_{t-2}		-0.021 (0.010)		
REV_t			-0.460 (0.126)	
REV_{t-1}			-0.172 (0.108)	
$RANGE_t$				-0.191 (0.051)
$RANGE_{t-1}$				-0.077 (0.043)
Q_t^E	0.029 (0.007)	0.023 (0.008)	0.028 (0.007)	0.026 (0.007)
$(I/K)_{t-1}$	0.041 (0.035)	0.017 (0.044)	0.062 (0.034)	0.061 (0.034)
m1	-9.769	-7.474	-8.378	-8.334
m2	-0.184	-1.357	0.152	-0.002
Sargan	0.232	0.394	0.504	0.544
Joint significance: uncertainty measures	0.012	0.073	0.000	0.000

Notes:
(s.e.)
Column 2: 655 firms, 2943 observations; 1990-2000;
All others: 655 firms, 3598 observations, 1989-2000

Table 7. Uncertainty Measures, Tobin's Q and Expected Future Profitability

	1	2	3	4	5	6	7	8	9
VOL_t	-0.007 (0.017)								
VOL_{t-1}	-0.044 (0.021)	-0.045 (0.021)						-0.034 (0.021)	-0.034 (0.021)
ERR_{t-1}			0.003 (0.011)						
ERR_{t-2}			-0.007 (0.010)						
REV_t				-0.335 (0.122)	-0.334 (0.122)			-0.285 (0.120)	
REV_{t-1}				-0.041 (0.113)					
$RANGE_t$						-0.142 (0.049)	-0.142 (0.049)		-0.124 (0.049)
$RANGE_{t-1}$						-0.027 (0.045)			
Q_t^E	0.010 (0.007)	0.010 (0.007)	0.017 (0.009)	0.015 (0.007)	0.015 (0.007)	0.014 (0.007)	0.015 (0.007)	0.011 (0.007)	0.011 (0.007)
$E\Pi_t$	0.227 (0.053)	0.233 (0.048)	0.271 (0.055)	0.182 (0.059)	0.190 (0.055)	0.175 (0.059)	0.188 (0.055)	0.189 (0.053)	0.186 (0.053)
$(I/K)_{t-1}$	0.044 (0.033)	0.044 (0.033)	0.006 (0.040)	0.068 (0.032)	0.071 (0.030)	0.067 (0.033)	0.072 (0.030)	0.056 (0.033)	0.057 (0.033)
m1	-9.959	-10.035	-7.321	-8.848	-9.675	-8.814	-9.630	-9.646	-9.576
m2	-0.389	-0.391	-1.773	0.337	0.493	0.214	0.438	0.018	-0.033
Sargan	0.804	0.812	0.479	0.716	0.743	0.729	0.760	0.821	0.834
(Joint) significance: uncertainty measures	0.106	0.035	0.611	0.018	0.006	0.011	0.004	0.009	0.005

Notes:
(s.e.)
Column 3: 655 firms, 2943 observations; 1990-2000;
All others: 655 firms, 3598 observations, 1989-2000

Table 8. Robustness to Additional Variables

	1	2	3	4	5	6
VOL_{t-1}	-0.034	-0.032	-0.035	-0.035	-0.033	-0.036
	(0.021)	(0.021)	(0.018)	(0.021)	(0.021)	(0.018)
REV_t	-0.284	-0.207	-0.208			
	(0.120)	(0.109)	(0.109)			
$RANGE_t$				-0.124	-0.089	-0.090
				(0.049)	(0.044)	(0.044)
Q_t^E	0.011	0.008		0.010	0.008	
	(0.008)	(0.007)		(0.008)	(0.007)	
$E\Pi_t$	0.230	0.151	0.174	0.226	0.149	0.172
	(0.076)	(0.053)	(0.048)	(0.076)	(0.053)	(0.048)
$(CF/K)_{t-1}$	-0.074			-0.074		
	(0.100)			(0.099)		
$(CS/K)_{t-1}$		0.072	0.070		0.070	0.068
		(0.046)	(0.046)		(0.046)	(0.046)
y		0.172	0.169		0.169	0.167
		(0.048)	(0.040)		(0.048)	(0.040)
$(I/K)_{t-1}$	0.050	-0.011		0.051	-0.009	
	(0.034)	(0.039)		(0.034)	(0.039)	
m1	-9.598	-9.921	-9.921	-9.529	-9.861	-9.908
m2	0.003	-0.585	-0.557	-0.049	-0.634	-0.624
Sargan	0.841	0.757	0.838	0.852	0.766	0.843
Joint significance: uncertainty measures	0.008	0.019	0.018	0.005	0.013	0.013

Notes:
(s.e.)
655 firms, 3598 observations, 1989-2000

Table 9. Uncertainty Interactions

	1	2	3	4
VOL_{t-1}	-0.039 (0.018)	-0.036 (0.018)	-0.037 (0.018)	-0.037 (0.018)
REV_t	-0.212 (0.113)	-0.215 (0.113)	-0.223 (0.111)	-0.218 (0.111)
VOL_{t-1}* y	0.021 (0.069)			
ERR_{t-1}* y		-0.090 (0.065)		
REV_t* y			-0.233 (0.598)	
$RANGE_t$* y				-0.037 (0.245)
$E\Pi_t$	0.198 (0.045)	0.223 (0.047)	0.198 (0.045)	0.198 (0.045)
y	0.128 (0.112)	0.168 (0.041)	0.171 (0.052)	0.164 (0.053)
m1	-9.726	-9.640	-9.694	-9.687
m2	-0.371	-0.434	-0.384	-0.366
Sargan	0.862	0.917	0.873	0.869

Notes:
(s.e.)
655 firms, 3598 observations, 1989-2000
Similar results with RANGE instead of REV

Table 10. Uncertainty Measures:
Cross-section Dispersion versus within-year Revisions to Forecasts

	1	2	3	4	5	6	7	8	9
$DISP_t$	-0.608		-0.460		-0.180	-0.166			-0.003
	(0.174)		(0.177)		(0.182)	(0.185)			(0.193)
$DISP_{t-1}$	-0.270		-0.190		-0.120				
	(0.235)		(0.172)		(0.171)				
REV_t		-0.164		-0.127			0.046		
		(0.130)		(0.123)			(0.138)		
REV_{t-1}		-0.561		-0.466			-0.270	-0.275	-0.274
		(0.143)		(0.132)			(0.136)	(0.135)	(0.139)
Q_t^E			0.029	0.024	0.013	0.015	0.012	0.013	0.013
			(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
$E\Pi_t$					0.243	0.248	0.220	0.211	0.211
					(0.062)	(0.061)	(0.073)	(0.065)	(0.067)
$(I/K)_{t-1}$	0.033	0.029							
	(0.046)	(0.036)							
m1	-7.665	-9.988	-8.787	-9.224	-8.746	-8.749	-8.653	-8.695	-8.643
m2	-0.491	-0.266	-0.488	-0.411	-0.705	-0.651	-0.462	-0.523	-0.518
Sargan	0.384	0.337	0.250	0.252	0.347	0.245	0.373	0.364	0.349
(Joint) significance: uncertainty measures	0.001	0.000	0.011	0.001	0.455	0.369	0.122	0.042	

Notes:
(s.e.)
498 firms 2829 observations 1989-2000