UNCERTAINTY AND COMPANY INVESTMENT: AN EMPIRICAL INVESTIGATION USING DATA ON ANALYSTS' PROFITS FORECASTS

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Abstract

We investigate the empirical relationship between company investment and measures of uncertainty, controlling for the effect of expected future profitability on current investment decisions. We consider three measures of uncertainty, based on: (i) volatility in the firm's daily stock returns; (ii) disagreement between different securities analysts in their forecasts of the firm's future profits; and (iii) the variance of forecast errors in analysts' forecasts of the firm's future profits. We consider two controls for expected profitability: (i) a standard measure of Tobin's q constructed from the firm's stock market valuation; and (ii) an alternative measure of the q ratio constructed from discounted forecasts of the firm's future profits stream.

Empirical results are presented for a sample of 946 publicly traded US companies that were tracked by two or more securities analysts for at least four consecutive years between 1982 and 1999. All three measures of uncertainty are found to be positively correlated with each other. When we consider these measures individually, in each case we find a significantly negative long run effect of higher uncertainty on capital accumulation, which is robust to the inclusion of either of our controls for expected profitability. When we consider these measures jointly, we find that the level of disagreement between analysts provides the most informative indicator for identifying this long run effect of uncertainty on capital accumulation. In addition we find a significantly negative short run interaction term between share price volatility and current sales growth, consistent with the idea that, at higher levels of uncertainty, investment will respond less to a given demand shock. These effects of uncertainty on investment are shown to be quantitatively as well as statistically significant.

1. Introduction

There is a longstanding interest in the effects of uncertainty on investment. This is reflected both in the academic research literature, and in the policy debate. How sensitive are investment levels, for example, to stability or instability in the macroeconomic environment? What effects could heightened uncertainty following the attacks of September 11, 2001 be expected to have on levels of business investment?

Theoretical analyses have suggested a variety of mechanisms through which uncertainty may influence investment decisions. Holders of risky assets require compensation for bearing those risks, so there will be a risk premium component in the required rate of return for investment projects whose outcomes are uncertain. Finance theory has emphasised that portfolio diversification can substantially reduce the individual's exposure to the risk associated with any particular asset. This implies that for firms whose shares are owned by diversified shareholders, the relevant risk premium should depend not on the variability of the firm's own returns but rather on the covariance between the firm's returns and the returns available on a wider portfolio of assets, as for example in the Capital Asset Pricing Model. Uncertainty about the firm's own future prospects may however be more important than this suggests in settings where managers influence investment decisions and cannot fully diversify their exposure to idiosyncratic risk – perhaps for incentive reasons, or because they have invested in firm-specific human capital.[1]

Hartman (1972) and Abel (1983) emphasised a different mechanism that could rationalise a positive effect of higher uncertainty on investment. The basic idea here is that expected profits may be a convex function of future prices for the firm's output. Suppose there is a mean-preserving spread in the distribution of future prices, so that the expected future price remains unchanged but more probability weight is attached to prices that are both very high and very low relative to this mean. If profits are a convex function of the output price, this will increase the expected level of future profits. If the

[1] Himmelberg, Hubbard and Love (2002) develop a formal model in which incentive contracts prevent managers from diversifying and firm investment then depends on idiosyncratic risk.

risk premium is given or responds sufficiently little to the increase in uncertainty about the firm's future product price, this increase in the expected level of future profits will increase the range of possible investment projects with positive net present values, and so lead the firm to undertake additional investment.

Abel (1983) showed that this mechanism operates in the Hayashi (1982) Q model of investment, characterised by perfect competition in all markets, constant returns to scale, and costs of adjusting the capital stock that are strictly convex in the level of investment. Caballero (1991) noted that this conclusion is sensitive to the assumptions of perfect competition and constant returns to scale, which make the firm's net revenue homogeneous of degree one in the scale of its operations. The convexity of the relationship between profits and output price can be weakened and eventually overturned by introducing a sufficient degree of either imperfect competition or decreasing returns to scale into the model. The impact of price uncertainty on investment may therefore be positive or negative, depending on the relevant market environment and technology with which a firm operates. We can also note that these effects on investment operate through the level of expected profitability, and would not be found in an empirical model of investment that controlled adequately for the effect of expected future profitability on current investment decisions. In Hayashi's Q model, for example, this effect is summarised by the average q ratio, which is shown to be a sufficient statistic for investment in that context.

More recent theoretical analyses have focused on the effects of 'real options', suggesting that the option to delay investment until more information has accumulated may become more valuable at higher levels of uncertainty.[2] Interestingly this option to delay investment is only valuable when both: (i) the net revenue function is not linearly homogeneous, for example due to imperfect competition or decreasing returns to scale; and (ii) adjustment costs are not strictly convex in investment, for example due to full or partial irreversibility, or to a fixed component of adjustment costs. Hence these real options effects are absent in the traditional Q model.

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[2] See, for example, Dixit and Pindyck (1994) and Caballero (1999).

When real options are valuable, the implications for the relationship between uncertainty and investment are also quite subtle. At higher levels of uncertainty, the firm has a greater incentive to wait until it has more information before commiting to an investment decision. This makes the firm's investment policy more 'cautious', or less likely to respond to a given demand shock. However, as stressed by Abel and Eberly (1999) and Caballero (1999), the effect of higher uncertainty on the average level of the capital stock in the long run is theoretically ambiguous. Although firms will invest less in response to a positive demand shock, they will also be stuck with more capital than they would like following a negative demand shock. Depending on which of these forces dominates, we may observe a tendency for firms to operate with higher or lower capital stocks under conditions of higher uncertainty. As noted by Bloom, Bond and Van Reenen (2001), the more robust prediction of this class of models is that the speed of adjustment of the capital stock should be slower at higher levels of uncertainty. Thus the principal effect of real options may be on short run investment dynamics, rather than on long run capital accumulation.

As this brief review indicates, the theoretical literature on investment and uncertainty leaves open both the sign and the persistence of any relationship between uncertainty and capital accumulation. Empirical evidence is therefore required to address these questions, as well as to quantify the magnitude of any short run or long run effects of uncertainty on investment. However empirical work in this area has to address two important challenges: (i) to find operational counterparts to the concepts of 'uncertainty' considered in theoretical analyses of investment under uncertainty; (ii) to control for other relevant influences on investment behaviour, notably the role of current expectations of future profitability.

The importance of the first challenge is self-evident. Even to test the null hypothesis that uncertainty has no effects on investment, we require a measure of uncertainty that is sufficiently correlated with the relevant underlying concept in order for our empirical tests to have power. To undertake the more ambitious task of quantifying the relationship, we require a measure of uncertainty that is either accurate or at least measured with a type of error for which the errors-in-variables bias in the estimated relationship can be easily corrected.

The importance of the second challenge is more subtle, but potentially very important in this context. The problem here is that measured uncertainty may plausibly proxy for other relevant but omitted variables in an econometric investment equation. Consider for example the airline industry in the aftermath of September 11, 2001. Investment in this industry may have fallen for at least two distinct reasons. First there would be a downward revision of forecasts of future demand for air transportation. Second there would be an increase in the uncertainty associated with these forecasts. Without further analysis is would be difficult to say which of these effects was more important. More generally, we may suspect that higher uncertainty could be associated with greater pessimism about the level of expected future profitability.[3] Unless we control carefully for the effect of expected profitability on current investment, we may erroneously attribute to uncertainty effects which are really due to the level of expected future returns. Note that the distinction between these two channels is potentially important for policy formulation: if the aim is to increase the level of investment, will anything be achieved by a policy that seeks to reduce uncertainty by pursuing stability, or should the emphasis rather be on policies that operate by raising expected future returns?

In this paper we aim to make a contribution to both these empirical challenges, as well as stressing the importance of distinguishing between short run effects of uncertainty on investment dynamics and long run effects of uncertainty on capital accumulation. The novel aspect of our approach in this context is to make use of data on forecasts of future profits for individual companies that were issued historically by professional securities analysts.[4] This data allows us to construct two indicators of the level of uncertainty facing a particular firm at a particular time, one based on the disagreement or dispersion in the profits forecasts issued by different analysts for that firm at that time, and one based on the variance of the forecast errors made by analysts forecasting profits for that firm in the

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[3] Commentators frequently suggest this association between the mean and the variance of the distribution of future demand or future profits. For example, commenting on the Confederation of British Industry's August 2002 Regional Trends Survey, Doug Godden, Head of Economic Analysis at the CBI, observed that "with so many new risks and uncertainties, output expectations have been scaled back in the majority of regions" (http://www.cbi.org.uk).

[4] Earlier papers that use data on analysts forecasts to study company investment include Cummins, Hassett and Oliner (1999), Bond and Cummins (2000, 2001), Bond, Klemm, Newton-Smith, Syed and Vlieghe (2002) and Abel and Eberly (2002a).

recent past. We compare these variables with a more standard measure of uncertainty based on high frequency volatility in the firm's stock returns, which was introduced into the empirical investment literature by Leahy and Whited (1996) and also used by, for example, Bloom, Bond and Van Reenen (2001).

An obvious concern with measures of uncertainty based on share price volatility is that they may be affected by 'excess volatility' or 'irrational exuberance' in the stock market, a concern which has been highlighted by our previous research on the relationship between stock market valuations, expected profits and company investment.[5] Related to this, the availability of data on profits forecasts allows us to construct an alternative control for the influence of expected future profitability in our empirical investment equations. Several of the papers cited in footnote 4 above have shown that using a simple valuation model to transform these forecasts of future profits into an estimate of the firm's 'fundamental' value provides a measure of the average q ratio that is far more informative about company investment than the standard Tobin's q measure constructed using the firm's stock market valuation. By considering both measures of average q in this investigation, we provide more robust controls for the effects of expected future profitability than previous empirical studies, and so obtain more appropriate tests of the null hypothesis that variation in the level of uncertainty has no effect on company investment beyond that which is summarised in current expectations of future profits.

The remainder of the paper is organised as follows. Section 2 discusses our econometric investment equations and relates these to the effects of uncertainty predicted by different theoretical approaches. Section 3 discusses our data and our empirical measures of uncertainty and average q. Section 4 presents our main empirical findings and illustrates the quantitative importance of the effects of uncertainty on company investment that we find. Section 5 concludes with some qualifications and suggestions for further research.

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[5] See, for example, Shiller (1981, 2000) and Bond and Cummins (2001).

2. Empirical investment equations

We estimate empirical investment equations with the general form

$$\left(\frac{I}{K}\right)_t = \alpha + \beta(q_t - 1) + \gamma\sigma_t + \theta\Delta y_t + \phi(\sigma_t * \Delta y_t) + \varepsilon_t$$

where I_t is gross investment in period t, K_t is the net capital stock at the end of period t, q_t is a measure of the average q ratio, σ_t is a measure of uncertainty, Δy_t is the growth rate of real sales in period t and ε_t is an error term. Abstracting from the presence of debt and taxes – which are both accounted for in our empirical work – our measures of the average q ratio have the form

$$q_t = \frac{V_t}{\kappa_t}$$

where V_t is a measure of the value of the firm, or the present value of the expected stream of future net cash distributions to its shareholders, at the start of period t; and κ_t is the replacement cost value at the start of period t of the capital stock that the firm inherits from the previous period.[6]

To interpret this equation, notice that under the null hypothesis $\gamma = \theta = \phi = 0$ this reduces to a version of the traditional Q model, in which the average q ratio is a sufficient statistic for the gross investment rate. This specification would be correct if firms choose investment in a homogeneous capital good to maximise their fundamental value (i.e. the present value of the expected stream of future net cash distributions to their shareholders), taking all prices as given, and having both constant returns to scale

[6] More precisely, letting $p_t^K K_t$ denote the replacement cost value of the firm's capital stock at the end of period t, and assuming the standard equation of motion for this capital stock $p_t^K K_t = (1-\delta)(p_{t-1}^K K_{t-1})(p_t^K / p_{t-1}^K) + p_t^K I_t$, where p_t^K is the price of capital goods in period t and δ is the rate of depreciation, then $\kappa_t = p_t^K (1-\delta) K_{t-1} = p_t^K K_t - p_t^K I_t$.

technologies and strictly convex costs of adjusting their capital stocks.[7] In this case the parameter β is inversely related to the importance of marginal adjustment costs and directly related to the speed at which firms adjust their capital stocks in response to deviations between average q and the value of unity that would be chosen in the absence of adjustment costs; and the error term reflects either additive shocks to marginal adjustment costs or additive errors in our measure of the average q ratio.

The inclusion of the additional terms in the empirical models we estimate thus tests the null hypothesis that our *measure* of average q is a sufficient statistic for company investment rates. We stress that a rejection of this null hypothesis does not necessarily imply a rejection of the underlying Q *theory*, essentially because there may be measurement errors in the available measures of average q that are correlated with either the uncertainty or sales growth variables. We return to this point at the end of the next section, after describing our measures of average q. However for practical purposes this limitation may be less important than the observation that, since we measure average q using either securities analysts' forecasts of future profits or using stock market valuations, significant coefficients on the uncertainty terms would indicate that company investment is related to these indicators of uncertainty, holding constant either observable expectations of future profitability or the firm's stock market valuation respectively.

Two simple measures can be calculated easily from the parameters of the estimated models and used to illustrate the magnitude of the estimated effects of uncertainty on investment. The first is an impact effect, or the partial elasticity of the investment rate with respect to the measure of uncertainty, holding constant both average q and real sales growth:

$$\frac{\sigma}{I/K} \cdot \left. \frac{\partial\, I/K}{\partial \sigma} \right|_{q,\Delta y} = \frac{(\gamma + \phi \Delta y)\sigma}{I/K}.$$

[7] Linearity of the investment-q relationship further requires adjustment costs that are quadratic. Interested readers are referred to Bond and Cummins (2001) for details of the timing and functional form assumptions that result in our particular null specification.

The second is a long run effect, or the partial elasticity of the capital stock with respect to the measure of uncertainty, holding constant the value of the firm. Appendix A shows that if we consider a steady state in which both the capital stock and real sales grow at rate g, this steady state partial elasticity has the form:

$$\frac{\sigma}{\kappa}.\frac{\partial \kappa}{\partial \sigma}\bigg|_V = \left(\frac{V}{\kappa}\right)\left\{\frac{\left(\frac{\gamma+\phi g}{\beta}\right)\sigma}{\left[1-\left(\frac{\gamma+\phi g}{\beta}\right)\sigma-\left(\frac{\theta}{\beta}\right)g\right]^2}\right\}.$$

Given the estimated parameters β, γ, θ and ϕ, these partial elasticities can be evaluated, for example at the sample means of the investment rates, q ratios, uncertainty measures and sales growth. They should be regarded only as illustrative and interpreted with considerable caution, since these parameters have no structural status under alternatives to the basic Q model in which uncertainty measures would influence investment behaviour conditional on average q. We consider them only to indicate whether the estimated effects of the uncertainty terms in our empirical models are trivially small, or sufficiently large to motivate further research.

These elasticities can also be used to relate the properties of our empirical model to the predicted effects of uncertainty on investment in some of the theoretical analyses. Notice first that in a stationarity state (g = 0), the long run effect would depend only on the parameter γ on the linear uncertainty term, and not on the parameter ϕ on the uncertainty-sales growth interaction term. More importantly, an empirical model with only a single, linear uncertainty term would impose that the short run and long run effects are determined by the single parameter on this variable. This seems unduly restrictive for testing purposes, since a number of authors have stressed that in the real options approach, there may be significant short run effects of uncertainty on investment dynamics without necessarily any long run relationship between uncertainty and capital intensity. Our empirical specification allows this pattern – for small g, this would correspond simply to a zero coefficient on the linear uncertainty term but not on the interaction term. Of course more flexible patterns of short run and long run effects can be introduced by adding lagged uncertainty terms to the model, or by considering further interactions, for example between uncertainty and average q measures. We explore both these possibilities in our empirical investigation. The interaction between uncertainty and sales growth is of particular interest, however, as Bloom, Bond and Van Reenen (2001) have shown that a weaker impact effect of demand shocks on investment at higher levels of (demand) uncertainty is a prediction of one class of real options models that is robust to aggregation across investment decisions in multiple capital goods; and significant effects of this kind have been reported in previous empirical studies.[8]

Finally we should comment on why we adopt this exploratory empirical approach in this investigation, rather than attempting to estimate a richer structural specification that would allow for effects of uncertainty on investment holding constant expected future profitability or stock market valuations. The basic reason is that, so far as we are aware, no-one has obtained an operational structural model using the real options approach that could be estimated directly. Abel and Eberly (2002a) derive a non-linear structural relationship between investment rates and average q in the presence of irreversibility, but only under conditions of perfect competition and constant returns to scale which rule out the real options effects. A second reason is that, to obtain a convincing specification for company level data, this approach would need to take seriously aggregation of investment decisions over the multiple types of capital goods, production plants and subsidiaries that are combined in the capital expenditure data found in company accounts. Given the obvious complexity of these tasks, we believe that a simpler empirical approach can provide useful evidence to inform policy discussions, and may stimulate further research towards a more satisfactory empirical framework for analysing these issues.

3. Data and empirical measures

We use data for an unbalanced panel of 946 publicly traded US companies. In addition to the availability of accounting and stock market data, we require that firms

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[8] See Guiso and Parigi (1999) and Bloom, Bond and Van Reenen (2001).

were tracked by at least two securities analysts, who supplied timely profits forecasts to I/B/E/S International Inc. for a minimum of four consecutive years between 1982 and 1999. This requirement may introduce a sample selection bias, although to the extent that selection into the set of firms tracked by multiple analysts is determined by time-invariant characteristics, this should be controlled for by the inclusion of firm-specific ‘fixed’ effects in our econometric specifications. Results for our basic average q models are similar for this sample and for a larger sample of firms tracked by one or more analysts, used in our previous research; and results for models that include our dispersion or error variance measures of uncertainty remain similar when we consider smaller samples of firms that are tracked by a minimum of three or five securities analysts.

The basic accounting data on investment expenditures, capital stocks, sales, profits and cash flow are obtained from Compustat. We adjust book values of the net capital stock to replacement cost estimates using a standard perpetual inventory procedure, and we adjust nominal sales to real sales using sectoral price indices. Stock market data on equity capitalisations and daily stock returns are obtained from CRSP. Further details of the series used and adjustments made are provided in Appendix B.

Our key data on analysts’ profits forecasts is kindly made available to us by I/B/E/S International Inc., the leading supplier of this data to the financial sector. I/B/E/S report forecasts only from analysts who meet a set of criteria designed to ensure that they are well informed about the business situation of individual companies. The forecasts we use were issued early in the current accounting period, and comprise forecasts of earnings per share for the current year and for the following year, as well as forecasts of the trend growth rate in earnings (per share?) over a three to five year horizon, known as the ‘long term growth’ forecasts. I/B/E/S report the (unweighted) mean of the forecasts issued for a particular firm by the individual analysts they cover, known as the ‘consensus’ forecast, as well as the standard deviation across these individual forecasts. We make use of both these means and standard deviations in our measures of expected profits and uncertainty respectively. The measure of ‘earnings’ corresponds to that used by the analysts tracking a particular firm. Broadly this corresponds to a measure of net profits after interest and taxes, although may remove a larger set of non-recurrent items than the exceptional/ extraordinary items reported in published accounts.

Uncertainty measures

We use this data to construct three different indicators of uncertainty for an individual firm at a particular time. The first is a relatively standard measure based on high frequency volatility in the firm's stock market valuation, introduced into the empirical literature on uncertainty and investment by Leahy and Whited (1996). The basic idea is that if new information leads to a marked reassessment of the firm's expected future profitability, this will be reflected in fluctuations in the firm's stock market valuation, provided there is a reasonable correspondence between stock market and 'fundamental' values. In this case, as noted by Leahy and Whited (1996), new information about future demand and costs would be weighted in relation to their influence on the present value of expected profits.

The specific measure we use, denoted VOL_t, is the standard deviation of daily stock returns during the firm's current accounting period, based on the index of [???] reported by CRSP. This is essentially the same measure used in their empirical work by Bloom, Bond and Van Reenen (2001). An obvious concern with this kind of measure is that to the extent that stock market valuations are influenced by bubbles, fads, or any factors other than the present value of expected future distributions to shareholders, then fluctuations in share prices may reflect changes in factors that are not perceived as relevant to investment decisions by the managers of firms. Shiller's (1981) term for such behaviour of share prices was 'excess volatility', and if actual share price volatility is dominated by such factors then tests using this measure may have little power to detect any effects of uncertainty on company investment. A different concern is that it is perfectly possible for future profits to be highly uncertain, in the sense that the distribution perceived at a particular point in time has a high variance, and yet for the expectation of future profits to be completely stable, if no relevant new information is revealed during a particular time interval.

To explore the robustness of empirical results based on this stock return volatility indicator of uncertainty, we therefore make use of the data on analysts' profits forecasts to construct two alternative indicators. Neither is conceptually perfect or necessarily superior to the volatility measure. The motivation is rather that by considering a wider range of indicators we may learn more about the nature of any relationship between uncertainty and company investment.

One of the measures that we consider is based on the disagreement between different securities analysts forecasting future profits for the same firm at the same time. We certainly see such disagreement in the I/B/E/S data, and the degree of disagreement varies both across firms and, for a given firm, over time. In the limit, if the level of future profits for a particular firm was completely certain, it would be surprising if all analysts did not report this common figure as their forecast. Hence it would be surprising if a low level of uncertainty about the level of future profits was not reflected in a low degree of disagreement between different analysts in their individual forecasts. It is less clear that a high level of uncertainty will necessarily be reflected in a high degree of disagreement between analysts. Differences in the forecasts issued by individual analysts may reflect differences in the information available to them, in the way they process this information, or in the objectives they are pursuing. It is clearly possible for the level of future profits to be highly uncertain, and yet to observe a set of analysts using similar information in a similar way, with similar objectives, arriving at a similar set of issued forecasts. Nevertheless we would expect the tendency to be for more observed disagreement to be associated with more underlying uncertainty. For example, to the extent that differences in forecasts reflect differences in the way different analysts convert the same current information into forecasts of future profits, we can consider the survival of these different models as indicative of underlying uncertainty about the correct process generating future profits. Alternatively, to the extent that analysts issuing optimistic forecasts are pursuing marketing strategies more aggressively than others, a high degree of uncertainty about the actual level of future profits would seem to be a necessary condition for the survival of these strategies in equilibrium.

The particular measure of dispersion across individual analysts' earnings forecasts that we use, denoted $DISP_t$, is the coefficient of variation in the forecasts of earnings per share for the current accounting period. A relative measure is warranted since the variation across firms in the level of earnings per share reflects measurement in essentially meaningless units. Since we observe only the mean and the standard deviation of the distribution, we are severely limited in the measures of relative dispersion we can compute.[9] The case for focusing on disagreement in the one year ahead forecasts is less clear, but has the practical advantage that typically we observe more analysts issuing forecasts for profits one year ahead than for longer time horizons.[10]

The final measure we consider is based on the variance of the errors made by securities analysts in forecasting the firm's profits in the recent past. Again if there was very little uncertainty about the level of future profits, we would expect to see analysts making very small forecast errors. Where we observe at least some analysts making large forecast errors, this could reflect the pursuit of objectives other than accurate forecasting, but a higher degree of uncertainty seems likely to be a permissive factor in the survival of such strategies.

The practical problems with this approach lie in the realised measure of profits with which the analysts forecasts are compared, and in the time period used to estimate the forecast error variance. As noted above, the measure of earnings per share forecast by analysts may not correspond precisely to the basis on which results are subsequently reported, for example if some restructuring has taken place in the intervening period. We use a measure of realised earnings per share reported by I/B/E/S which is intended to adjust for such differences, although the scope for making these adjustments accurately may be limited. Several trade-offs are implicit in the choice of time periods – using too few observations would result in noisy estimates of the variance, whilst using too many observations would produce limited time series variation in the resulting measure for each firm, and runs the risk of erroneously imposing the continued relevance of past levels of uncertainty. We keep these trade-offs implicit by including current and past

[9] We obtain estimated coefficients with the same sign but with weaker statistical significance in our investment equations if we use the simple standard deviation in place of the coefficient of variation. We also checked that our coefficient of variation measure does not simply proxy for information in the reciprocal of the mean earnings per share forecast (which could occur if the relationship between investment and expected profits were sufficiently non-linear); or in the number of analysts tracking a particular firm (which is positively correlated with this measure of relative dispersion, but uninformative in our investment models once we condition on $DISP_t$).

[10] Preliminary investigations suggested that similar results were found using the coefficient of variation for the two year ahead earnings per share forecasts.

realisations of the squared forecast errors as separate explanatory variables in our empirical investment equations, which allows more weight to be given to more recent experience, without imposing any particular pattern to the weights. However the small number of time series observations available for many firms in our sample limits the flexibility we have for including a long sequence of lagged values. The particular forecast error we use for this purpose is the difference between the consensus forecast, made at the start of the current accounting period, of earnings per share for that period, and the realisation of that measure reported by I/B/E/S. The squared value of that forecast error is denoted ERR_t in the results presented below.[11]

Average q measures

We consider two controls for the average q ratio in our null specifications, one constructed using the firm's stock market valuation in a standard way, and one in which a simple valuation model is used to obtain an alternative estimate of the value of the firm, based on the consensus forecasts at the start of the current accounting period for the firm's profits in that and subsequent periods. The standard measure is denoted q_t^E and the alternative measure is denoted $\hat{q}_t$. Both measures incorporate identical adjustments for the presence of debt, financial assets and corporate taxes; details are provided in Appendix B.

The particular valuation model we use here is taken from Bond and Cummins (2001). Letting $E\Pi_t$ denote the consensus forecast for earnings in period t, $E\Pi_{t+1}$ denote the consensus forecast for earnings in period t+1,[12] and Eg_t the consensus forecast for the long term trend growth rate of earnings, we estimate the firm's 'fundamental' value as

[11] Note that ERR_{t-1} is thus the most recent forecast error that has been observed at the start of period t.

[12] Forecasts for earnings per share are converted to forecasts for the level of earnings by multiplying by the number of shares outstanding at the time the forecasts were made.

$$\hat{V}_t = E\Pi_t + \beta_t E\Pi_{t+1} + \sum_{s=2}^{5} \beta_t^s (1 + Eg_t)^{s-1} E\Pi_t^* + TVC$$

where $E\Pi_t^* = (E\Pi_t + E\Pi_{t+1})/2$ is the average of the two earnings forecasts which we grow out over a five year horizon at rate Eg_t, β_t is a discount factor using the nominal interest rate on US government bonds in year t plus an 8% risk premium, and TVC is a terminal value correction which imposes the assumption that earnings growth beyond year t+5 reverts to the overall historical average for our sample of companies, which is around 6%. It should be stressed that our empirical results are not sensitive to the details of this particular calculation.

The motivation for considering this alternative measure here is that previous studies have found a much stronger relationship between company investment and these discounted profits forecasts than has generally been found between company investment and the firm's stock market valuation. This fact is consistent with the possibility of significant bubbles, fads or factors other than the present discounted value of expected future profits influencing fluctuations in stock market valuations – which motivates our interest in measures of uncertainty other than share price volatility – although there may be other explanations for the same pattern.[13] Here the objective is to obtain a more informative control for the influence of current expectations of future profitability on current investment decisions than can be achieved indirectly by using the firm's stock market valuation. By controlling for these observable forecasts of future profits, we reduce the risk that any estimated effects of our uncertainty variables are attributable to these uncertainty measures acting as proxies for the influence on investment of the mean rather than the variance of the distribution of future profits. This risk is clearly signalled by the models of Hartman (1972) and Abel (1983), which stress a causal link between (price) uncertainty and the expected level of future profits. More generally we are concerned about a possible correlation between uncertainty and expected profitability, for

[13] Abel and Eberly (2002b) develop a model in which long and variable lags between technological advances and profitable investment opportunities help to explain the weak relationship between stock market valuations and current investment expenditures.

example if periods of higher uncertainty tend to be associated with more pessimistic forecasts of future demand growth.

However in this context we should note one disadvantage of our discounted profits forecasts measure of average q, and that is the need to specify a discount factor. If we incorrectly specify the risk premium component of the firm's discount rate to be constant over time and common across firms, and the true variation in the risk premia used to evaluate investment decisions is correlated with one or more of our measures of uncertainty, then we could find significant coefficients on these uncertainty terms conditional on our measure of average q, even if firms' investment behaviour is consistent with the underlying Q theory of investment. Consequently our empirical tests should not be interpreted as testing the Q theory, but more narrowly as testing the null hypothesis that there are no significant effects of measured uncertainty on investment behaviour, holding constant observed forecasts of future profits. This would be a major concern if the only interesting question in this context was the validity of Hayashi's Q model. However for many purposes, such as forecasting the effects of fluctuations in measures of uncertainty on business investment, it will suffice to address simpler questions concerning the relationship between uncertainty and investment at a given level of expected future profitability.

We could extend our approach in the direction of testing the Q theory by incorporating some specific model of the risk premium component of the cost of capital into our measure of average q. However in the absence of a compelling explanation for variation in the risk premium, such extensions would remain unconvincing. Certainly equating the risk premium used to evaluate investment decisions with the equity risk premium that could be estimated from the firm's stock returns appears to us to be unwarranted, given the weak relationship observed between stock market fluctuations and company investment more generally. Of course a related problem applies when we consider using the firm's market valuation to measure average q – if share prices are affected by 'bubbles' and our uncertainty variables are correlated with this measurement error, significant coefficients on these uncertainty terms conditional on Tobin's q need not imply a rejection of the underlying investment theory.

We can make some progress by investigating whether the form of any relationship between measured uncertainty and company investment is consistent with the types of predictions made by particular theories – for example, do we find any evidence of the weaker impact effect of demand shocks at higher levels of uncertainty predicted by the real options approach? But ultimately such findings can only be regarded as suggestive. More direct tests will need to be developed if we are to discriminate confidently between alternative theoretical explanations for the empirical relationship between uncertainty and investment that we detect using our current approach.

4. Results

The behaviour of our uncertainty indicators

[TO FOLLOW]

Econometric results

We use the data described in section 3 to estimate a range of empirical investment models. Estimation is based on equations in first-differences to remove unobserved firm-specific 'fixed' effects that may be correlated with the explanatory variables. Year dummies are also included to control for unobserved time-specific effects. Both measures of q_{it} and the uncertainty terms are treated as endogenous variables in these investment equations. A common instrument set comprising $(I/K)_{i,t-2}$, $(I/K)_{i,t-3}$, $(CF/K)_{i,t-2}$ and $(CF/K)_{i,t-3}$ is used to estimate all the specifications reported, where CF is a measure of cash flow.[14] GMM estimates are computed using DPD98 for GAUSS (Arellano and

[14] Similar results were obtained using a range of alternative instrument sets, including, for example, lagged values of sales growth, Tobin's q, or the uncertainty measures.

Bond, 1998), with one-step results and heteroskedasticity consistent standard errors and test statistics being reported.

In Table 1 we report some simple specifications where only the lagged dependent variable is included in addition to current and lagged values of one of our uncertainty measures. In particular, there are no forward-looking controls for expected future profitability in these initial models. Column (i) indicates that we find significant negative coefficients on both current and lagged values of the stock market volatility measure. Column (ii) shows that we also find significant negative coefficients on current and lagged values of the measure based on dispersion in the analysts' profits forecasts. Column (iii) shows that we find significant negative coefficients on the lagged values of the squared forecast errors $ERR_{i,t-1}$ and $ERR_{i,t-2}$, suggesting a negative effect of the variance of these recent forecast errors. These results should be interpreted with a degree of caution, since the Sargan tests of overidentifying restrictions indicate that our instruments are not valid for these simple specifications - not surprisingly, explanatory variables other than these measures of uncertainty are required to explain company investment behaviour. Nevertheless they suggest a negative rather than a positive relationship between uncertainty and investment.

In Table 2 we introduce a standard measure of Tobin's q (q_t^E), constructed using the firm's stock market valuation, as a control for the effect of expected future profitability. The measure of Tobin's q has a significant positive coefficient in each of the three columns, but the inclusion of this variable has little effect on the significant negative coefficients found for each of the uncertainty measures in the simpler models of Table 1. The validity of the instruments used continues to be rejected at the 10% level of significance in column (i), and at the 2% level or lower in columns (ii) and (iii).

In Table 3 we include our alternative measure of average q ($\hat{q}_t$), constructed using discounted securities analysts' forecasts of the firm's future profits. This measure of average q also has a significant positive coefficient in each of the three columns. Including this measure reduces the statistical significance of the coefficients on $VOL_{i,t-2}$ in column (i), $DISP_{i,t-1}$ in column (ii), and $ERR_{i,t-2}$ in column (iii). Nevertheless we continue to find a significant negative effect from each of these measures of uncertainty, suggesting that the effects found in Tables 1 and 2 do not simply reflect higher measured uncertainty acting as a proxy for more pessimistic expectations of future profitability. We can also note that the validity of the instruments used is not rejected at any conventional level of significance by the Sargan test of overidentifying restrictions in the specifications reported in columns (ii) and (iii) of Table 3.

Table 4 considers which of our three measures of uncertainty is the more informative in this context. Column (i) includes all three uncertainty variables, together with our discounted profits forecasts measure of average q and the lagged dependent variable. We continue to find significant negative coefficients on the current volatility and dispersion variables, but the coefficients on the squared forecast errors are now individually and jointly insignificant. This suggests that the information in this variable that was identifying the significant negative effect of uncertainty found in column (iii) of the preceding Tables is captured better by the volatility and dispersion measures. Column (ii) omits these insignificant forecast error terms. The estimated coefficients on the dispersion measure are now significant at the 1% level, and those on the volatility measure are significant at the 10% level. However in each case the coefficient on the lagged uncertainty measure is not significantly different from zero at the 10% level, and the same applies when we consider these coefficients on the lagged uncertainty terms jointly.

Column (iii) omits these lagged terms, leaving us with a more parsimonious empirical specification in which uncertainty measured by the dispersion across analysts' current forecasts of the firm's profits remains highly significant, and uncertainty measured by volatility in the firm's current stock returns has a marginally significant additional effect on the firm's investment behaviour.[15] Expected profitability as

[15] Scherbina (2001) provides a different possible interpretation of the significant negative coefficient that we find on the dispersion in analysts' forecasts variable. She notes that the consensus forecast of profits at short time horizons appears to display a greater upward bias when there is greater disagreement between the analysts that issue these forecasts for a particular firm. If this were also true at longer time horizons, it could be that the inclusion of this dispersion term provides an implicit 'bias correction' to the consensus forecasts of future profits used to construct our measure of average q.

We confirmed the positive relationship between dispersion and upward bias in the analysts' forecasts of profits for the current accounting year, but found no similar relationship between dispersion and bias in the summarised by our alternative average q measure has a highly significant positive effect, and the inclusion of this term is important for the validity of our lagged investment and cash flow instruments. The significance of the lagged dependent variable indicates that there is more persistence in company investment rates than can be accounted for by a simple, static linear relationship with measures of uncertainty and expected future profitability. Column (iv) shows that, given analysts' forecasts of the firm's future profits, there is no additional information in the more familiar Tobin's q measure constructed using the firm's stock market valuation. This confirms our previous finding using different samples, although here we do find marginally significant information in the volatility of the firm's stock returns.

Table 5 investigates whether the relationship between investment and these measures of uncertainty is best described by the simple linear functional form that has been imposed in the preceding Tables. Recall from our discussion in section 2 that this specification imposes that the impact effect of higher uncertainty on current investment and the long run effect of higher uncertainty on capital accumulation must have the same sign, whilst this restriction need not hold in 'real options' models.

Column (i) explores interaction terms between our measure of average q and our more informative measures of uncertainty. In the basic Q model, the coefficient on average q is directly related to the speed of adjustment of the capital stock. Thus if the main effect of higher uncertainty were to slow down the adjustment process rather than to reduce the average level of the capital stock in the long run, we might expect this to show up as a smaller coefficient on average q for firms facing higher uncertainty, rather than as a negative coefficient on our linear uncertainty terms. However column (i) shows that we find no evidence for such an interaction effect using either of our uncertainty measures, whilst the coefficient on the linear dispersion term remains negative and highly significant in the presence of these interactions.

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analysts' forecasts of profits for the following accounting year, or in the long term growth forecasts. More importantly, we used simple regression models of realised profits on both forecast profits and our measure of dispersion to construct explicitly bias-corrected forecasts of future profits. Our finding of a significant negative coefficient on current dispersion in our investment equations was completely robust to using these corrected forecasts in place of the raw analysts' forecasts when constructing our measure of average q.

Columns (ii) and (iii) explore more directly the prediction of the real options literature that investment will respond less to a given demand shock at higher levels of uncertainty. Following Bloom, Bond and Van Reenen (2001) we include current real sales growth (Δy_{it}) as a measure of the demand shock. In column (ii), we find that a simple linear sales growth variable is insignificant when added to the investment model which includes our discounted analysts' forecasts measure of average q. This finding is consistent with our earlier results reported in Bond and Cummins (2001). However column (iii) shows that when we allow for heterogeneity in the response of investment to sales growth depending on the level of measured uncertainty, we do indeed find evidence of a weaker impact effect of sales growth on investment for firms that are subject to higher uncertainty. In particular we find a significant negative coefficient on the interaction between sales growth and the measure of uncertainty based on volatility in the firm's stock returns. The coefficient on the linear volatility term becomes insignificantly different from zero when this interaction term is included, but the coefficient on the linear dispersion term remains negative and highly significant.

Column (iv) reports our preferred parsimonious specification, which includes a significant linear term where uncertainty is measured by dispersion across analysts' forecasts of the firm's profits, and a significant interaction with sales growth, where uncertainty is measured by volatility in the firm's stock returns. This model thus indicates that our preferred measure of average q is not a sufficient statistic for company investment rates. Firms facing low levels of uncertainty increase their investment in response to a current demand shock by more than is captured by our average q variable, whilst firms facing high levels of uncertainty react less to demand shocks. In addition, we find a significantly negative long run effect of uncertainty on capital accumulation, holding constant the present discounted value of expected future profits. Column (v) confirms that these effects are robust to including a standard measure of Tobin's q in the empirical specification, and again we find that there is no additional information relevant for explaining current investment rates in the level of the firm's stock market valuation.

5. Conclusions

We find significant effects of measured uncertainty on company investment behaviour, controlling for the effect of observed expectations of future profitability. In the long run, we find that a 10% increase in uncertainty is associated with a 6% reduction in the level of the capital stock, holding constant the present discounted value of the firm's expected future profits. In the short run, we find an additional effect of higher uncertainty on the relationship between investment and current demand shocks. Accounting for this, we find that a 10% increase in uncertainty is associated with a reduction in current investment rates of around 4%. Interestingly, the long run effect of uncertainty on capital accumulation is identified most clearly using a measure of uncertainty based on dispersion across different analysts' forecasts of the firm's profits for the current year, whilst the short run effect on investment dynamics is identified most clearly using a measure of uncertainty based on high frequency volatility in the firm's stock returns.

We have noted that these quantitative estimates of the effects of higher uncertainty should be regarded with caution, since our econometric investment model is not derived from a structural analysis of the firm's investment problem that generates this particular specification. The more robust conclusion from this empirical investigation is that we reject the hypothesis that uncertainty has no effect on investment beyond that which is summarised in current expectations of future profits. However from a policy perspective our results also suggest that the effects of higher uncertainty on business investment are not trivial.

We have also stressed that our results should not be interpreted as a rejection of the Q theory of investment. Both measures of average q that we use in our empirical models are plausibly subject to measurement errors that could be correlated with our measures of uncertainty. The evidence that sales growth has a weaker impact effect on company investment for firms facing higher levels of uncertainty is consistent with one of the principal predictions of models that emphasise the role of the 'real option' to delay investment actions, but may also be rationalised within other approaches. The development of more direct tests of particular theoretical models that relate investment and uncertainty would seem to be an important topic for future research.

The approach taken in this paper could also be extended in interesting directions, in particular by considering heterogeneity in the effects of uncertainty on investment across firms with different characteristics. For example, if investment depends on uncertainty because managers are unable to fully diversify their exposure to idiosyncratic risk, along the lines suggested by Himmelberg, Hubbard and Love (2002), then we might expect the effects of uncertainty to be stronger in environments where managers are observed to have substantial equity stakes or other forms of high-powered incentive contracts. Alternatively if the relationship between uncertainty and investment reflects the importance of real options, then we might expect these effects to be stronger in sectors where the capital used has lower resale value or where firms have more market power. Further exploration of this cross-sectional heterogeneity, along the lines initiated by Guiso and Parigi (1999), would also seem to be a promising direction for future empirical work in this area.

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Appendix A

To obtain the steady state partial elasticity of capital with respect to uncertainty implied by our empirical model

$$\left(\frac{I}{K}\right) = \alpha + \beta\left(\frac{V}{\kappa} - 1\right) + \gamma\sigma + \theta\Delta y + \varphi(\sigma * \Delta y)$$

we first note that (I/K) ≈ Δk + δ, where Δk is the growth rate of the net capital stock and δ is the depreciation rate.

Now consider a steady state in which Δk = Δy = g and α = g + δ. Then

$$\beta\left(\frac{V}{\kappa} - 1\right) + \gamma\sigma + \theta g + \varphi\sigma g = 0$$

implying

$$\kappa = f(\sigma)V$$

with

$$f(\sigma) = \left[1 - \left(\frac{\gamma + \varphi g}{\beta}\right)\sigma - \left(\frac{\theta}{\beta}\right)g\right]^{-1}.$$

In this case

$$\frac{\sigma}{\kappa}\frac{\partial\kappa}{\partial\sigma}\bigg|_V = \left(\frac{V}{\kappa}\right)\sigma f'(\sigma)$$

$$= \left(\frac{V}{\kappa}\right)\left\{\frac{\left(\frac{\gamma + \varphi g}{\beta}\right)\sigma}{\left[1 - \left(\frac{\gamma + \varphi g}{\beta}\right)\sigma - \left(\frac{\theta}{\beta}\right)g\right]^2}\right\}.$$

Table 1. Uncertainty Measures

	(i)	(ii)	(iii)
VOL_t	-0.3375 (.1169)		
VOL_{t-1}	-0.4200 (.1140)		
VOL_{t-2}	-0.2390 (.1212)		
$DISP_t$		-0.6132 (.1418)	
$DISP_{t-1}$		-0.2982 (.1066)	
$DISP_{t-2}$		-0.0129 (.1378)	
ERR_t			-0.0140 (.0269)
ERR_{t-1}			-0.0755 (.0207)
ERR_{t-2}			-0.0633 (.0168)
$(I/K)_{t-1}$	0.2863 (.0353)	0.2721 (.0339)	0.3057 (.0325)
m1	-8.32	-10.02	-10.30
m2	-0.15	-0.10	-0.24
Sargan	.022	.006	.004
Joint significance: uncertainty measures	.001	.000	.001

Sample: 946 firms 5814 observations 1985-99

Instruments: $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$, $(CF/K)_{t-3}$

Table 2. Uncertainty Measures and Tobin's Q

	(i)	(ii)	(iii)
VOL_t	-0.3187 (.1125)		
VOL_{t-1}	-0.5046 (.1216)		
VOL_{t-2}	-0.2874 (.1205)		
$DISP_t$		-0.6830 (.1438)	
$DISP_{t-1}$		-0.2567 (.1105)	
$DISP_{t-2}$		0.0171 (.1345)	
ERR_t			-0.0285 (.0265)
ERR_{t-1}			-0.0860 (.0208)
ERR_{t-2}			-0.0500 (.0178)
q_t^E	0.0205 (.0052)	0.0189 (.0049)	0.0188 (.0053)
$(I/K)_{t-1}$	0.2267 (.0366)	0.2278 (.0353)	0.2634 (.0305)
m1	-7.00	-9.08	-9.75
m2	-0.95	-0.28	-0.58
Sargan	.089	.020	.004
Joint significance: uncertainty measures	.000	.000	.000

Sample: 946 firms 5814 observations 1985-99

Instruments: $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$, $(CF/K)_{t-3}$

Table 3. Uncertainty Measures and Forecast Q

	(i)	(ii)	(iii)
VOL_t	-0.2929		
	(.1113)		
VOL_{t-1}	-0.3079		
	(.1087)		
VOL_{t-2}	-0.1521		
	(.1145)		
$DISP_t$		-0.5999	
		(.1528)	
$DISP_{t-1}$		-0.1939	
		(.1277)	
$DISP_{t-2}$		0.0498	
		(.1355)	
ERR_t			-0.0341
			(.0275)
ERR_{t-1}			-0.0776
			(.0233)
ERR_{t-2}			-0.0418
			(.0204)
$\hat{q}_t$	0.0667	0.0730	0.0792
	(.0144)	(.0147)	(.0155)
$(I/K)_{t-1}$	0.2227	0.2031	0.2215
	(.0362)	(.0376)	(.0350)
m1	-9.08	-8.57	-9.19
m2	0.14	-0.25	-0.64
Sargan	.098	.268	.184
Joint significance: uncertainty measures	.012	.001	.005

Sample: 946 firms 5814 observations 1985-99

Instruments: $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$, $(CF/K)_{t-3}$

Table 4. Uncertainty Measures and Q Measures

	(i)	(ii)	(iii)	(iv)
VOL_t	-0.2324 (.1102)	-0.2355 (.1106)	-0.2210 (.1102)	-0.2097 (.1102)
VOL_{t-1}	-0.1609 (.1172)	-0.1546 (.1165)		
$DISP_t$	-0.3978 (.2068)	-0.5562 (.1658)	-0.5840 (.1546)	-0.6063 (.1577)
$DISP_{t-1}$	-0.1730 (.1638)	-0.1815 (.1293)		
ERR_{t-1}	-0.0375 (.0315)			
ERR_{t-2}	-0.0152 (.0251)			
$\hat{q}_t$	0.0693 (.0162)	0.0683 (.0152)	0.0771 (.0142)	0.0692 (.0164)
$(I/K)_{t-1}$	0.2011 (.0375)	0.1991 (.0377)	0.2152 (.0369)	0.2089 (.0372)
q_t^E				0.0058 (.0059)
m1	-7.95	-7.61	-10.16	-10.09
m2	-0.43	-0.36	0.92	0.93
Sargan	.443	.520	.611	.555
Joint significance:				
VOL	.078	.082		
DISP	.139	.004		
ERR	.489			
uncertainty lags		.144		

Sample: 946 firms 5814 observations 1985-99

Instruments: $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$, $(CF/K)_{t-3}$

Table 5. Uncertainty Levels and Interactions

	(i)	(ii)	(iii)	(iv)	(v)
VOL_t	-0.1373	-0.2168	-0.1114		
	(.1339)	(.1114)	(.1342)		
$DISP_t$	-0.7948	-0.5903	-0.5874	-0.6189	-0.6380
	(.2459)	(.1551)	(.1695)	(.1640)	(.1669)
$VOL_t * \hat{q}_t$	-0.0385				
	(.0330)				
$DISP_t * \hat{q}_t$	0.2325				
	(.1665)				
$VOL_t * \Delta y_t$			-1.0775	-1.2400	-1.2032
			(.4972)	(.4200)	(.4192)
$DISP_t * \Delta y_t$			-0.7334		
			(.7628)		
$\hat{q}_t$	0.0837	0.0758	0.0764	0.0794	0.0724
	(.0165)	(.0144)	(.0152)	(.0154)	(.0179)
$(I/K)_{t-1}$	0.2005	0.2270	0.2150	0.2144	0.2104
	(.0391)	(.0424)	(.0429)	(.0433)	(.0431)
Δy_t		-0.0319	0.4308	0.4204	0.4039
		(.0505)	(.1950)	(.1576)	(.1588)
q_t^E					0.0049
					(.0062)
m1	-10.20	-9.87	-9.61	-9.79	-9.74
m2	-0.63	0.88	0.14	0.10	0.17
Sargan	.652	.611	.708	.536	.529
Joint significance: Interactions	.319		.064		

Sample: 946 firms 5814 observations 1985-99

Instruments: $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$, $(CF/K)_{t-3}$

Notes to Tables

All results are for an unbalanced panel of 946 publicly traded US companies with at least four consecutive years of data available between 1982 and 1999. All firms are tracked by two or more securities analysts that supply profits forecasts to I/B/E/S International Inc.

In all cases the dependent variable is $(I/K)_t$.

Data on investment, capital, sales, profits and cash flow come from Compustat.

Data on market valuation and daily stock returns come from CRSP.

Data on analysts' profits forecasts come from I/B/E/S International Inc.

Investment rates and q measures are constructed using the same procedures as in Bond and Cummins (2001).

The measure of volatility (VOL_t) - the standard deviation of daily stock returns during the firm's current accounting period - is constructed using the same procedure as in Bloom, Bond and Van Reenen (2001).

The measure of dispersion ($DISP_t$) is the coefficient of variation across different analysts' forecasts of earnings per share for the firm's current accounting period.

The forecast error measure (ERR_t) is the square of the difference between the consensus forecast of earnings per share and the realised level of earnings per share for the firm's current accounting period.

Estimation is in first-differences to remove unobserved firm-specific effects. Time dummies (not reported) are included in all specifications. All current-dated right hand side variables are treated as endogenous. The instruments used for the first-differenced equations in period t are $(I/K)_{t-2}$, $(I/K)_{t-3}$, $(CF/K)_{t-2}$ and $(CF/K)_{t-3}$, common across all specifications. Estimates are computed using DPD98 for GAUSS (Arellano and Bond, 1998). One-step coefficients with heteroskedasticity consistent standard errors are reported.

m1 and m2 are tests for no first-order and no second-order serial correlation in the first-differenced residuals. These test statistics are asymptotically standard normal.

Sargan is a test for the validity of the overidentifying restrictions, based on the associated two-step GMM estimator to obtain an asymptotically chi-squared test statistic. P-values are reported (i.e. the probability of obtaining the recorded value of the statistic if the null hypothesis of valid moment conditions is correct).

Joint significance statistics are p-values from the Wald tests that the coefficients are equal to zero on the indicated sets of explanatory variables.