UNCERTAINTY AND FIRM INVESTMENT

D.Phil. Thesis - Economics

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The author would like to thank his supervisor Steve Bond for his guidance and support. The author would also like to thank his family for their love and support.

Abstract

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This thesis explores effects of uncertainty on firm investment that are described in estimates of firm level investment specifications which include proxies for uncertainty over expected future firm profitability. A panel data set of UK firms covering the period 1987-2000 is used to estimate firm level investment specifications. Within year volatility in stock returns - a common proxy for firm specific uncertainty in previous literature - is compared with covariance measures between stock returns and market returns representing un-diversifiable risk from the CAPM; and with alternative uncertainty proxies based on volatility in I/B/E/S securities analysts' forecasts of earnings per share. Within estimates of firm level investment specifications, the thesis investigates the sensitivity of coefficients on uncertainty terms to the choice of underlying investment specification: error correction model between the natural logarithms of capital and sales; or the Hayashi (1982) Q model of investment. Coefficients on stock return volatility measures of uncertainty terms are found to vary significantly between estimates of error correction and average q specifications. Differences between coefficients estimated on uncertainty terms across estimates of these two investment specifications are supported with simulated data. Uncertainty measures based on volatility in I/B/E/S securities analysts' forecasts of earnings per share are found to be much more informative of investment behaviour than within year stock return volatility in estimates of both error correction and average q specifications. Coefficients on I/B/E/S uncertainty proxies imply more consistent investment-uncertainty relationships across estimates of error correction and average q specifications for the UK panel data set.

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0.1 Thesis Introduction

The focus of this thesis is on the relationship between firm level investment and uncertainty. The concept of uncertainty being addressed is over the expected future operating environment that is relevant to the profitability of a firm's investment opportunities. This relationship is investigated empirically in a panel data set of UK listed firms over the period 1987-2000; as well as with simulated panel data sets generated by a program developed by Professor Nick Bloom of Stanford University. Econometric analysis is based on Generalized Methods of Moments estimates of firm level investment specifications.

In previous empirical literature on this topic (Leahy and Whited (1996), Bulan (2005), and Bloom, Bond and VanReenen (2007)), measurement of uncertainty over firm's expected future operating environments has been based on within year volatility in daily firm stock returns. Alternative measures of uncertainty have been used to investigate similar firm level investment-uncertainty relationships: Guiso and Parigi (1999) and Bond and Lombardi (2004) use proxies based on managers' perceptions of future demand uncertainty; and Bond and Cummins (2004) construct various measures based on disagreement in I/B/E/S securities analysts' forecasts of earnings per share to capture information on firm specific uncertainty over future operating environments.

Overall findings of this body of literature point to a negative effect of uncertainty - as controlled for by the various proxies - on firm investment. In select studies(Bloom, Bond and VenReenen (2007), Bond and Lombardi (2004) and Bond and Cummins (2004)), negative effects of uncertainty on firm investment responses to changes in demand have been implied by coefficients on uncertainty-sales growth interaction terms included in estimates of firm level investment specifications. This result is consistent with effects of greater uncertainty / volatility in demand conditions described by theoretical models in which firm investment decisions have real option values.

Chapters 1, 3, 4 and 5 of this thesis present econometric results from including different measures of uncertainty in estimates of firm level investment specifications with the same UK panel data set of firms. Chapter 1 focuses on measures of within year stock return volatility - the uncertainty proxy that appears most frequently throughout previous empirical literature on firm level investment-uncertainty relationships. As in previous empirical literature, results presented in Chapter 1 imply a negative effect of stock return volatility on firm investment responses to demand shocks.

Chapter 3 compares the effects of within year volatility in firm stock returns to covariance of firm stock returns with returns to a market index; the latter measure represents the concept of systematic or un-diversifiable risk addressed in Capital Asset Pricing Models (CAPM). This comparison was first made in Leahy and Whited (1996), in the contexts of a simple investment specification which included only terms in uncertainty, risk and average q. Bulan (2005) made a similar comparison by including linear uncertainty terms in a more general average q specification. Chapter 3 builds on this line of previous research by comparing effects of uncertainty and financial risk in the contexts of an error correction specification between the natural logarithms of capital and sales. Additionally, both linear and sales growth interaction terms in uncertainty and risk are included in estimates of investment specifications. Results presented in Chapter 3 are consistent with previous studies, in so far as controls for systematic risk from the CAPM have no significant effect in estimates of firm level investment specifications.

Chapter 4 decomposes the uncertainty measure based on within year volatility in stock returns into idiosyncratic and systematic components following two different approaches in Bloom, Bond and VanReeen (2007) and Bulan (2005). The findings of the latter studies are confirmed in the UK data set, in which firm investment-uncertainty relationships appear to be captured exclusively by firm specific or idiosyncratic components of within year volatility in stock returns.

Chapter 5 compares the effects of within year stock return volatility and volatility in I/B/E/S securities analysts forecasts of earnings per share. Bond and Cummins (2004) is the only previous work the author is aware of, which makes use of I/B/E/S analysts' forecasts of earnings per share to construct proxies for firm specific uncertainty over future operating environments. Whereas the I/B/E/S uncertainty measures in Bond and Cummins (2004) focus on disagreement between securities analysts' forecasts, the proxy in Chapter 5 incorporates different information into a measure based on volatility of forecasts over time. The results of Chapter 5 suggest that the I/B/E/S uncertainty measures are more informative of investment behaviour than within year stock return volatility.

Previous empirical research into the relationship between firm investment and uncertainty has focused on estimates of single investment specifications; in some cases comparing coefficients estimated on alternative measures of uncertainty, but always in the same specification. The analysis across the chapters of this thesis includes estimates of alternative investment specifications in order to assess the robustness of investment uncertainty relationships described by different uncertainty proxies. The two investment specifications compared throughout the thesis are based on an error correction model between the natural logarithms of capital and sales and the Hayashi (1982) Q model of firm investment. Empirical research into relationships between firm investment and uncertainty has focused almost exclusively on variants of these two specifications.

In the analysis presented in Chapter 1, estimates of firm level error correction and average q investment specifications describe roughly similar investment uncertainty relationships. However, negative coefficients on uncertainty-sales growth interaction terms are larger in magnitude and much more significant in estimates of the error correction specification. Differences in coefficients across estimates of the two investment specifications in Chapter 1 are significant enough to suggest that policy recommendations, attempting to take into account effects of uncertainty on firm level investment, could be influenced by the choice of estimated investment specification.

Chapter 2 uses a simulation program developed by Professor Nick Bloom of Stanford University to further explore differences between firm level investment-uncertainty relationships described by estimates of error correction and average q specifications in firm level panel data. The simulation program is driven by a stochastic demand process, which - combined with non convex cost functions to adjusting firm capital stocks - creates real option values to investment opportunities. Within year volatility in firm value functions is used as an *empirical* proxy to uncertainty - or volatility in the stochastic demand process driving the simulation. This simulated uncertainty proxy is included in estimates of both average q and error correction specifications as in the analysis of Chapter 1. Varying the magnitude of real option values, and introducing measurement error into uncertainty proxies based on within year volatility of firm value functions suggests that estimates of error correction and average q specification will not always provide consistent insights into firm level investment-uncertainty relationships in the same panel data set.

In Chapter 5, comparison between stock return volatility measures of uncertainty and the proxies based on volatility in I/B/E/S analysts' forecasts of earnings per share shows that the I/B/E/S proxy captures a more significant effect of uncertainty in estimates of error correction and average q investment specifications. In the UK data set of firms, stock return volatility measures of uncertainty do not contain any additional information that cannot be controlled for using I/B/E/S uncertainty terms based on within year volatility in security analysts' forecasts of earnings per share. Furthermore, whereas coefficients estimated on stock return volatility measures of uncertainty varied in magnitude and significance between error correction and average q specifications, coefficients on the I/B/E/S uncertainty measures describe more consistent investment-uncertainty relationships across estimates of the two specifications.

Results presented throughout this thesis have several implications for future research into relationships between investment and uncertainty over future operating environments of firms. When attempting to describe effects of uncertainty in estimates of firm level investment specifications, the magnitude and significance of such effects may be sensitive to the choice of underlying investment specification. This appeared to be an issue using stock return volatility measures of uncertainty in the UK data set used in this thesis; and was supported with results from simulation analysis. However, alternative uncertainty measures may be more informative than others and less sensitive to the choice of underlying investment specification. Any future study on the relationship between firm investment and uncertainty may meaningfully expand the scope of its analysis by comparing results from estimates of alternative investment specifications and measures of uncertainty. This thesis has found that focusing exclusively on estimates of a single investment specification and a single measure of uncertainty, one may overlook meaningful aspects of firm level investment-uncertainty relationships - and perhaps even overlook the relationship all together.

Chapter 1

Comparing Effects of Stock Return Volatility Based Proxies for Uncertainty in Estimates of Error Correction and Average Q Investment Specifications

1.1 Introduction

This chapter builds on previous empirical research into effects of uncertainty on firm level investment behaviour; comparing results from estimating alternative investment specifications with a panel data set of UK firms covering the period 1987-2000. Stock market based proxies for uncertainty over future operating environments are included in the investment specifications to investigate possible effects of uncertainty on firm investment behaviour. The two investment specifications being estimated are based on an error correction model between the natural logarithms of capital and sales, and the Q-model developed in Hayashi (1982). Bloom, Bond and VanReenen (2007) and Bond and Lombardi (2006) have estimated investment specifications based on error correction models, reporting negative coefficients on interaction terms between uncertainty proxies and sales growth; implying a negative effect of uncertainty on the response of investment to demand shocks. Similar results were reported in Bond and Cummins (2004) using an underlying investment specification based on controls for average q. Previous empirical research into this topic has been focused within the context of a single investment specification; possible differences in coefficients estimated on uncertainty proxies between different investment specifications have not previously been explored in the empirical literature on this topic.

The concept of uncertainty addressed in these studies (and in the current chapter) is based on uncertainty over (expected) future operating environments, which relates to variance in the expected profitability of a firm's investment opportunities. This chapter follows previous empirical literature[1] and constructs a proxy for this concept of uncertainty based on within year volatility of a firm's daily stock returns. Under the assumption that stock markets are pricing expected discounted revenues effectively, greater volatility in equity returns over a given period should reflect more significant changes in expectations arising from greater uncertainty over a firm's future operating environment.

This concept of uncertainty over a firm's future operating environment is related to volatility in demand/productivity conditions used to describe firm level investment-uncertainty relationships in the theoretical literature on investment under uncertainty. In theoretical models which consider risk neutral, value maximizing firms, irreversibility of investment in the capital stock can combine with volatility in demand conditions to create real option values to delaying investment decisions. The value of these options is positively related to the level of demand volatility/uncertainty; more valuable real options to delay then have a negative effect on investment responses to demand shocks in such models. Volatility in demand/productivity conditions can also result in positive or negative effects of uncertainty on optimal investment through Hartman-Abel effects on the expected marginal revenue product of capital. Stock market based proxies for uncertainty, similar to the one used in this chapter, have been relied on to investigate the predictions of theoretical models with real option and Hartman-Abel effects of uncertainty.[2]

[1] Leahy and Whited (1996), Bloom, Bond and VanReenen (2007), and Bulan (2005)
[2] Leahy and Whited (1996)

This chapter finds that in a panel data set of UK listed firms, estimates of average q and error correction investment specifications describe similar investment-uncertainty relationships. However, estimates of the average q specification implied weaker and less significant effects of uncertainty on firm investment. Effects of uncertainty on investment behaviour are captured in these two specifications by negative coefficients estimated on interaction terms between measured uncertainty and sales growth. Significant negative coefficients on these interaction terms imply lower investment responses to demand growth at higher levels of uncertainty; which is consistent with firms behaving as though they hold more valuable real options to delay their investment decisions. Whereas coefficients on uncertainty-sales growth interaction terms were significant at the 5% confidence level in the error correction specification, the same coefficients were smaller in magnitude and significant at only the 10% confidence level in average q specifications.

Differences between coefficients estimated on uncertainty sales growth interaction terms in the error correction and average q specifications arise due to the combined influences of the measure of investment used and differences in controls for investment dynamics between the two specifications. By comparing various estimates of *hybrid* investment specifications, containing both the forward-looking terms of the average q specification and the backward-looking terms of the error correction specification, the significance and magnitude of coefficients on uncertainty terms are shown to be sensitive to the measurement of investment as well as changes in explanatory variables.

If firms tended to delay investment decisions at higher levels of uncertainty, the impacts of fiscal and monetary policy on firm level capital expenditure could be severely delayed given high levels of uncertainty over future market conditions. It is important to confirm the consistency of evidence for such effects across estimates of alternative investment specifications, and to understand any differences that may arise as a result of specification choice. Based on estimates of investment specifications obtained using the data set of UK firms in this chapter, the results for the average q specification imply a smaller and less significant effect of uncertainty on firms' investment responses to demand shocks. These results suggest that policy recommendations, attempting to take into account effects of uncertainty on firm level investment, could be influenced by the choice of estimated investment specification. The findings presented here suggest that further empirical research may be needed, using other data sets, to confirm potential differences in effects of uncertainty described by alternative investment specifications. Future empirical research into effects of uncertainty on firm level investment should consider the sensitivity of results to the choice of estimated investment specification.

The remainder of the Chapter is organized into 7 sections: Section (2) reviews relevant empirical and theoretical literature on firm level investment-uncertainty relationships; Section (3) provides an overview of the two investment specifications estimated here; Section (4) briefly summarizes the panel data set of UK firms; Section (5) details the System GMM estimation procedure used in this Chapter and throughout the remainder of the thesis; Section (6) presents the empirical results from estimating the investment specifications; Section (7) compares estimates of investment specifications from this chapter to the findings of previous empirical literature; Section (8) concludes. The conclusion is followed by by Data Set and Instrument Selection appendices as well as an annex which addresses the sensitivity of key empirical results to the value of coefficients estimated and imposed on error correction and average q terms.

1.2 Literature Review

Hartman-Abel and real option effects are two important channels through which economic theory has modelled the effects of uncertainty on firm level investment. These models of investment define uncertainty as volatility in demand or productivity conditions faced by a value maximizing risk neutral firm in isolation. This concept of uncertainty can be contrasted with concepts of financial risk which emphasize covariance between rates of return (such as with CAPM models).

Hartman-Abel effects, named after their exposition in Hartman (1972) and Abel (1983), result from Jensen's inequality and uncertainty over the future price of output: if the marginal revenue product of capital is convex (concave) with respect to the price of output, uncertainty over the future price of output will have a positive (negative) effect on the expected future marginal product of capital, and the optimal level of the capital stock in the absence of capital adjustment costs; or on the target/desired level of capital in the presence of capital adjustment costs. The sign of this effect is to a large extent determined by the demand and production functions assumed for a firm, and the concavity/convexity of the firm's resulting net revenue function, which is also influenced by the functional form of capital adjustment costs [3]. Hartman-Abel effects of uncertainty operate on the optimal/desired level of the capital stock and can be contrasted with effects of uncertainty which influence adjustment towards that optimum/target level, such as real option effects of uncertainty.

The mechanics of investment uncertainty relationships arising from real options are thoroughly described in *Investment under Uncertainty* (1994) by Dixit and Pindyck. When investment is to some degree irreversible (or partially irreversible[4]), and the marginal revenue product of capital varies over time with output price (or more generally with demand or productivity conditions), the real options literature describes upper and lower bounds between which, values of marginal revenue products of capital result in no investment or disinvestment. Within this zone of inaction the real option value of delaying additional investment, while awaiting new price information, is greater than the discounted marginal revenue product of additional capital. The investment uncertainty relationship described by this literature is based on wider

[3] Caballero (1991)
[4] Reversing investment decisions is costly

zones of inaction (more valuable real options to investing) at higher levels of price (/demand or productivity) uncertainty. The wider zones of inaction, in turn, require higher prices (/demand or productivity conditions) to justify positive investment. Thus, real option values will cause firms to delay changes in their capital stocks, adjusting more flexible factors of production in response to changes in demand.

Real option values of investment require decreasing returns to scale in the net revenue function of a firm (resulting from some combination of decreasing returns to scale in the production function, and/or imperfect competition), combined with some fixed or irreversible component of capital adjustment costs[5]. Relative to Hartman/Abel effects, real options effects of uncertainty operate primarily through adjustment costs to changing the capital stock. There can be no real option value to delaying investment decisions if there is little cost to reversing them. Consequently, as irreversible (or partially irreversible) adjustment costs are augmented, real options become more valuable - intensifying the investment uncertainty relationship.

Comparing the implications of these two effects on optimal investment behaviour, real options have more short term effects, whereas Hartman Abel effects impact long run investment dynamics. The *direct* effect of real options is delayed investment responses to changes in demand at higher levels of uncertainty, resulting in (relatively) ambiguous changes to long run investment dynamics. Hartman-Abel effects directly impact optimal long run capital stocks, independently of costs to adjusting the capital stock.

1.2.1 Theoretical Predictions of Models with Real Options

The short run effect of real options on investment is more accurately described as changes in the timing of investment decisions and not in the amount of investment eventually undertaken by a firm. The real option, created by uncertainty in the future profitability of a (partially) irreversible investment, represents the expected value in waiting for new information instead of

[5]fixed cost to changing the capital stock, or a resale price of capital goods that is lower than their purchase price

investing immediately. Dixit and Pindyck (1994) describe this value as a wedge between the optimal expected net present value (NPV) of discounted future revenue at which investments should be undertaken, and the traditional zero NPV rule, under which all investments with positive NPV are undertaken. This wedge, or option value to investment, is increasing in the variability of the stochastic price process; thus higher uncertainty leads to a higher value of the option to delay investment.

Abel and Eberly (1996) examine the effects of real options in the contexts of variable (non-binary) investment for a Cobb-Douglas production unit facing a stochastic iso-elastic demand curve, and partial capital irreversibility, defined as a wedge between the selling and buying price of capital. They show that when capital is partially irreversible the firm holds put and call options on contracting and expanding the capital stock. These options result in an optimal trigger policy of investment by which the firm undertakes no investment (or disinvestment) whenever the marginal revenue products of additional capital increments lie between optimally defined lower and upper bounds. When the marginal revenue product of capital reaches one of these boundaries, the firm will either buy or sell capital to remain on the boundary of the inaction zone. The area between the two optimal trigger points (within which the firm undertakes no new investments) is shown to increase with the volatility of the stochastic component of the iso-elastic demand curve, reflecting the more valuable put and call options of contracting and expanding the capital stock.

Although higher levels of uncertainty lead to more cautious investment behaviour - in response to a given demand shock - in models with real options, there is no unambiguous effect of uncertainty on the amount of investment undertaken over a specific time period. In these models higher uncertainty implies higher productivity thresholds at which investment will be undertaken. However, higher uncertainty also implies more volatile productivity conditions over time; leading to ambiguous effects on the probability that investment thresholds are reached and the amount of investment undertaken over a given period of time.

In the context of a single dichotomous investment decision Sarkar (1999) investigates the effect of uncertainty, in the form of net cash flow volatility, on the adoption of an investment project with fixed sunk costs. The paper is partly motivated by past literature in which negative relationships between investment and uncertainty are predicted from the positive effect that uncertainty has on the value of call options to delay investment in models with irreversibility. Sarkar (1999) notes that, in such models, beneath the higher investment thresholds caused by greater uncertainty, expected returns take on greater volatility over time. Whereas the higher threshold has a negative effect on investment decisions, the greater volatility in expected returns exerts a positive effect on the probability of the threshold being reached. Sarkar (1999) evaluates the effect of uncertainty on investment by considering its effect on the probability of the stochastic expected cash flow reaching the investment threshold within a given time period T. The results show that the general effect of higher uncertainty on investment is ambiguous. Under the parameterizations chosen in the paper, the model demonstrates a positive relationship between the probability of investment and uncertainty at low values of uncertainty; but for higher values of uncertainty this relationship is reversed. However, the overall changes in the probability of investment over the range of uncertainty values considered was minimal.

Bloom (2000) shows that uncertainty (taken as the variance of stochastic demand conditions faced by a firm) affects investment behaviour primarily through the firm's short run investment response to demand shocks. This result is shown with a model developed in Eberly and Van Mieghem (1997) in which a firm makes partially irreversible hiring and investment decisions in multiple types of both labour and capital. Bloom (2000) demonstrates that both the vector of capital types and the vector of labour types will have the same long run growth rates as a firm facing complete reversibility in capital and labour. [6] Bloom (2000) notes that the only unambiguous effect that uncertainty has on investment behaviour is in the short run, by widening the region of inaction between the adjustment thresholds of capital and labour (as demonstrated in Eberly and Van Mieghem (1997)). In the case of each capital or labour good, greater demand shocks will be required to bring the marginal revenue product of the production input to its higher (or lower) adjustment threshold. This result decreases the aggregated investment -across the firm's different types of capital- in response to demand shocks at higher levels of uncertainty.

[6] This does not eliminate possible effects of uncertainty on the long run level of the capital stock. Optimal frictionless levels of labour and capital types may be higher or lower relative to the case of partial irreversibility, despite identical growth rates between the two cases.

The results presented in Bloom (2000) were shown to hold for all classes of models in which (i) the firm's revenue function is jointly concave and homogenous of degree $\gamma < 1$ in all lines of capital and labour; (ii) the individual lines of capital and labour types are complementary in production (ie. the revenue function is *super-modular*); (iii) all types of labour and capital are subject to partial irreversibility implied by a purchase price that is strictly higher than the resale price; (iv) the demand shocks have multiplicative impacts upon the revenue function and are generated by a stationary Markov process.

Abel and Eberly (1999) addresses the effect of higher uncertainty on long run expected capital stocks in the context of a single firm with Cobb-Douglas production technology, facing an iso-elastic, stochastic demand function, and completely irreversible capital investment decisions, and no depreciation of the capital stock. They show that in the long run the average level of the firm's capital stock under complete irreversibility, relative to the case of costless reversibility, will depend on the opposition of what they term *user cost* and *hangover* effects of irreversibility. User cost effects depress the irreversible capital stock, relative to the case of complete reversibility, as firms facing higher levels of uncertainty increasingly respond to demand shocks by delaying investment decisions in favour of holding their options. Whereas the hangover effect acts to increase the relative irreversible capital stock in periods when demand conditions have deteriorated from higher levels. Greater volatility in demand conditions cause such reversals to become both more frequent and substantial. Abel and Eberly (1999) show that the net impact of these opposing effects on the expected capital stock of firms facing complete irreversibility is ambiguous and depends on the entire history of demand shocks and investment decisions. For a given model parameterization, the relative irreversible capital stock is found to increase with uncertainty, at low levels of uncertainty, but at higher levels the relative capital stock tends to decrease with uncertainty. As in Sarkar (1999) the overall variation in capital stocks over the range of uncertainty values studied was vary small, varying only about 1%. Abel and Eberly (1999) notes that the long run effect of uncertainty does not only depend on the level of uncertainty, but also on the parameterization of their investment model. The sign and magnitude of the investment uncertainty relationship can change substantially with the chosen parameter values for the revenue function in Abel and Eberly (1999).

Bond, Soderbom and Wu (2007) shows through simulation study, the long run effects of uncertainty on capital accumulation in a model similar to that of Abel Eberly (1999) but in the separate contexts of fixed, partial and quadratic costs to adjusting the capital stock. The authors show that under partial irreversibility of capital, and separately under fixed costs to adjusting the capital stock, uncertainty has a similar effect on capital accumulation as in Abel and Eberly (1999) and Sarkar (1999). That is, increasing uncertainty from small levels tended to increase capital stocks relative to costless irreversibility; whereas increases from larger levels of uncertainty had the opposite effect on capital accumulation. However, as in Abel and Eberly (1999), the resulting changes in relative capital stock were minimal over the range of uncertainty values explored. In the case of strictly quadratic costs of capital adjustment, the study found a strong negative effect of uncertainty, decreasing capital stocks by as much as 20% relative to the case of costless reversibility. It is important to note that in the latter case there are no real option values to delaying investment decisions under strictly quadratic adjustment costs. Fixed costs, or partial irreversibility in adjusting the capital stock, are necessary to create real option values to investing. As in the case of Abel and Eberly (1999), the authors found that the sign and magnitude of long run effects of uncertainty on capital accumulation were sensitive to the parameterization of the underlying economic model; significant positive and negative long run effects of uncertainty resulted from different parameter choices for the simulation model.

The results from the various investment models discussed above, suggest that real option values to investment are not inconsistent with positive, negative or even insignificant effects of uncertainty on long run expected capital stocks, or the level of investment undertaken over specific time periods. The most robust prediction of models with real options is a negative, short run, effect of uncertainty on the investment response to demand shocks. This results from the wider zone of inaction between the optimal investment triggers at higher levels of uncertainty. For some current level of marginal productivity of capital within the zone of inaction, the greater the uncertainty, the larger is the demand or productivity shock required to bring the marginal revenue product to the investment trigger. Bloom, Bond and VanReenen (2007) use a simulated panel data set to show that this negative effect of uncertainty on the impact effect of demand shocks on investment is robust to extensive aggregation both across time and within firms over multiple production units.

1.2.2 Empirical Studies of Firm Investment Under Uncertainty

The relationships between uncertainty and investment predicted by the theoretical models discussed above rely on a rather restricted definition of uncertainty. Future costs of inputs, transport costs, taxes, regulatory or political conditions are all assumed to be known or constant, and the results are derived for changes in volatility of stochastic demand functions. Attempts to test the predictions of these models, and explore other possible relationships between investment and uncertainty in empirical data have relied on broader concepts of uncertainty faced by firms. Measures of within year volatility in stock returns were used to proxy for firm specific, idiosyncratic uncertainty in a firm's operating environment by Leahy and Whited (1996), Bulan (2005) and Bloom, Bond and VanReenen (2007). Survey data on managers' perceptions of the distribution of future demand was used as a proxy for demand risk by Guiso and Parigi (1999) as well as by Bond and Lombardi (2006). Disagreement in security analysts' equity forecasts was used as a proxy for uncertainty of firms' future profitability by Bond and Cummins (2004). Employing these various proxies of uncertainty, several empirical studies have uncovered firm level, investment uncertainty relationships consistent with the predictions of the theoretical literature. A significant number of these studies have relied on investment specifications based on either error correction models between the natural logarithms of capital and sales, or those based on measures of average q.

Leahy and Whited (1996) explored the effects of linear uncertainty terms in a regression of the ratio of current investment to capital stock ($\frac{I_{i,t}}{K_{i,t}}$) on measures of average q with US data covering the period 1981-1987. They found evidence of a negative relationship between uncertainty and the investment rate which was determined to operate through average q. Using a sample of US firms from 1964-1999, Bulan (2005) estimates a modified Q-theory investment specification which regressed the investment rate on linear uncertainty terms, average q and additional explanatory variables such as demand growth, lagged investment rates and cash flow terms. In this study significant, negative coefficients estimated on uncertainty terms implied additional effects of uncertainty not captured by average q. Bond and Cummins (2004) uses US data from 1982-1999 to estimate a similar modified Q-theory investment specification, which includes an additional interaction term between uncertainty and demand growth. Bond and Cummins(2004) find significant negative effects of uncertainty on the short run investment response to changes in demand, and on long run capital accumulation. These effects were found to influence investment behaviour beyond controls for current expectations of future profitability such as average q.

Using data on UK-listed companies over the period 1971-1991, Bloom, Bond and VanReenen (2007) estimates an error correction specification between capital and sales, which includes both linear uncertainty terms as well as uncertainty sales growth interaction terms. They find a significant negative coefficient on the interacted uncertainty term: implying a substitution towards more flexible factors of production and smaller investment response to changes in demand at higher levels of uncertainty. Bond and Lombardi (2006) use a similar error correction specification to Bloom, Bond and VanReenen (2007), also estimating a significant negative coefficient on an interaction term between uncertainty and sales growth.

Interpretations of estimated signs on uncertainty terms in the contexts of Hartman-Abel and real option effects of uncertainty have varied slightly between studies. There is a tendency in empirical literature to associate negative effects of uncertainty with the presence of real options or irreversibility of investment decisions. However, the real options literature does not predict a negative relationship between uncertainty and the growth rate of the capital stock. Higher levels of uncertainty directly affect the timing of investment decisions through real options. Long run effects of real options and uncertainty on average capital stocks relative to frictionless optimums are ambiguous. Leahy and Whited (1996) contrast models in which marginal revenue products of capital are convex or concave with respect to random variables, predicting positive or negative effects of uncertainty respectively. They emphasize models of irreversible investment with real options when interpreting a negative coefficient estimated in a regression of the investment rate on a linear uncertainty proxy. Bulan (2005) also interprets a negative coefficient estimated on a linear uncertainty term in a modified Q-theory investment specification, as evidence of real option effects of uncertainty.[7] However, linear relationships between investment rates (or the growth rate of the capital stock) and measures of uncertainty provide limited evidence of real options and irreversibility. In Bloom (2000) higher levels of uncertainty have no effect on the growth rate of the capital stock relative to the frictionless case. Abel and Eberly (1999) and Bond Soderbom and Wu (2007) show that in models with real options there is no clear relationship between uncertainty and the long run level of the capital stock either. The most robust relationship between uncertainty and investment behaviour in models with real options is the negative short run effect of delaying investment responses to changes in demand at higher levels of uncertainty.

Including an interaction term between sales growth and an uncertainty proxy in an investment specification is more appropriate to allow (or test) for the relationship between investment and uncertainty predicted by models with real options than including linear uncertainty terms. Negative coefficients estimated on such terms[8] are consistent with delayed investment responses to changes in demand at higher levels of uncertainty, as production becomes more intensive in flexible factors. Regardless of the effect of uncertainty on the growth rate or level of the capital stock, all theoretical models with real options predict a delayed investment response to demand growth at higher levels of uncertainty.

The investigation into the relationship between firm level investment and uncertainty in empirical data later in this chapter will allow for separate long run - linear - effects of uncertainty on the ratio of capital to sales; and short run effects of uncertainty on the investment response to demand. The latter effect will be allowed for in estimated investment specifications by including an interaction term between sales growth and the chosen uncertainty proxy. In conjunction with a linear term in sales growth, the interaction term will allow the investment response to demand growth to vary with the level of firm specific uncertainty. In the previous empirical

[7]Other empirical work including Ghosal and Loungani (2000), Mauer and Ott (1995) and Metcaff and Hasset (1995) have discussed the effects of real options in the contexts of negative effects of uncertainty on investment.

[8]As found by Bond and Cummins (2004), Bond and Lombardi(2004) and Bloom, Bond and VanReenen (2007)

literature specifications based on either error correction models or those based on average q have been the sole focus in exploring the effects of uncertainty on firm level investment. One of the main contributions of the current investigation, to that literature, will be to determine whether the significance of investment uncertainty relationship is dependent on the choice of underlying investment specification.

1.3 Investment Specifications

This section offers a brief overview of the investment specifications used to investigate the effects of uncertainty on firm level investment behaviour. These are an error correction specification between the natural logarithms of capital and sales and a specification based on the Hayashi (1982) Q-model of firm investment. The section provides an overview of the different assumptions which operationalize these two specifications, and how they are appended with uncertainty proxies.

1.3.1 Error Correction Model

The error correction specification described here is based on an assumption of CES production functions with or without constant returns to scale. Profit maximizing conditions derived for this class of production functions form the basis of a co-integrating relationship between the natural logarithms of firm capital stock and sales. The error correction specification separately controls for short run investment dynamics and the adjustment of the capital stock towards a long run optimum. This could be important for differentiating short run effects of uncertainty, possibly resulting from real options, from those that may impact long run investment dynamics.

The error correction specification is derived from a firm's static factor demand model for capital characterized by the following optimization problem:

$$V_t(K_{t-1}) = (max_{I_t,L_t}\Pi(K_t, L_t, I_t) + \beta_{t+1}E_t[V_{t+1}(K_t)]) \tag{1.1}$$

Where V_t is the maximized value of the firm in period t, $\Pi_t(.)$ is the firm's net revenue function in period t, K_t is the firm's capital input, L_t is the firm's labour input, I_t is gross investment in capital, $\beta_{t+1} = \frac{1}{1+\rho_{t+1}}$ is the firm's discount factor where ρ_{t+1} is the risk-free rate of interest between period t and period $t+1$ and $E_t[.]$ denotes the expected value conditional on information available in period t. The equation of motion for the capital stock is defined as

$$K_t = (1-\delta)K_{t-1} + I_t \tag{1.2}$$

where δ denotes the rate of depreciation for capital, which is assumed to be exogenous and fixed. In the absence of any adjustment costs the net revenue function takes the form[9]

$$\Pi_t(K_t, L_t, I_t) = p_t F(K_t, L_t) - p_t^K I_t - w_t L_t \tag{1.3}$$

where $F(K_t, L_t)$ is the production function, p_t the price of the firm's output, p_t^K the price of capital and w_t the wage rate of labour.

The solution to the optimization problem (1.1) subject to the constraint (1.2), can be characterized by the first order conditions

$$-\left(\frac{\partial \Pi_t}{\partial I_t}\right) = \lambda_t \tag{1.4}$$

$$\lambda_t = \left(\frac{\partial \Pi_t}{\partial K_t}\right) + (1-\delta)\beta_{t+1} E_t[\lambda_{t+1}] \tag{1.5}$$

$$\left(\frac{\partial \Pi_t}{\partial L_t}\right) = 0 \tag{1.6}$$

Where $\lambda_t = \frac{1}{1-\delta}\left(\frac{\partial V_t}{\partial K_{t-1}}\right)$ is the shadow value of inheriting one additional unit of capital in period t. Equation (1.4) implies that the cost of acquiring additional units of capital in period t will be equated with their shadow values. Equation (1.5) describes the evolution of the shadow value of capital along the optimal path of the capital stock, and equation (1.6) is the standard first-order condition for labour, equating its cost with its marginal revenue product.

Substituting $\left(\frac{\partial \Pi_t}{\partial I_t}\right) = -p_t^K$ into Equation (1.4) and combining the result with Equation (1.5) yields,

$$\left(\frac{\partial \Pi_t}{\partial K_t}\right) = \left(1 - (1-\delta)\beta_{t+1}\frac{E_t[p_{t+1}^K]}{p_t^K}\right) p_t^K \tag{1.7}$$

[9] Where p_t and p_t^K represent real prices

which implies that the marginal revenue product of capital will be equated with the Jorgensonian user cost of capital.

Assuming that the firm has a CES production function with elasticity of substitution σ and elasticity of scale υ, and faces a downward sloping iso-elastic demand curve given below by Equations (1.8) and (1.9), its gross -real- revenue function will be given by Equation (1.10).

$$F(L_t, K_t) = Q_t = A_t \left[a_L L_t^{\frac{\sigma-1}{\sigma}} + a_K K_t^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}\upsilon} \tag{1.8}$$

$$p_t = B_t Q_t^{\frac{-1}{\eta}} \tag{1.9}$$

Where B_t is homogeneous in a nominal price index p_t^{nom} - growth in which represents price inflation - whereby gross nominal sales can be deflated to real sales.[10]

$$B_t = B_0 p_t^{nom}$$

$$R_t^{nom} = B_t Q_t^{1-\frac{1}{\eta}}$$

$$R_t = B_0 Q_t^{1-\frac{1}{\eta}} \tag{1.10}$$

Based on Equation (1.3) for the firm's net revenue Π_t and Equation (1.10), the partial derivative $\frac{\partial \Pi_t}{\partial K_t} = \frac{\partial R_t}{\partial K_t}$ can be substituted into the first order conditions in Equation (1.7) to solve for the optimal level of capital in the firm's static factor demand model.

$$\frac{\partial \Pi_t}{\partial K_t} = \frac{\partial R_t}{\partial K_t} = \left(1 - \frac{1}{\eta}\right) B_0 Q_t^{\frac{-1}{\eta}} \frac{\partial Q_t}{\partial K_t} \tag{1.11}$$

[10] In the data set this is done based on the UK GDP deflator, for more details refer to the Data Set Section and Data Appendix.

$$\frac{\partial Q_t}{\partial K_t} = \left(\frac{\sigma}{\sigma-1}v\right) A_t \left(a_L L_t^{\frac{\sigma-1}{\sigma}} + a_K K_t^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}v-1} \left(\frac{\sigma-1}{\sigma}\right) a_K K_t^{\frac{\sigma-1}{\sigma}-1} \tag{1.12}$$

$$\frac{\partial Q_t}{\partial K_t} = v\left(\frac{A_t}{Q_t}\right)^{\frac{\sigma-1}{\sigma v}} Q_t a_K K_t^{\frac{\sigma-1}{\sigma}-1} \tag{1.13}$$

$$\frac{\partial Q_t}{\partial K_t} = v A_t^{\frac{\sigma-1}{\sigma v}} Q_t^{1-\frac{\sigma-1}{\sigma v}} a_K K_t^{\frac{\sigma-1}{\sigma}-1} \tag{1.14}$$

Before substituting the expression for $\frac{\partial Q_t}{\partial K_t}$ into Equation (1.11), it is re-arranged to be a function of R_t and not Q_t based on the relationship $Q_t = \left(\frac{R_t}{B_0}\right)^{\frac{\eta}{\eta-1}}$ implied by Equation (1.10) for revenue. This is done so that we will eventually arrive at an expression for optimal desired capital stock as a function of gross revenue or sales which is more easily observed than output.

$$\frac{\partial Q_t}{\partial K_t} = v A_t^{\frac{\sigma-1}{\sigma v}} \left(\frac{R_t}{B_0}\right)^{\frac{\eta}{\eta-1}\left(1-\frac{\sigma-1}{\sigma v}\right)} a_K K_t^{\frac{\sigma-1}{\sigma}-1} \tag{1.15}$$

Substituting Equation (1.15) into Equation (1.11) yields

$$\frac{\partial R_t}{\partial K_t} = \left(1-\frac{1}{\eta}\right) B v A_t^{\frac{\sigma-1}{\sigma}v} \left(\frac{R_t}{B_0}\right)^{\frac{\eta}{\eta-1}\left(1-\frac{\sigma-1}{\sigma v}\right)-\frac{1}{\eta-1}} a_K K_t^{\frac{\sigma-1}{\sigma}-1} \tag{1.16}$$

Substituting Equation (1.16) for $\frac{\partial \Pi_t}{\partial K_t}$ in the first order conditions in Equation (1.7) yields the following equation for the optimal level of the capital stock,

$$K_t^* = a_K^{\sigma} \left(\frac{R_t}{B_0}\right)^{\frac{\sigma\eta}{\eta-1}\left(1-\frac{\sigma-1}{\sigma v}\right)-\frac{\sigma}{\eta-1}} A_t^{\frac{\sigma-1}{v}} \left(B_0 v \frac{\eta-1}{\eta}\right)^{\sigma} C_t^{-\sigma} \tag{1.17}$$

Where C_t denotes the user cost of capital. Taking the natural logarithm of both sides yields

$$k_t^* = \sigma ln\left(a_K v B_0 \frac{\eta-1}{\eta}\right) + \theta y_t + \frac{\sigma-1}{v} a_t - \sigma c_t \tag{1.18}$$

where lower case letters denote natural logarithms, $ln(R_t)$ has been substituted with y_t and $\theta = \left(\frac{\sigma\eta}{\eta-1}\left(1-\frac{\sigma-1}{\sigma v}\right) - \frac{\sigma}{\eta-1}\right)$. The special case of a Cobb Douglas production function with constant returns to scale and elasticity of substitution of unity is implied by the parameter values $\sigma = 1$ and $v = 1$, and will reduce Equation (1.18) to

$$k_t^* = a + y_t - c_t \tag{1.19}$$

where $a_t = ln\left(a_K B_0 \frac{\eta-1}{\eta}\right)$ [11].

Equation (1.18) specifies a relationship between optimal capital stocks and sales for a firm with a CES production technology, but with no adjustment costs to changing the capital stock. In order to develop Equation (1.18) into an econometric specification that can be estimated with empirical data, it is necessary to assume a stationary difference between the natural logarithms of frictionless optimal capital stock ($k_{i,t}^* = log(K_{i,t}^*)$) and the natural logarithm of the optimal capital stock of a firm facing adjustment costs ($k_{i,t} = log(K_{i,t})$).

Assumption 1. *$k_{i,t} = k_{i,t}^* + \epsilon_{i,t}$ where $\varepsilon_{i,t}$ is a stationary series*

Similar assumptions have been made for error correction specifications in previous empirical research: Mairesse, Hall and Mulkay (1999), Caballero, Engel and Haltiwanger (1995), Bloom, Bond and VanReenen (2007) and Bond, Elston, Mairesse and Mulkay (2001). Theoretical results from Bloom (2000) have shown that for a firm facing partial irreversibility in the form of asymmetries between the purchase and sale price of capital, the growth rate of a firm's capital stock is the same as if it were hypothetically investing in a frictionless capital stock. This implies that if firms in the data sets faced only partial irreversibilities to changing their capital stocks, Assumption 1 should hold. Bloom, Bond and VanReenen (2007) show that in a simulated panel of firms, each made up of multiple individual production units, facing stochastic iso-elastic demand functions and a combination of fixed, partial and quadratic adjustment costs, the natural logarithm of firm level capital behaved as though it were co-integrated with the natural logarithm of sales; which in the case of their investment model implied that the growth rates of the capital stocks of these simulated firms were approximately equal to the growth rates of hypothetical, frictionless, desired capital stocks.[12]

Applying assumption 1 to Equation (1.18) results in a long run relationship between log capital

[11] In the case that the firm has constant returns to scale and faces perfect competition, there is no solution for the optimal frictionless capital stock, and this possibility has to be ruled out

[12] Consistent with this finding, Chapter 2 reports results obtained from simulated data sets generated by the Bloom, Bond and VanReenen (2007) program for multiple capital adjustment cost specifications, which support co-integrated behaviour between $k_{i,t}$ and $y_{i,t}$.

and log sales that forms the basis of the error correction model estimated with the firm level data. If $k_{i,t}$ and $y_{i,t}$ are non-stationary $I(1)$ series, and c_t is $I(0)$, and Equation (1.18) and Assumption 1 hold in the data, then the two series $k_{i,t}$ and $y_{i,t}$ should be co-integrated by the vector $\Theta' = [1, -\theta]$. It is also assumed that variation, across firms and over time, in the user cost of capital and remaining production and demand function parameters in Equation (1.18), can be controlled for by firm and time specific dummies.[13]

$$k_{it} = \theta y_{it} + a_i + b_t + \varepsilon_{i,t} \tag{1.20}$$

To control for potential serial correlation in the residuals of Equation (1.20) and to capture additional short run dynamics, lagged $k_{i,t}$ and $y_{i,t}$ terms are added to the regression specification.[14] Adding first and second lags of log capital and log sales to equation (1.20) yields the following autoregressive distributed lag specification with second order dynamics [ADL(2,2][15]

$$k_{it} = \beta_1 k_{i,t-1} + \beta_2 k_{i,t-2} + \alpha_0 y_{it} + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-2} + \hat{b}_t + \hat{a}_i + \epsilon_{it} \tag{1.21}$$

By simply adding and subtracting terms in log capital and log sales from both sides of Equation (1.21) it can be re-written in the following form.

$$\begin{aligned} \Delta k_{it} = \Big(\alpha_0 + \alpha_1 + \alpha_2 - (\theta)(1 - \beta_1 - \beta_2)\Big) y_{i,t-1} - \beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} \\ + \alpha_0 \Delta y_{i,t} - \big(1 - \beta_1 - \beta_2\big)\big(k_{i,t-1} - \theta y_{i,t-1}\big) + \hat{b}_t + \hat{a}_i + \epsilon_{i,t} \end{aligned} \tag{1.22}$$

Equation (1.22) is an error correction specification with an additional term in $y_{i,t-1}$. The restriction $\frac{\alpha_0+\alpha_1+\alpha_2}{1-\beta_1-\beta_2} = \theta$ (which implies the coefficient on $y_{i,t-1}$ is zero) can be imposed on the coefficients of the ADL[2,2] model in Equation (1.21), resulting in an error correction model of the type given below in Equation (1.25). When the ADL[2,2] model is re-arranged to the

[13]Similar assumptions were made in Mairesse, Hall and Mulkay (1999) and Bond, Elston, Mairesse and Mulkay (2001)

[14]The same assumption was made in Bond, Elston, Mairesse and Mulkay (2001) and dates far back in the investment literature to Bean (1981), and can also be motivated by the representation theorem of Engle Granger (1987) when parameterizing the equilibrium condition in an error correction specification.

[15]Where $\hat{a}_i$ and $\hat{b}_t$ are given by $a_i - \sum_{j=1}^{2} \rho_j a_i$ and $b_t - \sum_{j=1}^{2} \rho_j b_{t-j}$ under the assumption that $\varepsilon_{i,t} = \epsilon_{i,t} + \sum_{j=1}^{2} \rho_i \varepsilon_{i,t-j}$.

form of Equation (1.23) this restriction implies an equilibrium for constant $k_{i,t}$ and $y_{i,t}$ which is consistent with Equation (1.20) above.

$$k_{i,t} - \beta_1 k_{i,t-1} - \beta_2 k_{i,t-2} = \alpha_0 y_{i,t} + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-2} + \hat{a}_i + \hat{b}_t + \epsilon_{i,t} \tag{1.23}$$

$$(1 - \beta_1 - \beta_2)\, k = (\alpha_0 + \alpha_1 + \alpha_2)\, y + \hat{a}_i + \hat{b}_t + \epsilon_{i,t} \tag{1.24}$$

$$\Delta k_{i,t} = -\beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} + \alpha_0 \Delta y_{i,t} - (1 - \beta_1 - \beta_2)\,(k_{i,t-1} - \theta y_{i,t-1}) + \hat{b}_t + \hat{a}_i + \epsilon_{i,t} \tag{1.25}$$

When estimating Equation (1.22) a t-test of the coefficient on $y_{i,t-1}$ conveniently tests the null hypothesis $\frac{\alpha_0+\alpha_1+\alpha_2}{1-\beta_1-\beta_2} = \theta$. The failure to reject this null, together with evidence of co-integration between the individual time series $k_{i,t}$ and $y_{i,t}$, supports this error correction specification between the natural logarithms of sales and capital of firms in the panel data set. In the UK data set estimates of Equation (1.22) presented in Section 6 did not reject the hypothesis that $\frac{\alpha_0+\alpha_1+\alpha_2}{1-\beta_1-\beta_2} = \theta = 1$ based on t-tests of the coefficient estimated on $y_{i,t-1}$. This is consistent with Cobb Douglas Production functions with constant returns to scale, and an equation for optimal desired frictionless capital stocks given by Equation (1.19) as opposed to Equation (1.18).

1.3.2 Modified Q-Model

Investment specifications based on the Hayashi (1982) result, relate the investment rate to the expected value of additional units of capital through their shadow value. Relative to the error correction specification, which contains only backward looking measures, the shadow value of capital is a completely forward looking statistic for investment. The result of Hayashi (1982) is that under linear homogeneity of a firm's profit function, marginal q_t (defined as the ratio of the shadow value of an additional unit of capital λ_t to its replacement cost p_t^I) is equal to average q.

$$q_t \equiv \frac{\lambda_t}{p_t^I} = \frac{V_t}{p_t^I(1-\delta)K_{t-1}} \tag{1.26}$$

Here V_t is the expected discounted value of the profit maximizing firm, δ is the depreciation rate of capital and K_{t-1} is the previous period's capital stock. If the firm is assumed to operate in a perfectly competitive environment, with a profit function of the form of Equation (1.27) and costs to adjusting the capital stock given by Equation (1.28), the first order condition for optimal investment can be expressed in the form of Equation (1.29).

$$\Pi(K_t, I_t, \epsilon_t) = p_t F(K_t) - p_t^I [I_t + G(I_t, K_t, \epsilon_t)] \tag{1.27}$$

$$G(I_t, K_t, \epsilon_t) = \frac{b}{2}\left[\left(\frac{I_t}{K_t}\right) - a - \epsilon_t\right]^2 K_t \tag{1.28}$$

$$\frac{I_t}{K_t} = a + \frac{1}{b} Q_t + \epsilon_t \tag{1.29}$$

Here $Q_t \equiv (q_t - 1)$, $F(K_t)$ is output, I_t is investment, p_t is the price of output and ϵ_t is a stochastic shock to the adjustment cost function.

Relative to the error correction specification this Q-model of investment does not require a specific functional form of the production function. However, the Q-model does require constant returns to scale and perfect competition for linear homogeneity of the profit function, together with the quadratic adjustment costs to arrive at the linear relationship between the investment rate and average q described by Equation (1.29).

When the Hayashi (1982) assumptions hold Q_t is a sufficient statistic for the investment rate, and all effects of uncertainty should affect investment through Q_t. Moreover, the assumptions of perfect competition, constant returns to scale and strictly convex adjustment costs eliminate real options from investment decisions. Thus, only Hartman-Abel type effects should be acting on investment (through Q_t) when these assumptions are valid, and any coefficients estimated on uncertainty terms added to Equation (1.29) should be insignificant [16].

When the Hayashi (1982) assumptions do not hold, or stock market data used to construct average q_t ($V_{i,t}$ in Equation (1.26)) is influenced by non-"fundamental" factors[17], $Q_{i,t}$ in Equa-

[16] Leahy and Whited (1996) found that regressing investment rates on uncertainty terms resulted in significant negative coefficients which became insignificant once they controlled for average q

[17] Unrelated to the expected discounted value of future profits

tion (1.29) will not capture all relevant information about the expected future profitability of investment. In such cases additional variables can add explanatory power to the basic Q-model for the investment rate.[18] If the structure of the original Q model is maintained, the additional variables control for information about the expected future profitability of capital. In the specification estimated in this chapter (and throughout the thesis) the lagged variable ($\frac{I_{i,t-1}}{K_{i,t-1}}$) is added to the "basic" average q specification, to mitigate serial correlation in the residuals, and a sales growth term is added to try to separately control for short run investment responses to changes in demand. Adding an additional term in lagged sales growth creates a correspondence with the structure of the error correction specification.

$$\frac{I_{i,t}}{K_{i,t}} = \lambda_1 Q_{i,t} + \lambda_2 \frac{I_{i,t-1}}{K_{i,t-1}} + \lambda_3 \Delta y_{i,t-1} + \lambda_4 \Delta y_{i,t} + a_i + b_t + \epsilon_{i,t} \tag{1.30}$$

Although the basic Q-theory specification in Equation (1.29) is based on a relationship between investment and the expected future profitability of capital, the modified Q-theory specification in Equation (1.30) can also be roughly interpreted as a type of non-linear error correction specification. Comparing $Q_{i,t} = \frac{V_t}{p_t^I(1-\delta)K_{t-1}} - 1$ to an error correction term, it could be controlling for an adjustment of the capital stock towards an equilibrium ratio of firm value to capital stock. If the firms in a data set were making some long run adjustment towards an optimal capital stock that was proportional to the value of the firm, the $Q_{i,t}$ term in Equation (1.30) could be capturing aspects of these investment dynamics. Further to this point the $Q_{i,t}$ term in the average q specification is a forward looking measure based on discounted present value of the firm, whereas the error correction term represents a backward looking measure meant to capture convergence towards equilibrium desired capital stocks.

[18] See Bond and Cummins (2004) and Bulan (2005) in which significant coefficients are estimated on additional explanatory variables in Average Q specifications.

1.3.3 Uncertainty Terms

The effects of uncertainty on investment will be investigated by adding both linear terms in an uncertainty proxy ($\Delta\sigma_{i,t}$, $\sigma_{i,t-1}$) and a term which interacts the uncertainty proxy with sales growth ($\sigma_{i,t} * \Delta y_{i,t}$) to each of the investment specifications. Equation (1.31) below includes these terms in the error correction specification from Equation (1.26)

$$\Delta k_{i,t} = -\beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} + \alpha_0 \Delta y_{i,t} + \gamma_0 \sigma_{i,t} * \Delta y_{i,t} + \gamma_1 \Delta\sigma_{i,t} + \gamma_2 \sigma_{i,t-1} \tag{1.31}$$

$$+ (1 - \beta_1 - \beta_2)(k_{i,t-1} - \theta y_{i,t-1}) + \hat{b}_t + \hat{a}_i + \epsilon_{i,t}$$

The coefficient γ_0 estimated on the interaction term $\sigma_{i,t} * \Delta y_{i,t}$ allows for the uncertainty proxy to influence the investment response to changes in demand. A significant negative estimated coefficient on this interaction term would be consistent with the predictions of theoretical investment models with real options: at higher levels of uncertainty, firm level investment is less responsive to shocks in demand; reflecting the wider zone of inaction between boundaries of the optimal trigger policy of firm investment described in Abel and Eberly (1996). If changes in sales are resulting in smaller changes in capital stock at higher levels of uncertainty, it implies firms are substituting away from capital to more flexible factors of production, in response to demand shocks at greater levels of uncertainty.

The term $\sigma_{i,t-1}$ allows the error correction term and the long run optimal capital stock to vary with uncertainty. Equation (1.20) can be re-written as below, which allows the long run capital stock to vary with uncertainty. Co-integrating relationships between $k_{i,t}$ and $y_{i,t}$ are not compromised by the inclusion of $\sigma_{i,t}$ in the expression derived for the long run desired capital stock - provided that $\sigma_{i,t}$ is stationary.

$$k_{i,t} = \theta y_{i,t} + \zeta \sigma_{i,t} + a_i + b_t + \epsilon_{i,t}$$

Allowing the long run desired capital stock to vary with uncertainty as in the expression above, results in the uncertainty appended error correction term in which $(1-\beta_0-\beta_1)\zeta \equiv \gamma_2$ in Equation (1.31).

$$(1-\beta_1-\beta_2)(k_{i,t-1}-\theta y_{i,t-1})+(1-\beta_0-\beta_1)\zeta\sigma_{i,t-1}$$

A significant positive (or negative) coefficient estimated on $\sigma_{i,t-1}$ could indicate the relative importance of *hangover* and *user cost* effects on capital accumulation, relative to the frictionless optimum $k^*_{i,t} = a + y_{i,t} - c_t$ given in equation (1.19)[19]. The coefficient estimated on the term $\Delta\sigma_{i,t}$ allows for additional short run effects of uncertainty on the investment rate ($\Delta k_{i,t}$) not captured by the coefficient estimated on the uncertainty interaction term.

The modified Q-model, appended with the uncertainty terms is shown below.

$$\frac{I_{i,t}}{K_{i,t}} = \lambda_1 Q_{i,t} + \lambda_2 \frac{I_{i,t-1}}{K_{i,t-1}} + \lambda_3 \Delta y_{i,t-1} + \lambda_4 \Delta y_{i,t} + \gamma_0 \sigma_{i,t} * \Delta y_{i,t} + \gamma_1 \Delta\sigma_{i,t} + \gamma_2 \sigma_{i,t-1} + a_i + b_t + \epsilon_{i,t} \tag{1.32}$$

It is important to note that the nature of the modified Q model can blur the interpretation of coefficients estimated on the uncertainty terms. When Hayashi's (1982) assumptions are valid all effects of uncertainty impact investment indirectly through changes in $Q_{i,t}$. Theoretically, as the assumptions are relaxed or measurement error is introduced into $V_{i,t}$, it is difficult to determine how much of the uncertainty effects continue to operate through $Q_{i,t}$, and to what extent additional uncertainty terms can independently control for them. Abel et al (1996) show that marginal q reflects changes in real options values and uncertainty. The results of Chapter 2, obtained with simulated data, demonstrate that using data in which firms hold real option values to investment decisions, lower investment responses to changes in demand can be captured appropriately by coefficients on uncertainty sales growth interaction terms. However, it is conceivable that changes in marginal q resulting from greater real option values at higher levels of uncertainty, could be controlled for by average q.[20]

[19] In the case of the Cobb Douglas production function

[20] Results with the simulated data provided no indication that changes in real option values and lower investment responses to demand growth at higher levels of uncertainty were being captured by average q terms, given the specific parameterization of the underlying investment model.

1.4 Data Set

The data set used in this chapter is based on panel data used in Bond et al. (2004), which merged data from the DATASTREAM and I/B/E/S databases in an investigation into the role of cash flow, Tobin's Q and expected profitability in estimates of firm level investment specifications. Data on securities analysts' earnings forecasts for 703 publicly traded UK companies between 1987 and 2000 was provided by I/B/E/S International, which was matched with stock market valuations and company accounts data on investment, sales and other financial variables obtained from DATASTREAM International. The resulting data set of Bond et al. (2004) covered 703 UK listed firms between 1987 and 2000, which were represented in both the I/B/E/S and DATASTREAM data. Beginning with the Bond et al. (2004) data set four proxies of firm level uncertainty were constructed using stock return data and forecasts of earnings per share from the I/B/E/S data; observations in the top and bottom percentiles of these uncertainty measures were removed from the Bond et al. (2004) data set, resulting in a subset of 655 firms, for which there were at least 4 consecutive firm year observations. The 655 firms provide 4,908 firm year observations with which to estimate error correction and average q investment specifications.[21] The average time dimension available for estimating the specifications is 5.49 years - taking into account firm year observations lost to lagged variables in the specifications.[22] [23]

Among other variables, the data set in Bond et al. (2004) contains time series of average q, capital stocks[24], investment, and real sales for each firm, which are used to estimate the average q and error correction specifications in this Thesis. Both sales and investment are expressed in constant prices (real terms), with nominal sales reported in DATASTREAM adjusted by the GDP deflator, and investment having been deflated by the quarterly business investment deflator implied by the UK National Accounts. [25] The stock return volatility based proxy for uncertainty used in the current chapter ($\sigma_{i,t}$) is calculated as the standard deviation of daily

[21] Sectoral coverage of firms included in the sample is presented in Table D1 of the data appendix

[22] The average time dimension for the sample itself if 7.49 years, as the average q and error correction specification include second order lagged variables.

[23] The author would like to thank Steve Bond (Nuffield College Oxford), Richhild Moessner (The Bank of England), Haroon Mumtaz (The Bank of England) and Murtaza Syed (The International Monetary Fund) for their work in calculating uncertainty proxies based on I/B/E/S earnings per share forecasts in the Bond et al. (2004) data set.

[24] Calculated according to a standard perpetual inventory method, see the data appendix for more details

[25] Details on the variables used to calculated the investment and sales series, along with capital and average q can be found in the Data Appendix

percentage changes in stock prices over a 365 calendar day period ending on the date of the accounting period observation from DATASTREAM. For more details on the construction of the latter variables please refer to the data set appendix at the end of this chapter.

Table 1 below presents some summary statistics for the variables used to estimate the average q and error correction specifications in the current Chapter. The means of the first difference of the natural logarithm of capital $\Delta k_{i,t}$ and the ratio of investment to the capital stock $(\frac{I_{i,t}}{K_{i,t}})$[26] are very similar relative to their standard deviations. The mean growth of the capital stock $(\Delta k_{i,t})$ is larger than the mean growth of sales $(\Delta y_{i,t})$, which is consistent with decreasing returns to scale in the marginal revenue product of capital. Both mean values of the error correction term $(k_{i,t} - y_{i,t})$ and the average q term $(Q_{i,t})$ are consistent with adjustment towards larger optimal capital stocks within the contexts of the average q and error correction investment specifications.

[TABLE 1 HERE]

Table 2 below presents summary statistics for similar variables from the data set used in Bloom, Bond and Van Reenen (2007), which estimates similar error correction investment specifications over a much longer, but older, panel data set covering 672 publicly traded firms from the DATASTREAM data base between the periods of 1972 to 1991. In the Bloom Bond and Van Reenen data set, sales is reported in constant (real) prices, whereas investment and capital are reported in current prices. Aside from the time period and pricing, the key difference between the data set in the current chapter and the Bloom, Bond and Van Reenen (2007) data set, is the selection of firms covered by the I/B/E/S data base. On average, one would expect firms covered by securities analysts in the I/B/E/S data base to be larger publicly traded companies than those in the Bloom, Bond and Van Reenen (2007) data base. However, the common variables between Tables 1 and 2 all have very similar mean values, within roughly half a standard deviation from each other. As in the case of the smaller and more recent data set used in the current chapter the mean value of $\Delta k_{i,t}$ is larger than that of $\Delta y_{i,t}$. What is most striking is the similarities between the uncertainty proxies $\sigma_{i,t}$ in these two data sets[27];

[26] The two measures of investment in the error correction and average q specifications respectively.

[27] The uncertainty proxy calculated in Bloom, Bond and Van Reenen (2007) is calculated in the same way using daily DATASTREAM firm stock return data.

both the mean and standard deviation of $\sigma_{i,t}$ is almost unchanged between Tables 1 and 2.

[TABLE 2 HERE]

1.5 Estimation

The estimation results presented throughout this chapter (and in the remainder of the thesis) are obtained using a System Generalized Method of Moments (GMM) procedure developed by Arellano and Bover (1995) and Blundell and Bond (1998).[28] GMM formulates a set of orthogonality restrictions or moment conditions for specific econometric models and finds parameter estimates that come as close as possible to achieving those orthogonality properties in the sample. For example:

$$y_i = f(x_i, \beta) + u_i \qquad i = 1, ..., N \qquad \beta \quad is \quad Kx1$$

$$g(x_i) = z_i \qquad s.t. \quad E(z_i' u_i) = 0 \qquad z_i \quad is \quad Lx1$$

The econometric model specifies L (population) orthogonality restrictions $E(z_i' u_i) = 0$

$$b_n(\beta) = \frac{1}{N} \sum_{i=1}^{N} z_i' u_i = \frac{1}{N} \sum_{i=1}^{N} z_i' [y_i - f(x_i, \beta)]$$

GMM estimators choose $\hat{\beta}_{GMM}$ to minimize the distance between $b_n(\hat{\beta}_{GMM})$ and zero.

Relative to the basic First Differenced GMM estimator (see Arellano and Bond (1991)), which uses lagged levels of endogenous variables in moment conditions of equations in first differences, the System GMM estimator exploits additional linear moment conditions between equations in levels and lagged first differences of endogenous explanatory variables. The key requirement of System GMM estimators is that unobserved individual specific effects be uncorrelated with the instruments used in the levels equations. In the case of equations in first differences, individual specific effects are eliminated by the difference transformation. The validity of the instrument sets for equations in levels and in differences is evaluated using Sargan/Hansen tests of over-identifying restrictions. The validity of several alternative sets of instrumental variables and lag lengths is evaluated using Differenced Sargan/Hansen tests in the Instrument Appendix. The advantage of using System GMM estimates over more basic First Differenced GMM estimates is that the former should have greater efficiency and smaller finite sample bias

[28]The System GMM estimator is implemented using Stata 10 through the xtabond2 command for panel data with a two step covariance matrix and Windmeijer (2005) robust standard errors.

than the latter, as a result of exploiting additional, valid, linear moment conditions[29].

When using small T large N panel data sets to estimate equations which contain unobserved individual specific effects, GMM estimators provide more accurate results compared to OLS or Within Groups estimators which become inconsistent when individual specific effects are correlated with explanatory variables. This point can be clearly illustrated with the example of a simple AR[1] model with unobserved individual specific effects:

$$y_{i,t} = \alpha y_{i,t-1} + (\eta_i + \nu_{i,t}) \qquad |\alpha| < 1 \qquad t = 2, ..., T$$

In the case that $E[y_{i,t-1}\nu_{i,t}] = 0$ then $plim\hat{\alpha}_{OLS} > \alpha$ as a result of positive correlation between $y_{i,t-1}$ and η_i. In the case of within groups estimators obtained by using OLS on transformed variables:

$$\tilde{y}_{i,t} = y_{i,t} - \frac{1}{T-1}(y_{i,2} + ... + y_{i,T})$$
$$\tilde{y}_{i,t-1} = y_{i,t-1} - \frac{1}{T-1}(y_{i,1} + ... + y_{i,T-1})$$
$$\tilde{\nu}_{i,t} = \nu_{i,t} - \frac{1}{T-1}(\nu_{i,2} + ... + \nu i, t)$$

$\tilde{y}_{i,t-1}$ and $\tilde{\nu}_{i,t}$ are correlated even though the transformation eliminates the presence of individual specific effects. With regards to the Within Groups transformed variables, all correlations of order $\frac{1}{T-1}$ are negative: $corr(y_{i,t-1}, \frac{-1}{T-1}\nu_{i,t-1})$ and $corr(\nu_{i,t}, \frac{-1}{T-1}y_{i,t})$. This suggests that $E[\tilde{y}_{i,t-1}\tilde{\nu}_{i,t}] =< 0$ and is of order $\frac{1}{T-1}$ (i.e. $E[\tilde{y}_{i,t-1}\tilde{\nu}_{i,t}] \to 0$ as $(T-1) \to \infty$.[30] Thus $plim_{N\to\infty}\hat{\alpha}_{WG} < \alpha$ for fixed T, and the Within estimator is inconsistent as the cross-section dimension of the panel becomes large. However, the Within estimator is consistent as the time dimension of the panel becomes large.

In the case of the error correction and average q investment specifications estimated using firm level panel data, firm specific effects would undoubtedly be present across heterogeneous firms in the sample. Such firm specific effects would be correlated with lagged dependent vari-

[29]See Blundell and Bond (1998)
[30]For more details see Nickell (1981)

ables, average q and sales growth terms in the investment specifications. Thus we would expect OLS and Within Groups estimates of the investment specifications to have respective upward and downward biases in the presence of unobserved firm specific effects. Blundell and Bond (1998) show using Monte-Carlo simulations that in the case of simple autoregressive models with unobserved firm specific effects, OLS estimates are biased above the true parameter estimates and Within Groups estimators have a negative downward bias. Furthermore they show that First Differenced GMM estimates have a downward bias and lie above Within Groups estimates. System GMM provided the most accurate estimates lying between those produced by First Differenced GMM and OLS. Blundell and Bond (1998) show that within small samples, weak instruments cause large finite sample biases when using first Differenced GMM to estimate autoregressive models for moderately persistent series; the authors show that these finite sample biases can be dramatically reduced by the additional linear moment conditions of the system GMM estimation procedure. In Section 6 System GMM parameter estimates of the error correction specification are shown to lie between OLS and First Differenced GMM estimates; the latter being higher than Within Groups estimates.

For each set of GMM results presented in this chapter and throughout the remainder of the thesis Arellano-Bond tests for autocorrelation are reported for the differenced residuals of the specifications. The Arellano-Bond test statistics are reported for up to 4th order serial correlation in the differenced residuals. Under the null hypothesis of no serial correlation in the first differenced residuals the test statistics should follow a standard normal distribution. It is expected to find evidence of first order autocorrelation in the differenced residuals due to the presence of $\epsilon_{i,t-1}$ terms in both $\Delta\epsilon_{i,t}$ and $\Delta\epsilon_{i,t-1}$. Therefore to test the null hypothesis of no first-order serial correlation in $\epsilon_{i,t}$ in levels, the null hypothesis of no second-order serial correlation in differences should be tested, to investigate correlation between $\epsilon_{i,t-1}$ in $\Delta\epsilon_{i,t}$ and $\epsilon_{i,t-2}$ in $\Delta\epsilon_{i,t-2}$. Rejection of the hypothesis of no n^{th} order autocorrelation in differenced residuals implies that lag n of endogenous variables are invalid as instruments for equations in first differences, and lag $n-1$ of first differenced endogenous variables are invalid instruments for equations in levels.

For each set of GMM estimation results the p-value of the Sargan-Hansen (or Hansen J) test of over-identifying restrictions is reported. The Sargan-Hansen test statistic is the minimized value of the two-step GMM criterion function[31]. Under the null hypothesis that the moment conditions are valid, the test statistic should follow a χ^2 distribution with degrees of freedom equal to the number of instruments less the number of explanatory variables.

[31] As implemented in the xtabond2 command in STATA 10

1.6 Empirical Results

This section presents results from estimating the specifications based on average q and the error correction models appended with uncertainty terms. The results are obtained using System GMM[32]. Significant negative coefficients were estimated on the interaction term $\sigma_{i,t} * \Delta y_{i,t}$ in both the error correction and average q specifications. However, the magnitude and significance of coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ were consistently lower in estimates of the average q specification.[33] Estimating *hybrid* models which include the right hand side variables of both specifications suggest that including error correction terms in the specification may be important for estimating significant coefficients on uncertainty interaction terms. However, of the two controls for investment behaviour: $(k_{i,t-1} - y_{i,t})$ and $Q_{i,t}$, the latter is more informative when both terms are included in the hybrid investment specifications. It also appears that $Q_{i,t}$ controls for some linear effects of uncertainty that are captured by larger and more significant coefficients on $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ terms when $Q_{i,t}$ is excluded from estimates of the average q specification. Furthermore, estimates of the hybrid investment specifications imply that the measurement of investment has a significant effect on coefficients estimated on uncertainty sales growth interaction terms; whereby specifications in which investment is measured as $\Delta k_{i,t}$ tended to have larger and more significant coefficients on uncertainty interaction terms.

1.6.1 Time Series Properties of the Variables

Table 3 below shows OLS estimates of AR[1] models for the series of the natural logarithm of capital and sales ($k_{i,t}$ and $y_{i,t}$), their first differences, and the error correction term $(k_{i,t} - y_{i,t})$.[34] The data is found to support a co-integrating vector of $\Theta = [1, -1]$ between the natural logarithms of capital and sales, which is consistent with Cobb Douglas production technology.[35] The error correction specification assumes stationarity in the series $(k_{i,t} - \theta y_{i,t})$, which controls

[32]Implemented in STATA 10 using the command *xtabond2* with a two step covariance matrix and Windmeijer (2005) robust standard errors

[33]These results are broadly robust to adjustments of the uncertainty proxy for effects of financial leverage and for weekend effects, however using within year standard deviations in weekly as opposed to daily stock returns decreased the significance of coefficients on uncertainty sales growth interaction terms.

[34]Each regression included a full set of year dummies for the sample

[35]Results presented in Tables 6 and 7 demonstrate that this value of θ is indeed consistent with the restriction placed on the coefficients of the ADL[2,2] and ADL[1,1] models, which result in error correction specifications.

for convergence towards an equilibrium level of capital stock.

[Table 3 Here]

The autoregressive (AR[1]) coefficients estimated using the series $k_{i,t}$ and $y_{i,t}$ are highly persistent, and the time series of their first difference appears stationary.[36] Although, the AR[1] coefficient estimated on $(k_{i,t} - y_{i,t})$ is also indicative of a highly persistent series, it is significantly lower than the coefficients estimated with its individual components in columns 1 and 2. Table 4 below shows results from estimating AR[4] models for the series $k_{i,t}$, $y_{i,t}$ and $(k_{i,t} - y_{i,t})$ using OLS and a full set of year dummies.[37]

[Table 4 Here]

A Wald test of the joint insignificance of the coefficients estimated on the lagged differences of the dependent variable rejected the null for the series $k_{i,t}$ and $y_{i,t}$; the same test failed to reject the null hypothesis for the series $(k_{i,t} - y_{i,t})$. The sum of the AR coefficients in the first two columns of Table 4 are slightly closer to 1 than in the case of the simpler AR[1] models in Table 3. The most important feature of the results presented in Table 4 is that taking the difference between $k_{i,t}$ and $y_{i,t}$ decreases persistence of the series relative to its individual components. Evidence of stationarity in the series $(k_{i,t} - y_{i,t})$ in the two tables above support the use of the error correction specification to describe investment in this data set.

Table 5 below presents OLS estimates of AR[1] models (including full sets of year dummies) for the variables used to estimate the specification based on average q, and the uncertainty proxy. The hypotheses of unit roots can be rejected for all variables based on estimated AR coefficients and their standard errors.

[36] Bond Nuages and Windmeijer (2005) show that when testing for unit roots in simulated dynamic panel data sets with large N and short T dimensions, generated by a simple AR[1] process, a Wald test on an OLS estimate of the AR coefficient is consistent under the null and sufficiently powerful in rejecting the null hypothesis of a unit root when the null is false.

[37] Terms are arranged so that the coefficient estimated on the first lag of the dependent variable represents the sum of all autoregressive coefficients.

[Table 5 Here]

1.6.2 Error Correction Specification

Tables 6 and 7 below present various estimation results of re-arranged ADL[1,1] and ADL[2,2] models using Within Groups, First Differenced and System GMM[38], as well as OLS. Using panel data, Blundell and Bond (1998) show that in the case of AR[1] models these estimators will be biased in the presence of unobserved individual specific effects. Estimates obtained by System GMM should be the most accurate, with respective upward and downward biases on the OLS and First Differenced GMM estimates.[39]

[Table 6 Here]

[Table 7 Here]

In these specifications the coefficient on the error correction term represents the sum of the coefficients on the lags of log capital from the original ADL specifications less 1 ($\beta_0 + \beta_1 - 1$ in Equation (1.25)). It is in this coefficient that the biases of the different estimation methods are most clearly manifested. In both tables the coefficients estimated on the error correction terms with system GMM are between those obtained from OLS and First Differenced GMM, reflecting the relative biases of these estimators, as suggested by Blundell and Bond (1998) in the presence of unobserved individual specific effects.

In both tables the coefficient estimated on $y_{i,t-1}$ by System GMM is not significantly different from zero at the 5% significance level, supporting the restriction imposed on the coefficients of

[38] The First Differenced GMM estimates were obtained using 3rd and 4th lags of the dependent and independent variables as instruments for the equations in first differences; the System GMM estimates added a set of preferred instruments for equations in levels. The selection of the preferred instrument set is based on Differenced Sargan/Hansen tests between the First Differenced GMM estimates and System GMM estimates obtained with alternative instrument sets for equations in levels. This is discussed further in the instrument appendix

[39] Specifically OLS estimates of the coefficient on the lagged dependent variable were found to have a strong upward bias, GMM in first differences a downward bias somewhat less severe than on the Within Groups estimates, and with the least amount of bias in the System GMM estimates which were found to be above the estimates obtained by GMM in first differences and below those produced by OLS.

the ADL models that results in the error correction specification. The hypothesis that coefficients on $\Delta k_{i,t-1}$ and $\Delta y_{i,t-1}$ were jointly insignificant was not rejected by Wald tests when the ADL[2,2] specification was estimated by First Differenced GMM. However, the same test rejects the null hypothesis when the specification is estimated by System GMM.

Table 8 below presents the preferred System GMM estimation results of the restricted ADL[2,2] error correction specification, omitting $y_{i,t-1}$. The same preferred instrument set from Tables 6 and 7 above is used to obtain the results in Table 8. In addition to 3rd and 4th lags of the dependent and independent variables as instruments for equations in first differences, the preferred System GMM instrument set also contains first differences of variables as instruments for equations in levels. The preferred set of instruments for equations in levels is based on Differenced Sargan/Hansen tests between alternative instrument sets presented in the instrument appendix to this chapter.

The first column in Table 8 restricts coefficients of the ADL[2,2] model by imposing the coefficient on $y_{i,t-1}$ to be zero. The second column adds all of the uncertainty terms to the error correction specification. The insignificant coefficient estimated on $\sigma_{i,t-1}$ does not suggest any effect of higher uncertainty on the capital sales ratio in this specification of the error correction model. The coefficient estimated on $\Delta\sigma_{i,t}$ is only marginally significant, and a Wald test of the hypothesis that coefficients on $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ are jointly insignificant cannot be rejected based on a p-value of 0.14. The small and marginally significant coefficient estimated on $\Delta\sigma_{i,t}$ may capture some short run effects of uncertainty not controlled for by the coefficient estimated on the uncertainty interaction term. The significant negative coefficient estimated on the latter term is consistent with smaller investment responses to demand shocks at higher levels of uncertainty; a prediction of theoretical investment models with real options. Column 3 drops the uncertainty interaction term, resulting in a substantial increase in the magnitude and significance of the coefficient estimated on $\sigma_{i,t-1}$, and relatively no change to the coefficient estimated on $\Delta\sigma_{i,t}$ relative to Column 2. The coefficient estimated on $\sigma_{i,t-1}$ is consistent with a lower capital sales ratio at higher levels of uncertainty, however given the change in this coefficient between Columns 2 and 3, it is likely proxying for effects of uncertainty controlled for by $\sigma_{i,t} * \Delta y_{i,t}$ in Column 2. Column 4, drops the linear uncertainty terms and retains the uncertainty interaction term, the coefficient on which remains significant, negative and almost identical to the estimate in column 2.

[Table 8 Here]

Table 9 below reports System GMM estimates of a restricted ADL[1,1] error correction specification.[40] The results demonstrate that if the error correction specification was based on the less rich dynamic structure of the ADL[1,1] model the results would be broadly similar. Estimates of error correction specifications based on both ADL[1,1] and ADL[2,2] lag structures include significant negative coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ with strikingly similar magnitudes in these coefficients across the two specifications. Coefficients estimated on linear uncertainty terms are not as stable between these specifications. In Column 2 the coefficient on $\sigma_{i,t-1}$ becomes marginally significant, whereas the coefficient on $\Delta\sigma_{i,t}$ is insignificant. A Wald test does not reject the hypothesis that coefficients on $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ are jointly insignificant based on a p-value of 0.17. The same test rejects the null hypothesis based on a p-value of 0.02 for the set of results presented in Column 4.

[Table 9 Here]

1.6.3 Specification Based on Average Q

Table 10 below presents results from estimating the specification based on average q using System GMM. The preferred instrument set for these estimates uses the 3rd to 4th lags of the dependent and independent variables as instruments for equations in first differences, as well as first differences of the variables as instruments for equations in levels. The preferred instruments for equations in levels are chosen on the basis of Differenced Sargan/Hansen tests comparing System GMM estimation results obtained with alternative instrument sets to First Differenced

[40] The instrument set is held constant across the System GMM estimates in Tables 8 and 9.

GMM estimates[41].

Column 1 of Table 10 reports results from estimating the basic Q model which describes the ratio of investment to the capital stock ($\frac{I_{i,t}}{K_{i,t}}$) as a linear function of $Q_{i,t} = q_{i,t} - 1$.[42] Column 2 adds an additional term in $\Delta y_{i,t}$, on which a positive and significant coefficient is estimated. Column 3 adds the lagged dependent variable ($\frac{I_{i,t-1}}{K_{i,t-1}}$) and $\Delta y_{i,t-1}$ to the right hand side of the specification, on which coefficient estimates were jointly[43] and individually insignificant. The latter coefficients are retained in the average q specification for sake of comparability with the error correction specification; coefficient estimates on the remaining coefficients are robust to their exclusion. Column 4 adds all three uncertainty terms to the average q specification in Column 3. Coefficients estimated on linear uncertainty terms $\sigma_{i,t-1}$ and $\Delta\sigma_{i,t}$ are individually insignificant in Column 4, and the hypothesis that they are jointly insignificant is not rejected by a Wald test based on a p-value of 0.16.

The coefficient estimated on the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$ is negative and significant at the 10% level, however it is roughly half the magnitude of corresponding coefficients in estimates of the error correction specification, which were significant at the 5% confidence level[44]. Dropping the uncertainty sales growth interaction term in Column 6 causes the coefficient estimated on the linear uncertainty term $\sigma_{i,t-1}$ to become significant, suggesting that the latter term is capturing negative effects of uncertainty controlled for by $\sigma_{i,t} * \Delta y_{i,t}$ in Column 5. This is similar to the case of the error correction specification in Table 8. Column 7 drops the linear uncertainty terms from the specification in Column 5, resulting in almost no change to the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$.

[Table 10 Here]

[41] The selection of the instrument set is outlined in further detail in the appendix to this chapter

[42] In the case of column 1 there were no valid moment conditions available for equations in levels, and results obtained with First Differenced GMM are reported.

[43] A Wald test of the hypothesis that coefficients on $\frac{I_{i,t-1}}{K_{i,t-1}}$ and $\Delta y_{i,t-1}$ were jointly insignificant yielded a p-value of 0.69.

[44] In error correction specifications which excluded linear uncertainty terms the negative coefficient estimated on the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$ was significant at the 1% confidence level, in Table 8

1.6.4 Adjustment to Uncertainty Terms

This section tests the robustness of results presented in Tables 8 and 10 to several adjustments of the uncertainty proxy based on within year standard deviations in daily stock returns. The most important of these is a gearing adjustment to the uncertainty measures meant to correct for volatility in stock returns resulting from financial leverage. Christie (1982) offers a summary of literature emphasizing the positive relationship between stock return volatility and the financial leverage of a firm. To compensate for the presence of stock return volatility arising from financial leverage, and unrelated to uncertainty over future operating environments of the firm, the uncertainty proxy $\sigma_{i,t}$ is adjusted using a gearing ratio calculated as the ratio of Total Assets to the sum of Total Assets, Long Term Debt and Borrowings from the Firms' Annual accounts in the DATASTREAM data base[45]:[46] $\frac{TotalAssets}{TotalAssets+LTDebt+Borrowings} * \sigma_{i,t} = g_{i,t} * \sigma_{i,t}$ Previous empirical work on the investment uncertainty relationship has used similar gearing adjustment to stock return based proxies for uncertainty.[47]

The second adjusted uncertainty measure, $\sigma^{w}_{i,t}$, is based on an adjustment of the daily stock returns which takes into account any financially relevant events that take place over weekends - resulting in disproportionately larger returns between Friday and Monday. If the valuations of companies were consistently changing while markets were closed, due to significant events occurring over weekends, stock returns between Friday and Monday could be disproportionately higher than between other trading days as a result; leading to potentially higher values of within year standard deviations in daily stock returns. To correct for this possibility, weekend returns are divided into three and split between Saturday, Sunday and Monday after inserting observations for Saturday and Sunday into the returns data of each firm. This results in slightly smaller within year standard deviations in daily stock returns as a result of smoothing returns over weekends. The third adjusted uncertainty proxy, $w\sigma_{i,t}$ is calculated as the within year standard deviation in weekly stock returns, resulting in a comparable uncertainty proxy to $\sigma_{i,t}$

[45]Total Assets: item code ds392; Long Term Debt: item code 321; Borrowings: item code 309

[46]This gearing adjustment relies on book values of capital and book values of debt, and was preferred over alternative gearing ratios which use the market value of equity instead of a book value of assets. The latter alternative was not used due to concern over possible cross correlations between market valuations of equity and volatility in stock returns that may arise due to bubbles or trading fads. Another alternative gearing adjustment could have used both the market values of debt and equity; however, market values of debt were not available for all the firms in the sample.

[47]See Bloom, Bond and VanReenen (2007) and Bulan (2005)

that relies on lower frequency returns data. Table 11 below summarizes each of the adjusted uncertainty proxies alongside the original measure $\sigma_{i,t}$.

[Table 11 Here]

In Table 12 below, adjusting the uncertainty terms for effects of financial leverage in the error correction specification reduces the significance of the coefficient on the uncertainty sales growth interaction term. The coefficient estimated on $g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$ in Column 2 is very similar in magnitude to the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 1, however the latter coefficient is more significant. Interestingly, adjusting the uncertainty proxy for effects of financial leverage between Columns 1 and 2 of Table 12 causes the negative coefficient estimated on the lagged linear uncertainty term to become significant. This suggests that lower equilibrium capital-sales ratios at higher levels of uncertainty in the error correction specification are better described by using "un-levered" uncertainty measures. Column 3 of Table 12 excludes the linear uncertainty terms from Column 2, resulting in very little change to the coefficient estimated on the remaining uncertainty sales growth interaction term.

Column 4 of Table 12 presents estimates of the average q specification from Column 4 of Table 10. Column 5 of Table 12 presents estimates of the latter specification using the uncertainty measures adjusted for effects of financial leverage $g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$. The marginally significant coefficient on the uncertainty sales growth interaction term in Column 4 becomes insignificant as a result of the adjustment for effects of financial leverage; however the coefficient estimates are of similar magnitude. Adjusting the uncertainty term for effects of financial leverage between Columns 4 and 5 has little to no effect on coefficients estimated on linear uncertainty terms in the average q specification. Column 6 excludes the linear uncertainty terms from Column 5 yielding almost no change to the coefficient estimate on the remaining uncertainty sales growth interaction term.

[Table 12 Here]

Adjusting the uncertainty proxy for effects of financial leverage appears to decrease the significance of coefficients on these terms in both the error correction and average q specification. However, Table A5 in the appendix of this chapter compares estimates of the specifications in Table 12 to those obtained using an alternative instrument set, in which coefficients on uncertainty sales growth interaction terms are more significant. The alternative estimates are obtained by excluding $\Delta^2 y_{i,t}$ from the instruments for equations in levels. The appendix shows that the validity of the latter instrument for equations in levels is not supported by Differenced Sargan/Hansen Tests, in the case of the error correction specification which controls for uncertainty with $g_{i,t} * \sigma_{i,t}$.

Table 13 below presents results from including the adjusted uncertainty measures $\sigma_{i,t}^{w}$ and $w\sigma_{i,t}$ in the error correction and average q specifications. Columns 1 and 2 report estimates of the error correction specification using $\sigma_{i,t}^{w}$ and $w\sigma_{i,t}$ as proxies for uncertainty, and Columns 3 and 4 include these proxies in the average q specification. Comparing Columns 1 and 3 in Table 13 to the corresponding specifications in Columns 1 and 4 of Table 12, adjusting the uncertainty proxy for potential weekend effects has relatively little impact on coefficient estimates in either specification. Coefficients estimated on uncertainty sales growth interaction terms in Columns 1 and 3 of Table 13 are slightly larger than in Table 12, however this is likely due to the smaller mean values of $\sigma_{i,t}^{w}$ relative to $\sigma_{i,t}$ shown in Table 11. Using within year standard deviation in weekly (as opposed to daily) stock returns to proxy for uncertainty in Columns 2 and 4 of Table 13, yields insignificant coefficients on uncertainty sales growth interaction terms in both the error correction and average q specifications. However, coefficients on lagged linear uncertainty terms become more significant in the latter columns, relative to estimates presented in Columns 1 and 4 of Table 12. This suggests that information contained in the volatility of higher frequency stock returns may be more relevant to real option values to investment decisions held by firms.

[Table 13 Here]

1.6.5 Hybrid Model

The chief differences between specifications based on the error correction model and on measures of average q, are the use of the term $(k_{i,t-1} - y_{i,t-1})$ in place of $Q_{i,t}$, and the measurement of the dependent variables. Although the timing of dependent variables differs between these specifications, they are quite similar: $\Delta k_{i,t} \approx \frac{I_{i,t}}{K_{i,t-1}} - \delta$ vs. $\frac{I_{i,t}}{K_{i,t}}$. Either of these differences, or a combination of them, could influence coefficients estimated on the uncertainty sales growth interaction terms between these two specifications. Tables 14 and 15 below present estimates of hybrid specifications which include both the forward looking measure $Q_{i,t}$ and the backward looking error correction term $(k_{i,t-1} - y_{i,t-1})$; estimates of error correction and average q specification which interchange $\Delta k_{i,t}$ for $\frac{I_{i,t}}{K_{i,t}}$ and $\frac{I_{i,t}}{K_{i,t}}$ for $\Delta k_{i,t}$ respectively; as well as estimates of simple accelerator type models, excluding average q and error correction terms, using either $\frac{I_{i,t}}{K_{i,t}}$ or $\Delta k_{i,t}$ as measures of investment.

The set of results presented in this section indicates that coefficients on uncertainty sales growth interaction terms are affected by both the measurement of the dependent variable and the presence of average q and error correction terms. Between Tables 14 and 15, coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms in hybrid specifications (which differ only in the measurement of investment) were slightly larger in magnitude when investment was measured as $\Delta k_{i,t}$ as opposed to $\frac{I_{i,t}}{K_{i,t}}$. Appending either the error correction or average q specifications with $Q_{i,t}$ or $(k_{i,t-1} - y_{i,t-1})$ respectively had a small impact on coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms; yielding coefficients in the respective hybrid specifications that are closer to each other than in comparisons between the error correction and average q specifications. Adding $(k_{i,t-1} - y_{i,t-1})$ to the average q specification yields coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ that are slightly larger in magnitude; whereas adding $Q_{i,t}$ to the error correction specification results in a slight decrease in the magnitude of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$. However, relative to simpler accelerator investment specifications, in which coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms are insignificant, the inclusion of $(k_{i,t-1} - y_{i,t-1})$ in the error correction specification and $Q_{i,t}$ in the average q specification appear to play a role in identifying coefficients on uncertainty interaction terms. In the average q specification $Q_{i,t}$ also appears to control for some linear effects of uncertainty that are captured by a significant negative coefficient on $\sigma_{i,t-1}$ in estimates of accelerator models which measure investment as

$\frac{I_{i,t}}{K_{i,t}}$.

Table 14 below presents various investment specifications with $\Delta k_{i,t}$ as the dependent variable, including sales growth interaction and linear $\sigma_{i,t}$ uncertainty terms. Column 1 reports System GMM estimates of the error correction specification obtained with the preferred instrument set from Table 8. Column 2 adds the average q term to the specification, without adding it to the instrument set, resulting in a slight decrease in the magnitude of coefficients estimated on the $\sigma_{i,t} * \Delta y_{i,t}$ and $\Delta\sigma_{i,t}$ terms; the latter of which becomes insignificant. Interestingly, the coefficient on the error correction term ceases to be significant, implying that it is not controlling for any additional information not already contained in $Q_{i,t}$. Column 3 adds lagged values of $Q_{i,t}$ to the instrument set, resulting in no significant changes to coefficient estimates from Column 2. Column 4 drops the error correction term from the specification, resulting in almost no change to coefficient estimates relative to those in Column 3. Column 5 drops the error correction term from the instrument set, causing the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to become insignificant. The error correction term appears to be an important instrumental variable for estimating the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$. The specification in Column 5 is essentially the average q specification, in which $\frac{I_{i,t}}{K_{i,t}}$ has been replaced on both sides of the specification, and in the instrument set, by $\Delta k_{i,t}$. Paramaterizing investment as $\Delta k_{i,t}$ in the average q specification does not lead to any improvement in the significance or magnitude of the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms; the correct measurement of investment in the average q specification (namely $\frac{I_{i,t}}{K_{i,t}}$) yields a slightly more significant coefficient on $\sigma_{i,t} * \Delta y_{i,t}$.

[TABLE 14 HERE]

Column 6 of Table 14 removes $Q_{i,t}$ from the specification in Column 5, resulting in an accelerator type investment model. Comparing Columns 6 and 1 in Table 14, the addition of $(k_{i,t-1} - y_{i,t-1})$ to the accelerator model in the former column causes the insignificant coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ to roughly double in magnitude, becoming statistically significant in the error correction specification. The controls for long run investment dynamics in the error correction specification appear to play an important role in identifying lower investment responses to demand at higher levels of uncertainty.

The columns of Table 15 below follow roughly the same format as in Table 14, but beginning with the average q specification. Column 1 presents System GMM estimates of the average q specification using the preferred instrument set from Table 10. Column 2 adds the error correction term to the specification in Column 1, but excludes it from the instrument set, yielding an insignificant coefficient on the error correction term, and virtually no change in coefficient estimates relative to Column 1. Column 3 adds the error correction term to the instrument set in Column 2, causing the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ to become slightly larger and more significant, and also results in a marginally significant coefficient on $\Delta\sigma_{i,t}$. Comparing hybrid investment specifications in Column 3 of Tables 14 and 15 the only difference is in the measurement of investment ($\Delta k_{i,t}$ in Table 14 and $\frac{I_{i,t}}{K_{i,t}}$ in Table 15). Measuring investment as $\Delta k_{i,t}$ in Column 3 of Table 14 results in a larger coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ relative to Column 3 in Table 15. The magnitudes of coefficients on the latter terms are closer together in the hybrid specifications than between the error correction and average q specification; this is due to $Q_{i,t}$ decreasing the magnitude of the coefficient in the error correction specification and $(k_{i,t-1} - y_{i,t-1})$ increasing the magnitude of the coefficient in the average q specification. Changes in coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ between error correction, average q and their respective hybrid specifications were relatively minor and rather insignificant with respect to standard errors on those coefficients. However, the direction of these changes is noteworthy; and implies there is likely some level of sensitivity of coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to the choice of controls for investment dynamics in these specifications.

Column 4 of Table 15 drops $Q_{i,t}$ from the specification in Column 3, but retains it as an instrumental variable. As a result the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ ceases to be significant and the significance of coefficients on the linear uncertainty terms increases drastically. Column 5 drops $Q_{i,t}$ from the instrument set in Column 4, causing the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to become marginally significant. The specification in Column 5 of Table 15 is very similar to the error correction specification from Column 1 of Table 14, however investment has been measured as $\frac{I_{i,t}}{K_{i,t}}$ as opposed to $\Delta k_{i,t}$. As a result of which the coefficient estimated on the uncertainty sales growth interaction term is considerably smaller in magnitude and less significant in Column 5 of Table 15.

Column 6 of Table 15 drops the error correction term from the specification and instrument set in Column 5, resulting in an accelerator specification with investment measured as $\frac{I_{I,t}}{K_{i,t}}$. Comparing Columns 6 and 1, the inclusion of $Q_{i,t}$ in the average q specification may play a small role in identifying the marginally significant coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 1, which is insignificant in Column 6. It does appear clear that $Q_{i,t}$ is controlling for some linear effects of uncertainty in the average q specification; captured by the significant negative coefficient on $\sigma_{i,t-1}$ in the accelerator model in Column 6; this coefficient is insignificant in Column 1. The latter effect is also evident by comparing any of the significant coefficients on $\sigma_{i,t-1}$ in the specifications of Columns 4, 5 and 6 of Table 15 (which exclude $Q_{i,t}$) to the specifications in Columns 1, 2 and 3 (which include $Q_{i,t}$).

[TABLE 15 HERE]

Results presented across Tables 14 and 15 suggest that controlling for long run dynamics - or convergence of capital to long run optimal levels defined by $(k_{i,t-1} - y_{i,t})$ and $Q_{i,t}$ - is important for estimating significant negative coefficients on uncertainty sales growth interaction terms in the error correction and (to a lesser extent in the) average q investment specifications. A point of interest being that $Q_{i,t}$ appeared to control for all relevant information controlled by $(k_{i,t-1} - y_{i,t-1})$ in specifications which contained both terms. The fact that adding the error correction term to the average q specification slightly increases the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$, and adding $Q_{i,t}$ to the error correction specification has the opposite effect illustrates that the choice between such controls for investment dynamics impacts coefficients on uncertainty sales growth interaction terms. However, including $Q_{i,t}$ in investment specification does not always decrease the significance of coefficients on the uncertainty terms. When $Q_{i,t}$ is added to the accelerator specification between Columns 6 and 1 of Table 15, the insignificant coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ in the accelerator model becomes significant in the average q specification. Between the average q and error correction specifications, it appears that a combined effect of the different measurements of investment together with the alternative controls for investment behaviour $(k_{i,t-1} - y_{i,t-1})$ and $Q_{i,t}$ contribute to the lower magnitude and significance of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ in the average q specification.

1.7 Previous Literature

The author is not aware of a previous study which has compared results obtained by including controls for effects of uncertainty in both error correction and average q investment specifications estimated using the same data set; or in estimates of hybrid specification which include both error correction and average q terms. Previous empirical investigations into the effects of uncertainty on firm level investment have focused on a single specification. However, it is worthwhile to compare estimates of the individual error correction and average q specifications presented in this chapter, to previous literature that has estimated similar specifications with different data sets. Coefficient estimates on uncertainty terms presented in this chapter are generally consistent with the findings of previous literature, as are coefficients estimated on underlying parameters of the error correction and average q specifications.

The error correction specification in this chapter is very similar to those estimated in Bond and Lombardi (2006), and Bloom, Bond and VanReenen (2007). All three error correction specifications include the same uncertainty terms except for in Bond and Lombardi (2006) which omits a term in $\Delta\sigma_{i,t}$. As discussed in the literature review of this chapter Bond and Lombardi (2006) use a proxy for uncertainty based on survey data on managers' perceptions of expected demand, whereas Bloom, Bond and VanReenen (2007) employ an empirical proxy for uncertainty that is equivalent to $\sigma_{i,t}$. The significance of coefficients on uncertainty sales growth interaction terms is very similar across all three estimates, in terms of their t-statistics. The coefficient on the uncertainty sales growth interaction term is smallest in Bloom, Bond VanReenen (2007), at -0.162. In the current chapter, the point estimate on the latter term in the error correction specification was -0.207. The point estimate on this term was significantly larger in the error correction specification estimated in Bond and Lombardi (2006): -0.8331, however this is likely due to differences in the uncertainty proxies themselves. As in the results presented in this chapter, both in Bond and Lombardi (2006) and Bloom, Bond and VanReenen (2007) coefficients estimated on lagged linear uncertainty terms were insignificant.

The average q specification estimated in this chapter is similar to those estimated in Bond and Cummins (2004) and Bulan (2005). As in the case of the latter studies, the effects of uncertainty on investment identified in the average q specification in this chapter were independent of controls for average q - a result which contrasts the findings of Leahy and Whited (1996) in which effects of uncertainty on investment were found to operate through average q. All four of these studies rely on within year standard deviations in daily stock returns to proxy for firm level uncertainty; in addition to which Bond and Cummins (2004) also employ an uncertainty proxy based on disagreement in I/B/E/S security analysts' forecasts of earning per share ($DISP_{i,t}$ in their notation)[48]. The preferred investment specification in Bond and Cummins (2004), uses within year volatility in daily stock returns to control for uncertainty-sales growth interaction effects on the investment response to demand in their average q specification.

Coefficients estimated on interaction terms between sales growth and stock return volatility proxies of uncertainty were significantly larger in Bond and Cummins (2004) relative to those reported in this chapter: -1.24 compared to -0.107. This represents substantially greater heterogeneity in investment responses to demand shocks captured by coefficients estimated on sales growth and on uncertainty sales growth interaction terms; as coefficients on sales growth terms in Bond and Cummins (2004) were 0.420, compared to 0.415 in Table 10 of this chapter. Negative linear effects of uncertainty captured by coefficients on $DISP_{i,t}$ in estimates of the preferred average q investment specification in Bond and Cummins (2004) were not reflected by similar negative and significant coefficients on $\sigma_{i,t-1}$ terms in estimates of the average q specification presented in Column 4 of Table 10, which include uncertainty-sales growth interaction terms. Differences in the uncertainty proxies themselves make it difficult to directly compare the magnitudes of these coefficients, however their common sign is consistent with similar firm level investment uncertainty relationships.

Unlike the specifications estimated in this chapter and in Bond and Cummins (2004), estimates of the average q specification presented in Bulan (2005) do not include uncertainty sales growth interaction terms. Effects of uncertainty are exclusively controlled for in Bulan (2005) study by linear uncertainty terms.[49] The coefficient estimated on the linear uncertainty term in

[48]This proxy was calculated as the coefficient of variation over security analysts' one year ahead forecasts of earnings per share, made at the beginning of every accounting period.

[49]Whereas Bulan (2005) goes on to break down uncertainty proxies based on within year volatility in daily stock returns, into firm, industry and market components, the comparison here is limited to the aggregated measure. Chapter 4 of the thesis follows Bulan (2005) in breaking down the uncertainty proxy $\sigma_{i,t}$ into firm

the average q specification in Bulan (2005) is much larger in magnitude relative to coefficients estimated on $\sigma_{i,t-1}$ in Column 5 of Table 10 (which only includes linear controls for effects of uncertainty): -0.366 with a t-ratio of -4.17, compared to -0.027 with a t-ratio of -2.08. Although significant negative coefficients estimated on linear uncertainty terms are interpreted in Bulan (2005) as evidence of effects of real options on firm level investment; evidence of such effects is more clearly captured by coefficients on uncertainty sales growth interaction terms, as in Bond and Cummins (2004) and in the chapter. Significant negative coefficients on uncertainty sales growth interaction terms are consistent with lower investment responses to changes in demand, the only unambiguous effect of uncertainty predicted by models of investment with irreversibility and real options.

Comparing estimates of both the error correction specification and average q specification presented in this chapter, to similar specifications estimated in previous literature, investment uncertainty relationships described therein were broadly consistent. Although estimates of the average q specification appeared to diverge slightly more from previous literature, the data sets used in Bond and Cummins (2004) and Bulan (2005) were substantially larger; whereas data sets were of similar size - though slightly larger - in Bloom, Bond and VanReenen (2007) and Bond and Lombardi (2006).

specific and market wide components.

1.8 Conclusion

This chapter presented estimates of investment specifications based on both error correction models between the natural logarithms of capital and sales, and the Hayashi (1982) Q investment model; comparing differences and similarities in the investment-uncertainty relationships described between each. Estimates of both these specifications suggested broadly similar investment-uncertainty relationships. However, while negative coefficients on uncertainty-sales growth interaction terms demonstrated evidence of lower investment responses to demand growth at higher levels of uncertainty in estimates of both specifications, the coefficient on this interaction term was half the size and less statistically significant in estimates of the average q specification.

Based on estimates of hybrid investment specifications (which include both average q and error correction terms) and accelerator investment specifications (which include neither) the significance and magnitude of coefficients estimated on uncertainty-sales growth interaction terms were sensitive to both the measurement of investment used and the inclusion of error correction and average q terms. Including the error correction and average q terms in their respective specifications was important for identifying significant coefficients on uncertainty-sales growth interaction terms; these coefficients were insignificant in estimates of simpler accelerator investment specifications. Insignificant coefficients estimated on error correction terms in the hybrid investment specifications implies that average q terms control for all information relevant to investment dynamics contained in the error correction terms. Given that coefficients estimated on uncertainty-sales growth interaction terms tended to be smaller (in absolute value) and less significant in specifications that included controls for average q, it is possible that some of the additional information contained in average q terms is relevant to the effects of uncertainty on firm investment responses to demand growth. However, the fact that removing controls for average q from the average q specifications leads to a deterioration in the significance of the coefficients estimated on uncertainty sales growth interaction terms suggests that controls for investment dynamics captured by the average q term play some role in identifying coefficients on the uncertainty sales growth interaction term in the average q specification.

The sensitivity of coefficients estimated on uncertainty terms to the measure of investment used and the inclusion of alternative controls for investment dynamics highlights the need to evaluate the robustness of conclusions across alternative investment specifications when investigating effects of uncertainty on firm level investment behaviour. Relationships between investment and uncertainty - based on the signs of coefficients estimated on uncertainty terms - were broadly consistent across estimates of alternative investment specifications in this chapter; however, differences in the statistical significance and magnitude of coefficients could impact conclusions drawn regarding the sensitivity of firm investment behaviour to uncertainty.

Using a simulation program written by Professor Nick Bloom of Stanford University, the following chapter explores investment-uncertainty relationships described by these investment specifications estimated using simulated panel data sets. The key advantage of using simulated data is that the level of uncertainty, or volatility in demand/productivity conditions faced by firms, is directly observable in the simulated data. Within the investment model driving the simulation program, underlying demand volatility has effects on firm level investment behaviour through the real option values described by theoretical literature on investment under uncertainty. An empirical proxy for uncertainty is also calculated based on within year volatility of returns to a firm's value function. This empirical proxy in the simulated data corresponds (roughly) to $\sigma_{i,t}$ in the empirical data, and can be included in estimates of the average q and error correction specifications to investigate the underlying real option effects of uncertainty on firm investment behaviour. An important question is then whether the effects of uncertainty on investment estimated using these different specifications for the simulated data are broadly similar or substantially different to those found using empirical data for UK firms and reported in this chapter.

1.9 Data Appendix

The empirical data set used throughout this thesis is based on data initially constructed in Bond et al. (2004), used to investigate the role of cash-flow and expected profitability in estimates of firm level average q investment specifications. The Bond et al. (2004) data set was based on firm level accounting and share price data from the DATASTREAM data-base which covered UK-quoted companies from 1968 onwards. The accounting data was added to analysts' earnings forecasts data from the I/B/E/S database covering a sub-sample of UK-quoted companies from 1987 onwards. Approved securities analysts are asked by I/B/E/S to provide forecasts of earnings per share for current year t, and the years $t+1$ and $t+2$, as well as forecasts of *long-term* growth in *trend earnings*. The Bond et al. (2004) data set focuses on UK companies for which forecasts of earnings per share in years t and $t+1$ were available, resulting in a panel of 703 firms for which there were at least 4 consecutive annual observations of these forecasts between 1987 and 2000.

Based on I/B/E/S forecasts available in the data set from Bond et al. (2004) 4 measures of uncertainty are constructed to capture uncertainty over future firm operating conditions reflected in the earnings per share forecast data. Two measures were based on monthly observations on the consensus forecasts of earnings per share for the current year; calculated as the un-weighted mean of analysts' forecasts for the same firm. The first of these measures ($REV_{i,t}$) 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 ($RANGE_{i,t}$) 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.

The other two uncertainty measures, constructed with I/B/E/S data, are based on those used in Bond and Cummins (2004). The first, $ERR_{i,t}$ is the square of the difference between ex ante consensus forecasts 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. The second, $DISP_{i,t}$ is the coefficient of variation across different analysts' one year ahead forecasts of earnings per share, made at the beginning of the current accounting period. The author would like to thank Steve

Bond[50], Richhild Moessner[51], Haroon Mumtaza[52] and Murtaza Syed[53] for their work in constructing the uncertainty proxies $REV_{i,t}$, $RANGE_{i,t}$, $ERR_{i,t}$ and $DISP_{i,t}$; preliminary versions of programs they used to construct these measures were tested and reviewed extensively prior to estimating results. In order to reduce the impact of outliers, firm year observations with the top and bottom percentiles of the uncertainty measures were removed from the original Bond et al. (2004) data set, reducing the data set from the 703 firms to 655 firms for which there were at least 4 consecutive annual observations between 1987 and 2000. Sectoral coverage of firms in the data set used in Chapters 1, 3, 4 and 5 is presented in Table D1 below.

[Table D1 Here]

Although the I/B/E/S uncertainty measures are not used to produce the results of this Chapter, the outlying values of these measures were used to truncate the data set from Bond et al. (2004). Chapter 5 of the thesis employs the I/B/E/S indicators of uncertainty, to describe firm level investment uncertainty relationships in the contexts of the error correction and average q investment specifications. The analysis of the current chapter is limited to uncertainty proxies based on within year standard deviations in daily, firm stock returns. For the sake of comparability between results presented in Chapter 1 and Chapter 5, the analysis in Chapter 1 is limited to the 655 firm subset of the Bond et al. (2004) data set.

The proxy for uncertainty used in Chapter 1, based on within year volatility of daily stock returns ($\sigma_{i,t}$), is constructed as the standard deviation of the daily percentage return of a firm's share price[54]. For each annual accounting observation t for firm i, daily share price returns available within a 365 calendar day period ending on the date of the accounting observation were used to calculate $\sigma_{i,t}$.

The Table D2 below presents summary statistics of the uncertainty measure $\sigma_{i,t}$ and the vari-

[50]Nuffield College, Oxford
[51]Bank of England
[52]Bank of England
[53]International Monetary Fund
[54]Taken as the DATASTREAM Returns Index, RI, includes on a daily returns basis the capital gain on the stock, dividend payments, the value of rights issues, special dividends and stock dilutions.

ables used in estimating the error correction and average q specifications. Table D3 presents the covariance matrix for these variables. As one would expect both $\Delta k_{i,t}$ and $\frac{I_{i,t}}{K_{i,t}}$ have a very strong correlation. Both measures exhibit positive and very similar levels of correlation with both $Q_{i,t}$ and $\Delta y_{i,t}$. The error correction term $(k_{i,t-1} - y_{i,t-1})$, is negatively correlated with $\Delta k_{i,t}$ as implied by a co-integrating relationship between the natural logarithms of capital and sales. The proxy for uncertainty is negatively correlated with $\Delta k_{i,t}$, $\frac{I_{i,t}}{K_{i,t}}$, $\Delta y_{i,t}$ and $Q_{i,t}$, which is consistent with negative effects of uncertainty on investment and on investment responses to changes in demand at higher levels of uncertainty. The uncertainty proxy $\sigma_{i,t}$ is positively correlated with the error correction term $(k_{i,t-1} - y_{i,t-1})$, indicating a positive effect of uncertainty on the capital sales ratio. This correlation has the opposite sign from what one would expect based on a negative effect of uncertainty on capital. Although coefficients on $\sigma_{i,t-1}$ terms were not always significant in estimates of average q and error correction specifications, their signs were always negative. However, figures in Table D3 are only raw correlations.

[TABLE D2 HERE]

[TABLE D3 HERE]

The construction of the capital stock measure in the data set follows the perpetual inventory method in Blundell et al. (1992). Using the book value of capital stock in the first year, capital stock in the remaining years is calculated according to the recursive formula:

$$K_{i,t+1} = (1 - \delta)K_{i,t} + I_{i,t+1} \tag{1.33}$$

Where $I_{i,t}$ is investment by firm i in year t and $K_{i,t}$ is the capital stock of firm i at the end of year t. Investment is defined as follows, where the DATASTREAM item code is preceded by ds.

$$I = ds1026 + ds479$$

where $ds1026$ is net payments for fixed assets and $ds479$ is net fixed assets of subsidiaries acquired or sold. Where $ds1026$ was not available investment was defined as follows[55]:

$$I = ds431 - ds423 + ds479$$

where $ds431$ is purchases of fixed assets and $ds423$ is sales of fixed assets. Due to the fact that investment was reported in nominal terms, it was deflated by the quarterly business investment deflator implied by the UK National Accounts to create an investment series in constant (1995) prices.

The measure of initial capital stock was taken $ds339$, the book value of fixed capital. A depreciation rate of 8% was assumed for all capital goods following Bond et al. (2003). Some price inflation in previous years is allowed for by revaluing the first available book measure, by the business investment deflator, to reflect investment goods price inflation over the proceeding three years. Observations were dropped for which the capital stock was negative or the estimate of the capital stock was out of line with the book value by more than a factor of four.

Real sales is obtained by deflating nominal sales ($ds104$) by the GDP deflator. The measure of average q is adjusted in the data to take into account debt financing as in Blundell et al (1992).

$$q_{i,t} = \frac{V_{i,t} + H_{i,t}}{p_t^I (1-\delta) K_{i,t-1}}$$

Where $H_{i,t}$ is a measure of the stock of debt of the firm, obtained by the difference between a firm's liabilities (measured as the sum of total loan capital (ds321), total deferred and future tax (ds312), total long term provisions excluding deferred tax (ds313) and minority interests (ds315)) and assets (measured as the sum of total intangibles (ds344), total investment including assets (ds356), net current assets (ds390) and other assets (ds359)). $V_{i,t}$ is the market value of the firm obtained by the product of the firm's share price and the number of outstanding shares. $K_{i,t}$ is the perpetual inventory capital stock, which is multiplied by the business investment deflator to obtain a nominal measure; δ the depreciation rate.

[55] $ds1026$ replaced $ds423$ and $ds431$ after an accounting change in 1990

1.10 Instrument Appendix

1.10.1 Instrument Choice: Error Correction Specification With Instruments Lagged $t-2:t-4$ for Equations in First Differences

The first two columns of Table A1 below evaluate System GMM estimates of the error correction specification (including all uncertainty terms) relative to First Differenced GMM estimates using lagged values of the R.H.S. and L.H.S. variables as instruments for equations in first differences. In addition to the moment conditions used in First Differenced GMM estimates, System GMM estimates exploit non-redundant moment conditions for equations in levels: $E[\Delta^2 k_{i,t-1}\hat{\epsilon_{i,t}}] = 0$. In the contexts of simple $AR[1]$ models, using these additional moment conditions for equations in levels yields dramatic improvements in the efficiency of System GMM estimates, relative to those obtained with GMM in First Differences, as well as a reduction in finite sample bias.[56] In the case of the more general, dynamic error correction specification, efficiency gains of System GMM estimates over those obtained by First Differenced GMM will be greater with more persistent dependent and explanatory variables, which leads to weak instruments for equations in first differences; as well as imprecise parameter estimates and more serious finite sample bias with First Differenced GMM.

The first column of Table A1 presents the results from estimating the error correction specification using GMM in first differences with instruments in levels lagged $t-2:t-4$, not using any moment conditions for equations in levels. The second column presents System GMM estimates obtained by adding the first difference of the dependent variable as an instrument for equations in levels, adding $E[\Delta^2 k_{i,t-1}\hat{\epsilon_{i,t}}] = 0$ to the moment conditions used to generate the First Differenced GMM estimates in column 1. A Differenced Sargan/Hansen test is used to compare the null hypothesis that the addition linear moment condition $E[\Delta^2 k_{i,t-1}\hat{\epsilon_{i,t}}] = 0$ is valid, against the alternative hypothesis that only the strict subset of moment conditions for equations in first differences, from Column 1, are valid. If the null hypothesis is valid neither of the Sargan/Hansen test statistics should reject, and the difference between the two of them

[56]See Blundell and Bond (1998). In the contexts of simple AR[1] models Ahn and Schmidt (1995) show that the use of quadratic moment conditions can also improve the efficiency of GMM estimates, however Blundell and Bond (1998) show that efficiency gains are even greater when using the linear moment conditions in System GMM Estimates; particularity in the case when series become more persistent. The later linear moment conditions also make quadratic moment conditions redundant in the contexts of the AR[1] model

should have a χ^2 distribution with degrees of freedom equal to the difference in the number of instruments used in each of the estimates. The value of 1 less the p-value of the Difference Sargan/Hansen test between estimation results of columns 1 and 2 is reported at the bottom of column 2. Given the drastic change in the size of the Sargan/Hansen test statistics between Columns 1 and 2, the difference Sargan/Hansen test rejects the hypothesis that the difference between these two statistics follows the appropriate χ^2 distribution. This makes it difficult to accept the hypothesis that the additional System GMM moment condition is valid relative to the subset of moment conditions based on instruments for equations in first differences from Column 1.

[Table A1 Here]

Columns 3 through 6 in Table A1 above present results from adding the first difference of each of the explanatory, right hand side (R.H.S.), variables as instruments for equations in levels to the set of instruments used in Column 1. The validity of additional moment conditions obtained by using these instruments for equations in levels will depend on whether the first difference of the R.H.S. variables are correlated with unobserved firm specific effects in the residuals, ie whether the covariance between the R.H.S. variables and the firm specific effects is constant over time.[57] The validity of additional moment conditions added in Columns 3 to 6, relative to the set of moment conditions used in the First Differenced GMM estimates from Column 1, are tested using Differenced Sargan/Hansen tests. The value of 1 less the p-value of each Differenced Sargan/Hansen test is reported at the bottom of Columns 3 through 6. As in the case between Columns 1 and 2, the differences in the Sargan/Hansen test statistics between Columns 1 and Columns 3 through 6 are very large, and the Differenced Sargan/Hansen tests reject the hypotheses that the additional moment conditions used across Columns 3 through 6 are valid, relative to the alternative hypothesis that only the subset of moment conditions from Column 1 is valid.

[57]See Arellano and Bover (1995)

1.10.2 Instrument Choice: Error Correction Specification With Instruments Lagged $t-3:t-4$ for Equations in First Differences

Given the poor evidence supporting System GMM moment conditions (and moment conditions for equations in levels) based on instruments for equations in first differences lagged $t-2:t-4$, Table A2 below evaluates moment conditions for equations in levels, relative to a set of instruments for equations in first differences lagged $t-3:t-4$. In Column 1 of Table A1, the test statistic for second order serial correlation in the differences residuals in suspiciously high, and throughout the Columns of Table A2 below Arellano-Bond tests reject the hypothesis of no second order serial correlation in the first differenced residuals. In the presence of second order serial correlation in the first differenced residuals of the error correction specification, it would be inappropriate to use instruments for equations in first differences lagged $t-2$ periods.

The first column of Table A2 below reports First Differenced GMM estimates using instruments in levels dated $t-3:t-4$. Column 2 adds $\Delta^2 k_{i,t}$ lagged $t-2:t-2$, as an instrument for equations in levels, which yields System GMM estimates. Sargan/Hansen test statistics do not change drastically between Columns 1 and 2, and a Differenced Sargan/Hansen test does not reject the hypothesis that the System GMM moment conditions in Column 2 are valid, relative to the alternative that only the subset of moment conditions from Column 1 are valid. Columns 3 through 6 add the first difference of the explanatory variables, lagged $t-2:t-2$, as instruments for equations in levels to the instrument set in Column 2. The validity of the additional moment conditions in Columns 3 through 6, rests on the assumption that the lags of the first difference of the explanatory variables is uncorrelated with both the first difference of current residuals, as well as any unobserved firm specific effects. Differenced Sargan/Hansen tests do not reject the Hypotheses that $\Delta^2 y_{i,t-2}$, $\Delta\sigma_{i,t-2}$, $\Delta(\sigma_{i,t-2} * \Delta y_{i,t-2})$ are valid instruments for equations in levels, relative to the alternative Hypothesis that only the moment conditions from Column 2 are valid. Large Differences between the Sargan/Hansen test statistics reported in Columns 2 and 4 imply that using the moment $E[\Delta(k_{i,t-2} - y_{i,t-2})\hat{\epsilon_{i,t}}] = 0$ significantly increase the Sargan/Hansen test statistic relative to the System GMM results presented in Column 2. This brings into doubt the validity of the additional moment conditions, and thus $(k_{i,t-1} - y_{i,t-1})$ is excluded from the preferred instrument set; estimation results for which are reported in Column

7.

[Table A2 Here]

Given the evidence of second order serial correlation of the first differenced residuals in Table A2 and Column 1 of Table A1, as well as the lack of support for the additional instruments by the Differenced Sargan/Hansen test statistics in Table A1, instruments for equations in first differences lagged $t-2$ are not used to estimate the error correction specification. The preferred instrument set for the error correction specification uses instruments in levels lagged $t-3:t-4$ for equations in first differences and instruments in first differences lagged $t-2$ for equations in levels.

1.10.3 Instrument Choice: Average q Specification

Columns 1 and 2 of Table A3 below present First Differenced and System GMM estimation results for the average q specification, excluding terms in $\frac{I_{i,t-1}}{K_{i,t-1}}$ and $\Delta y_{i,t-1}$, using instruments for equations in first differences lagged $t-2:t-4$. Unlike the case of the error correction specification above, the Differenced Sargan/Hansen test statistic reported, supports the validity of additional moment conditions in System GMM estimates of the basic average q specification using instruments for equations in first differences lagged $t-2:t-4$. Columns 3 through 6 add the lag of the first difference of each explanatory R.H.S. variable as instruments for equations in levels to the System GMM instrument set from Column 2. Similar to Table A2 above Difference Sargan/Hansen tests compare the null hypothesis that the additional moment conditions added in Columns 3 through 6 are valid, relative to the moment conditions used in the System GMM estimates reported in Column 2.

[Table A3 Here]

Column 7 of Table A3 above presents System GMM estimates of the average q specification obtained by using the preferred instruments for equations in levels, and instruments for equations in first differences lagged $t-2:t-4$. Under the assumption that the $t-2:t-4$ lagged instruments for equations in first differences were valid in estimating the average q specification in Column 1 of Table A3, the additional validity of System GMM moment conditions and (most) moment conditions based on equations in levels were not rejected by Difference Sargan/Hansen test statistics. This contrasts the results from estimating the error correction specification using instruments for equations in first differences lagged $t-2:t-4$ in Table A1.

Column 1 of Table A4 below presents the preferred estimates of the basic average q specification from Column 7 of Table A3 above. Column 2 of Table A4 restricts the instrument set from Column 1, excluding $t-2$ lagged instruments for equations in first differences, and appropriately adjusts the timing of the instruments for equations in levels. As a result of using the longer lagged instrument set in Column 2, the Sargan/Hansen test statistic is significantly decreased relative to Column 1. A differenced Sargan/Hansen test statistic marginally rejects the hypothesis that the additional instruments in Column 1 are valid relative to the alternative hypothesis that only the instruments in Column 2 are valid, with a p-value of only 0.098. The coefficient on the uncertainty interaction term almost triples in magnitude in Column 2, relative to Column 1. Coefficients estimated on linear uncertainty terms decrease significantly in magnitude between Columns 1 and 2. The instability of coefficients estimated on uncertainty terms between Columns 1 and 2, and the low p-value of the Differenced Sargan-Hansen test reported in Column 2 bring into question the validity of instruments dated $t-2$.

Column 3 of Table A4 adds lagged terms in $\frac{I_{i,t-1}}{K_{i,t-1}}$ and $\Delta y_{i,t-1}$ to the specification in Column 2. The version of the average q specification in Column 3 of Table A4 corresponds closely with the error correction specification from Tables A1 and A2. Comparing Columns 3 and 2 in Table A4, the Sargan/Hansen test statistic appears to increase just slightly as a result of introducing the additional lagged variables to the average q specification; however, coefficient estimates are very stable across the two columns.

[Table A4 Here]

Based on the comparison of results across Table A4, and for the sake of comparability with estimates of the error correction specification, the System GMM instrument set from Column

3 of Table A4 is used to estimate the average q specification in the body of this chapter.

1.10.4 Gearing Adjustment

Table A5 below compares alternative instrument sets used to estimate the error correction and average q specification from Table 12, in which uncertainty proxies are adjusted for effects of financial leverage. Comparisons based on Differenced Sargan/Hansen tests reported in Table A5 below suggest that $\Delta^2 y_{i,t}$ may not be a valid instrument for equations in levels used to estimate the error correction specification in which uncertainty terms are adjusted for effects of financial leverage. Excluding the latter moment condition increases the significance of coefficients estimated on uncertainty sales growth interaction terms.

Column 1 of Table A5 presents estimates of the error correction specification from Column 2 of Table 12, but excludes $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels. Column 2 of Table A5 adds $\Delta^2 y_{i,t-2}$ as an instrument for equations in levels to the instrument set in Column 1. A Differenced Sargan/Hansen test is used to evaluate the null hypothesis that the additional moment condition in Column 2 of Table A5 is valid against the alternative that only the moment conditions from Column 1 of Table A5 are valid. The value of one less the p-value of the Differenced Sargan/Hansen test statistic is reported in the bottom of Column 2, which rejects the validity of the null hypothesis.

[TABLE A5 HERE]

Column 3 of Table A5 presents estimates of the average q specification from Column 5 of Table 12, but excludes $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels. Column 4 adds the latter instrument to the instrument set from Column 3. Unlike the case of the error correction specification a Differenced Sargan/Hansen test does not reject the null hypothesis that the moment conditions in Column 4 are valid, relative to the alternative that only the subset of moment conditions from Column 3 are valid.

1.11 Annex 1

1.11.1 Error Correction Specification

Coefficients on $(k_{i,t-1} - y_{i,t-1})$ terms in the error correction specifications presented in Table 7 represents the sum of coefficients on lagged dependent variables in the ADL[2,2] specification between the natural logarithms of capital and sales, less one (see Equation 1.25). As explained in section 1.6.2, biases described by Blundell and Bond (1998) in coefficients estimated on lagged dependent variables should be manifested in coefficients on the error correction term. As noted in the text in section 1.6.2, the direction of the biases in coefficients estimated on the error correction specification are consistent with the findings of Blundell and Bond (1998): the Within groups estimates appear to be biased downwards, as do First Differenced GMM estimates - although not to the same extent - , whereas OLS estimates appear biased upwards and System GMM estimates lie between the OLS and First Differenced GMM estimates.

System GMM estimates of the coefficient on the error correction term in Column 3 of Tables 6 and 7 appear quite close to the coefficients estimated by OLS in Column 4 of the same tables. Given that bias in the OLS estimates caused by unobserved firm specific effects is expected to be quite strong, it may be questionable as to how close the System GMM estimates of the coefficient on the error correction term could be to the *true* value. Correlation between the error correction term and unobserved firm specific effects, together with poor instruments for the $(k_{i,t-1} - y_{i,t-1})$ term in equations for levels could be leading to an upward bias in the coefficient estimated on this term in Column 3 of Tables 6 and 7.

Using first differences of lagged endogenous variables as instruments for equations in levels in GMM estimates relies on the assumption of constant correlation between endogenous variables and unobserved firm specific effects; whereby differencing lagged endogenous variables provides valid moment conditions in GMM estimates. In the case of the error correction term $(k_{i,t-1} - y_{i,t-1})$, first differences are unlikely to provide valid moment conditions for equations in levels, as both $\Delta k_{i,t}$ and $\Delta y_{i,t}$ are also endogenous variables in the investment specification and themselves correlated with unobserved firm specific effects: $E[\Delta k_{i,t-2} \hat{\epsilon_{i,t}}] \neq 0$ $E[\Delta y_{i,t-2} \hat{\epsilon_{i,t}}] \neq 0$. This is only an issue in moment conditions for equations in levels, as unobserved firm specific effects are eliminated by taking first differences of the investment specification in moment conditions for equations in first differences. Indeed, in the Instrument Appendix, Section 1.10.2, Differenced Sargan/Hansen tests did not support the validity of $\Delta(k_{i,t-2} - y_{i,t-2})$ as an instrument for equations in levels in System GMM estimates of the error correction specification. Using moment conditions based on the latter instruments in the System GMM estimates in Table A2 of Section 1.10.2 significantly increased the minimized value of the criterion function and Sargan/Hansen Test statistics, relative to estimates which excluded such moment conditions. Furthermore - individually - $\Delta^2 k_{i,t-2}$ and $\Delta^2 y_{i,t-2}$ may be poor instruments for the the error correction term in moment conditions for equations in levels.

To explore the impact of possible biases in coefficients estimated on $(k_{i,t-1} - y_{i,t-1})$ terms in System GMM estimates of the error correction specification, Table A6 below presents estimates of the error correction specification with alternative values *imposed* for the coefficient on $(k_{i,t-1} - y_{i,t-1})$. The values imposed on the coefficient are 0.1, 0.15, 0.2 and 0.3. The error correction specifications in Table A6 also include the three uncertainty terms included in investment specifications throughout Chapter 1: $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$. The significance of negative coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms appears to be sensitive to changes in coefficients imposed on the error correction term in Table A6. As the *imposed* speed of adjustment of the capital stock towards its equilibrium value is increased above 0.1, the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ ceases to be significant.

[TABLE A6 HERE]

Column 1 of Table A6 above presents the preferred system GMM estimates of the error correction specification from Column 2 of Table 8. The coefficient on the error correction term implies a 5% annual speed of adjustment to equilibrium capital stocks. Column 2 increases the speed of adjustment to 10%, implying a downward adjustment to the sum of coefficients on lagged $k_{i,t}$ terms in the context of the ADL[2,2] specification. As a result the coefficient on the uncertainty sales growth interaction term decreases in magnitude, whereas its standard error remains relatively constant, decreasing the significance of the coefficient. Column 3 imposes a speed of adjustment of 15% in the error correction specification, causing the coefficient on the uncertainty sales growth interaction to decrease again in magnitude; without any change to its standard error the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ ceases to be significant in Column 3. The coefficient on the latter term decreases monotonically as the coefficient on the error correction term is increased to 0.2 and 0.3 in Columns 4 and 5 respectively.

Comparing the p-values of Sargan/Hansen test statistics across the Columns of Table A6, they remain relatively constant. This implies that the criterion function being minimized to produce the System GMM estimates is relatively flat with respect to the coefficient on the error correction term.

Table A7 below re-produces the results of Table A6, but using only $\Delta^2 k_{i,t-2}$ as an instrument for equations in levels. Although results presented in the instrument appendix 1.10.2 supported the validity of additional instruments for equations in levels, there are arguments to prefer the restricted instrument set in Table A7. The larger Sargan/Hansen p-values in Table A7, and instability in coefficients between Tables A6 and A7 (particularly on the uncertainty terms) are reasons to question the validity of the larger instrument set from Table A6. Furthermore, coefficients on uncertainty terms are more stable across the columns of Table A7 as alternative coefficient values are imposed on the error correction term. Comparing the Sargan/Hansen p-values between Columns 1 and 4, changing the coefficient value on $(k_{i,t-1} - y_{i,t-1})$ terms causes the minimized value of the GMM criterion function to increase more in Table A7 than in Table A6. Moreover, comparing coefficients on error correction terms between Column 1 of Tables A6 and A7, restricting the instrument set for equations in levels increases the magnitude of the coefficient on the error correction term. The coefficient on the error correction term in Column 1 of Table A7 is therefore larger in magnitude than the corresponding OLS estimate and is likely reflecting less bias in the estimate.

[TABLE A7 HERE]

Although the instrument set used in Table A7 is different from the preferred instrument set used throughout the thesis, results discussed throughout the thesis are robust to the use of the more restricted instrument set. Using only $\Delta^2 k_{i,t-2}$ or $\Delta\frac{I_{i,t-2}}{K_{i,t-2}}$ as instruments for equations in levels for the error correction and average q specification respectively, does not affect conclusions drawn from comparing coefficients on uncertainty terms within or between these two specifications. The following subsection repeats the analysis in Tables A6 and A7 for the average q specification. The final section of this annex presents estimation results from Chapter 1 using the restricted instrument sets for equations in levels, commenting on some minor changes in results. Results from using the restricted instrument set are also presented for specifications from Chapter 5 in a similar Annex at the end of that chapter.

1.11.2 Average Q Specification

It is worthwhile to note that the issue of bias in the coefficient on the $(k_{i,t-1} - y_{i,t-1})$ term in the error correction specification may arise analogously in the average q specification. The two specifications are not very different given that the average q term $Q_{i,t}$ could be interpreted as a type of non-linear error correction term as noted in Section 1.3.2. Furthermore, the relationship between $\frac{I_{i,t}}{K_{i,t}}$ and $ln(Q_{i,t}) = ln(V_{i,t} - p^I_t(1-\delta)K_{i,t-1}) - ln(p^I_t(1-\delta)K_{i,t-1})$[58] should be very similar to the relationship between $\Delta k_{i,t}$ and $(k_{i,t-1} - y_{i,t-1})$ in the error correction specification. The semi-elasticity of $\frac{I_{i,t}}{K_{i,t}}$ with respect to $Q_{i,t}$ is given by $\frac{\partial \frac{I_{i,t}}{K_{i,t}}}{\partial ln(Q_{i,t})} = \frac{\partial \frac{I_{i,t}}{K_{i,t}}}{\partial Q_{i,t}} Q_{i,t}$, and can be approximated by the product of the coefficient estimated on $Q_{i,t}$ in the average q specification, and the mean of average q. The semi-elasticity of $\frac{I_{i,t}}{K_{i,t}}$ with respect to $Q_{i,t}$ is comparable to the coefficient on the $(k_{i,t} - y_{i,t-1})$ term in the error correction specification. Thus coefficients on $Q_{i,t}$ can be imposed to values of $\frac{0.1}{\bar{Q}_{i,t}}, \frac{0.15}{\bar{Q}_{i,t}}, \frac{0.2}{\bar{Q}_{i,t}}, \frac{0.3}{\bar{Q}_{i,t}}$,[59] implying semi-elasticities of $\frac{I_{i,t}}{K_{i,t}}$ with respect to $Q_{i,t}$ which are comparable to the values of 0.1,0.15,0.2,0.3 imposed on the coefficients on $(k_{i,t-1} - y_{i,t-1})$ in the error correction specification. Table A8 below presents System GMM estimates of the average q specification, with the above mentioned values imposed on the coefficient on $Q_{i,t}$ across Columns 2-5. Column 1 presents the unrestricted System GMM estimate

[58]See Equation 1.26

[59]Where $\bar{Q}_{i,t}$ denotes the sample mean of $Q_{i,t}$

of the average q specification from Column 4 of Table 10.

[TABLE A8 HERE]

Two important distinctions to note between Tables A6 and A8 are with regards to the significance of coefficients on the uncertainty sales growth interaction term and the p-values of the Sargan/Hansen test statistics. Coefficients on uncertainty sales growth interaction terms are similar between Columns 1 and 2 of Table A8, both in terms of magnitude and significance. Coefficients on uncertainty sales growth interaction terms are not significant in Columns 3, 4 and 5, however the Sargan/Hansen test strongly rejects the validity of the instrument set in these columns. As the imposed coefficients on the $Q_{i,t}$ term are increased across the Columns of Table A8, the Sargan/Hansen test statistics (and the minimized value of the System GMM criterion function) increase commensurately. This was not the case with estimates of the error correction specification in Table A6, in which Sargan/Hansen test statistics did not appear very sensitive to the coefficient on the $(k_{i,t-1} - y_{i,t-1})$ term.

Table A9 below reproduces estimates presented in Table A8, using only $\Delta\frac{I_{i,t-2}}{K_{i,t-2}}$ as an instrument for equations in levels. As in the results presented in Table A8, the p-values of Sargan/Hansen test statistics steadily decrease across the columns of Table A9 - rejecting the validity of the instrument set in Columns 4 and 5. Unlike in the results presented in Table A8, the coefficient on the uncertainty sales growth interaction term is only significant in Column 1 of Table A9.

[TABLE A9 HERE]

1.11.3 Chapter 1 Results Based on Alternative Instrument Sets

This subsection compares System GMM estimation results presented in Tables 8, 9, 10, 12, 13, 14 and 15 from Chapter 1, with results obtained using a restricted subset of instruments for equations in levels. As mentioned above, conclusions drawn from the tables in Chapter 1 are largely unaffected by changing the instrument set in this way. For ease of comparability tables are labeled as in the body of the Chapter, for example Table 8* corresponds to Table 8 in the chapter; these tables are presented in the final section of Chapter 1 following the instrument appendix tables.

Tables 8* and 9* below present estimates of error correction specifications from the corresponding tables in the body of Chapter 1. The chief difference to note is the larger magnitude and greater significance of coefficients on the uncertainty sales growth interaction term and error correction term in the tables below. Coefficients on linear uncertainty terms are also more significant in the tables below.

[TABLE 8* HERE]

[TABLE 9* HERE]

Table 10* below presents estimates of the average q specifications from the corresponding table in the body of Chapter 1. In the table below the coefficient on the uncertainty sales growth interaction term is larger in magnitude but of similar statistical significance relative to results presented in the body of Chapter 1. As in the case of the error correction specification coefficients on linear uncertainty terms are larger in magnitude and more significant in the set of results with the restricted instrument set.

[TABLE 10* HERE]

Tables 12* and 13* below present estimates of the error correction and average q specifications from Tables 8* and 10* above - adjusting uncertainty terms for leverage and weekend effects on stock return volatility. Coefficients on uncertainty sales growth interaction terms in the error correction specification are more significant in the set of results with the restricted instrument set; as are coefficients on linear uncertainty terms. Adjusting the uncertainty terms in the average q specification causes marginally significant coefficients on these terms to become insignificant.

[TABLE 12* HERE]

[TABLE 13* HERE]

Tables 14* and 15* below present estimates of the hybrid investment specifications in which instrument sets have been restricted relative to those used to produce results presented in the body of the Chapter. Table 14* below presents results from adding and removing terms from the error correction specification. As a result of the restricted instrument set the coefficient on the error correction term is no longer insignificant in Column 3, in which average q terms have been added to the specification and instrument set. However, the magnitude and significance of the coefficient on the error correction term is still diminished relative to Column 1, as a result of adding the average q term to the specification and instrument set. As in results presented in Chapter 1, replacing the error correction term with the average q term in the specification and instrument set between Columns 1 and 5 decreased the magnitude and significance of the coefficient on the uncertainty sales growth interaction term. Removing the average q term between Columns 5 and 6 causes the coefficient on the uncertainty sales growth interaction term to increase in magnitude. Comparing coefficients on uncertainty sales growth interaction terms between Columns 1 and 6, including the error correction term in the specification in Column 1 results in a much more significant coefficient.

[TABLE 14* HERE]

As in results presented in the body of Chapter 1, adding the error correction term to the average q specification between Columns 1 and 3 of Table 15* has a limited impact on the coefficient on the uncertainty sales growth interaction term. Unlike in the case of Table 14* above, the coefficient on the error correction term in Column 3 of Table 15* below is not significant. Comparing Columns 1 and 5 in Table 15* below, replacing the average q term with the error correction term causes the coefficient on the uncertainty sales growth interaction term to become slightly more significant. Unlike the results presented in the body of Chapter 1, adding the average q term between Columns 6 and 1 has almost no effect on the coefficient on the uncertainty sales growth interaction term.

[TABLE 15* HERE]

1.12 Tables of Results

Table 1
Summary Statistics

	(1) mean	(2) std. dev.	(3) min	(4) max
$\Delta k_{i,t}$	0.0959	0.1560	-0.7707	1.2294
$\frac{I_{i,t}}{K_{i,t}}$	0.1494	0.1273	-0.9498	0.7316
$\Delta y_{i,t}$	0.0467	0.1618	-1.0091	1.0373
$(k_{i,t} - y_{i,t})$	-1.0315	0.8372	-4.6187	2.5615
$Q_{i,t}$	1.4056	1.7729	-0.8603	13.4544
$\sigma_{i,t}$	1.5330	0.6586	0.4465	4.3567

Table 2
Summary Statistics BBVR

	(1) mean	(2) std. dev.	(3) min	(4) max
$\Delta k_{i,t}$	0.1626	0.1159	-0.1258	0.9017
$\frac{I_{i,t}}{K_{i,t}}$	0.1275	0.1366	-0.1102	1.2056
$\Delta y_{i,t}$	0.0312	0.1578	-0.79.15	1.2183
$(k_{i,t} - y_{i,t})$	-0.8622	0.5622	-3.2864	1.3924
$Q_{i,t}$	.	.	.	.
$\sigma_{i,t}$	1.5532	0.6841	0.0067	5.0000

Table 3
Autoregressive Models

	AR[1] Models				
	$x_{i,t} = k_{i,t}$	$x_{i,t} = \Delta k_{i,t}$	$x_{i,t} = y_{i,t}$	$x_{i,t} = \Delta y_{i,t}$	$x_{i,t} = (k_{i,t} - y_{i,t})$
	(1)	(2)	(3)	(4)	(5)
$x_{i,t-1}$	.991 (.001)***	.209 (.023)***	.986 (.001)***	.361 (.024)***	.978 (.004)***

Table 4
Autoregressive Models

	AR[4] Models			
	$x_{i,t} = y_{i,t}$	$x_{i,t} = k_{i,t}$	$x_{i,t} = (k_{i,t} - y_{i,t})$	$x_{i,t} = (k_{i,t} - y_{i,t})$
$x_{i,t-1}$	.993 (.002)***	.994 (.002)***	.982 (.006)***	.978 (.004)***
$\Delta x_{i,t-1}$	.314 (.033)***	.173 (.029)***	-.016 (.035)	
$\Delta x_{i,t-2}$	-.048 (.028)*	.061 (.029)**	-.045 (.027)*	
$\Delta x_{i,t-3}$	.016 (.030)	.048 (.025)*	-.008 (.032)	

Table 5
Autoregressive Models

	$x_{i,t} = \frac{I_{i,t}}{K_{i,t}}$	$x_{i,t} = Q_{i,t}$	$x_{i,t} = \sigma_{i,t}$
$x_{i,t-1}$	.246 (.021)***	.888 (.015)***	.558 (.017)***

Table 6
Re-Arranged ADL[1,1] Specification

	(1)	(2)	(3)	(4)
	Within	GMM DIFF	GMM SYS	OLS
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	-.289	-.027	-.035	-.003
	(.015)***	(.041)	(.021)*	(.001)***
$\Delta y_{i,t}$	.370	.249	.245	.439
	(.017)***	(.092)***	(.102)**	(.021)***
$(k_{i,t-1} - y_{i,t-1})$	-.577	-.364	-.146	-.014
	(.018)***	(.094)***	(.053)***	(.003)***
Sargan/Hansen		.27	.654	
DoF		77	137	
AR1		-5.683	-7.822	
AR2		-1.606	-.559	
AR3		-.427	-.216	
AR4		.402	.428	
Instruments For Equations in First Differences				
$\Delta k_{i,t}$		t-3:t-4	t-3:t-4	
$\Delta y_{i,t}$		t-3:t-4	t-3:t-4	
$(k_{i,t} - y_{i,t})$		t-3:t-4	t-3:t-4	
$\sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4	t-3:t-4	
$\sigma_{i,t}$		t-3:t-4	t-3:t-4	
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$			t-2:t-2	
$\Delta^2 y_{i,t}$			t-2:t-2	
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$			t-2:t-2	
$\Delta \sigma_{i,t}$			t-2:t-2	

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 7
Re-Arranged ADL[2,2] Specification

	(1)	(2)	(3)	(4)
	Within	GMM DIFF	GMM SYS	OLS
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	-.314	-.040	-.049	-.003
	(.022)***	(.043)	(.025)*	(.001)**
$\Delta k_{i,t-1}$	-.091	-.180	-.244	.036
	(.023)***	(.090)**	(.114)**	(.027)
$\Delta y_{i,t-1}$	-.073	-.044	.055	.032
	(.021)***	(.069)	(.055)	(.022)
$\Delta y_{i,t}$	.386	.318	.269	.399
	(.018)***	(.098)***	(.105)**	(.026)***
$(k_{i,t-1} - y_{i,t-1})$	-.676	-.330	-.162	-.010
	(.027)***	(.081)***	(.054)***	(.003)***
Sargan/Hansen		.406	.462	
DoF		75	135	
AR1		-2.594	-2.294	
AR2		-2.555	-2.66	
AR3		-.641	.056	
AR4		.497	.482	
Instruments For Equations in First Differences				
$\Delta k_{i,t}$		t-3:t-4	t-3:t-4	
$\Delta y_{i,t}$		t-3:t-4	t-3:t-4	
$(k_{i,t} - y_{i,t})$		t-3:t-4	t-3:t-4	
$\sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4	t-3:t-4	
$\sigma_{i,t}$		t-3:t-4	t-3:t-4	
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$			t-2:t-2	
$\Delta^2 y_{i,t}$			t-2:t-2	
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$			t-2:t-2	
$\Delta\sigma_{i,t}$			t-2:t-2	

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 8
Error Correction Investment Specification 2nd Order Lags

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.137	-.116	-.188	-.080
	(.102)	(.131)	(.115)	(.112)
$\Delta y_{i,t-1}$	.073	.078	.071	.076
	(.051)	(.051)	(.052)	(.051)
$\sigma_{i,t} * \Delta y_{i,t}$		-.207		-.237
		(.093)**		(.089)***
$\Delta y_{i,t}$	.418	.715	.393	.774
	(.105)***	(.173)***	(.100)***	(.171)***
$(k_{i,t-1} - y_{i,t-1})$	-.076	-.049	-.065	-.054
	(.030)**	(.028)*	(.029)**	(.029)*
$\Delta\sigma_{i,t}$		-.030	-.032	
		(.018)*	(.018)*	
$\sigma_{i,t-1}$		-.029	-.043	
		(.018)	(.017)***	
Sargan/Hansen	.194	.397	.323	.351
DoF	136	133	134	135
AR1	-3.624	-2.985	-2.991	-3.541
AR2	-1.918	-1.424	-1.991	-1.472
AR3	.029	-.121	.023	-.123
AR4	.611	.589	.573	.708
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 9

Error Correction Investment Specification 1st Order Lags

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta y_{i,t}$	.378	.684	.351	.752
	(.094)***	(.168)***	(.098)***	(.162)***
$\sigma_{i,t} * \Delta y_{i,t}$		-.188		-.218
		(.083)**		(.078)***
$(k_{i,t-1} - y_{i,t-1})$	-.076	-.054	-.066	-.059
	(.030)**	(.027)**	(.028)**	(.028)**
$\Delta \sigma_{i,t}$		-.024	-.027	
		(.019)	(.019)	
$\sigma_{i,t-1}$		-.027	-.038	
		(.015)*	(.014)***	
Sargan/Hansen	.441	.547	.516	.589
DoF	138	135	136	137
AR1	-8.591	-9.131	-8.834	-8.932
AR2	-.225	-.112	-.117	-.266
AR3	-.107	.03	-.128	.065
AR4	.524	.452	.464	.561
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

See Note to Tables 6, 7 and 8.

Table 10
Average Q Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$			.029	-.015	-.042	-.022
			(.119)	(.103)	(.105)	(.098)
$\Delta y_{i,t-1}$			.039	.033	.038	.048
			(.049)	(.043)	(.044)	(.042)
$\Delta y_{i,t}$		.303	.271	.415	.232	.446
		(.069)***	(.089)***	(.128)***	(.079)***	(.123)***
$\sigma_{i,t} * \Delta y_{i,t}$				-.107		-.118
				(.063)*		(.062)*
$Q_{i,t}$	.020	.015	.015	.020	.019	.020
	(.011)*	(.004)***	(.004)***	(.005)***	(.005)***	(.005)***
$\Delta\sigma_{i,t}$				-.012	-.016	
				(.015)	(.015)	
$\sigma_{i,t-1}$				-.017	-.027	
				(.013)	(.013)**	
Sargan/Hansen	.617	.684	.571	.734	.633	.606
DoF	41	91	89	147	148	149
AR1	-10.149	-9.24	-4.309	-4.528	-4.326	-4.606
AR2	-1.022	-.113	-.458	-.709	-.864	-.924
AR3	.115	-.041	-.076	-.262	-.113	-.194
AR4	-.167	.8	.83	.953	.831	.985
Instruments For Equations in First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$		t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta\frac{I_{i,t}}{K_{i,t}}$		t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$		t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$		t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t} * \Delta y_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2

See Note to Tables 6, 7 and 8.

Table 11
Adjusted Uncertainty Terms

	Adjusted Uncertainty Measures			
	(1)	(2)	(3)	(4)
	mean	standard deviation	minimum	maximum
$\sigma_{i,t}$	1.533	0.659	0.446	4.357
$g_{i,t} * \sigma_{i,t}$	1.299	0.549	0.313	3.977
$\sigma^w_{i,t}$	1.212	0.522	0.278	3.595
$w\sigma_{i,t}$	1.739	0.706	0.274	7.722

Table 12
Effects of Financial Leverage

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.116	-.178	-.135			
	(.131)	(.123)	(.112)			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.015	-.078	-.060
				(.103)	(.109)	(.108)
$\Delta y_{i,t-1}$	.078	.089	.084	.033	.046	.058
	(.051)	(.050)*	(.053)	(.043)	(.044)	(.044)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207			-.107		
	(.093)**			(.063)*		
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$		-.215	-.232		-.073	-.094
		(.124)*	(.123)*		(.085)	(.086)
$\Delta y_{i,t}$	.715	.667	.700	.415	.347	.387
	(.173)***	(.170)***	(.172)***	(.128)***	(.134)***	(.127)***
$Q_{i,t}$				.020	.019	.019
				(.005)***	(.005)***	(.005)***
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.051	-.054			
	(.028)*	(.030)*	(.030)*			
$\Delta\sigma_{i,t}$	-.030			-.012		
	(.018)*			(.015)		
$\sigma_{i,t-1}$	-.029			-.017		
	(.018)			(.013)		
$\Delta(g_{i,t} * \sigma_{i,t})$		-.037			-.018	
		(.023)			(.021)	
$g_{i,t-1} * \sigma_{i,t-1}$		-.045			-.024	
		(.022)**			(.017)	
Sargan/Hansen	.397	.286	.212	.734	.411	.463
DoF	133	133	135	147	147	149
AR1	-2.985	-2.844	-3.274	-4.528	-4.025	-4.163
AR2	-1.424	-1.943	-1.842	-.709	-1.146	-1.172
AR3	-.121	-.113	-.1	-.262	-.196	-.116
AR4	.589	.515	.628	.953	.833	.881
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$k_{i,t} - y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$g_{i,t} * \sigma i, t$		t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$						
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2			t-2:t-2		
$\Delta\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2			t-2:t-2		
$\Delta(g_{i,t} * \sigma_{i,t})$		t-2:t-2	t-2:t-2		t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t} * \Delta y_{i,t})$		t-2:t-2	t-2:t-2		t-2:t-2	t-2:t-2

See Note to Tables 6, 7 and 8.

Table 13

Weekend Effects and Weekly Standard Deviation in Stock Returns

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{_{i,t}}{K_{i,t}}$	$\frac{_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.099	-.155		
	(.137)	(.139)		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.019	-.028
			(.104)	(.107)
$\Delta y_{i,t-1}$	.079	.077	.027	.051
	(.051)	(.058)	(.043)	(.044)
$\sigma^w_{i,t} * \Delta y_{i,t}$	-.268		-.143	
	(.125)**		(.083)*	
$w\sigma_{i,t} * \Delta y_{i,t}$		-.129		-.069
		(.093)		(.057)
$\Delta y_{i,t}$	.703	.663	.422	.389
	(.177)***	(.200)***	(.132)***	(.137)***
$Q_{i,t}$			.020	.018
			(.005)***	(.005)***
$(k_{i,t-1} - y_{i,t-1})$	-.048	-.066		
	(.029)*	(.028)**		
$\Delta\sigma^w_{i,t}$	-.039		-.018	
	(.022)*		(.019)	
$\sigma^w_{i,t-1}$	-.034		-.022	
	(.024)		(.018)	
$\Delta w\sigma_{i,t}$		-.028		-.014
		(.015)*		(.013)
$w\sigma_{i,t-1}$		-.041		-.026
		(.021)**		(.013)*
Sargan/Hansen	.461	.39	.764	.766
DoF	133	133	147	147
AR1	-2.931	-2.698	-4.403	-4.339
AR2	-1.258	-1.612	-.678	-.862
AR3	-.075	.019	-.29	-.012
AR4	.526	.554	.93	.802
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4		
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$k_{i,t} - y_{i,t}$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma^w_{i,t}$	t-3:t-4		t-3:t-4	
$\sigma^w_{i,t} * \Delta y_{i,t}$	t-3:t-4		t-3:t-4	
$w\sigma_{i,t}$		t-3:t-4		t-3:t-4
$w\sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4		t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta\frac{I_{i,t}}{K_{i,t}}$			t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta\sigma^w_{i,t}$	t-2:t-2		t-2:t-2	
$\Delta\sigma^w_{i,t} * \Delta y_{i,t}$	t-2:t-2		t-2:t-2	
$\Delta w\sigma_{i,t}$		t-2:t-2		t-2:t-2
$\Delta w\sigma_{i,t} * \Delta y_{i,t}$		t-2:t-2		t-2:t-2

See Note to Tables 6, 7 and 8.

Table 14

$\Delta k_{i,t}$ Hybrid Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.116	-.120	-.148	-.154	-.126	-.089
	(.131)	(.101)	(.107)	(.108)	(.122)	(.146)
$\Delta y_{i,t-1}$	.078	.007	.047	.055	.058	.089
	(.051)	(.053)	(.049)	(.050)	(.050)	(.058)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207	-.184	-.180	-.190	-.133	-.121
	(.093)**	(.089)**	(.077)**	(.071)***	(.082)	(.106)
$\Delta y_{i,t}$	.715	.609	.580	.591	.487	.522
	(.173)***	(.171)***	(.142)***	(.137)***	(.156)***	(.216)**
$Q_{i,t}$		.044	.028	.029	.027	
		(.009)***	(.006)***	(.005)***	(.006)***	
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.024	-.010			
	(.028)*	(.023)	(.020)			
$\Delta \sigma_{i,t}$	-.030	-.018	-.021	-.021	.0007	-.002
	(.018)*	(.016)	(.015)	(.015)	(.019)	(.021)
$\sigma_{i,t-1}$	-.029	-.011	-.017	-.018	-.015	-.029
	(.018)	(.016)	(.016)	(.016)	(.016)	(.017)*
Sargan/Hansen	.397	.672	.664	.692	.806	.594
DoF	133	132	164	165	144	113
AR1	-2.985	-3.885	-3.543	-3.585	-3.356	-2.994
AR2	-1.424	-1.214	-1.63	-1.676	-1.451	-1.171
AR3	-.121	-.413	-.191	-.165	-.054	.145
AR4	.589	.812	.744	.755	.902	.779
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

See Note to Tables 6, 7 and 8.

Table 15

$\frac{I_{i,t}}{K_{i,t}}$ Hybrid Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.015	-.009	-.049	-.047	-.049	-.020
	(.103)	(.106)	(.093)	(.103)	(.118)	(.139)
LD.ly	.033	.032	.040	.065	.061	.060
	(.043)	(.042)	(.040)	(.042)	(.043)	(.049)
sdret-dly	-.107	-.115	-.124	-.065	-.115	-.089
	(.063)*	(.067)*	(.057)**	(.068)	(.070)*	(.074)
D.ly	.415	.430	.446	.410	.489	.421
	(.128)***	(.132)***	(.119)***	(.139)***	(.143)***	(.165)**
Q	.020	.020	.021			
	(.005)***	(.005)***	(.005)***			
L.ecm		.004	-.0009	-.028	-.019	
		(.013)	(.014)	(.014)**	(.019)	
D.sdret	-.012	-.013	-.022	-.023	-.037	-.025
	(.015)	(.015)	(.011)*	(.011)**	(.013)***	(.017)
L.sdret	-.017	-.016	-.018	-.036	-.036	-.033
	(.013)	(.014)	(.013)	(.013)***	(.014)**	(.015)**
Sargan/Hansen	.734	.709	.767	.574	.658	.734
DoF	147	146	167	168	136	116
AR1	-4.528	-4.4	-4.489	-4.219	-3.806	-3.542
AR2	-.709	-.644	-.948	-1.185	-.966	-.737
AR3	-.262	-.278	-.324	-.048	-.228	-.088
AR4	.953	.962	.927	.757	.718	.741
Instruments For Equations in First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$			t-3:t-4	t-3:t-4	t-3:t-4	
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4		
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta \frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2		
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
	t-3:t-4					
$\Delta(\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

See Note to Tables 6, 7 and 8.

Table D1
Firm Industry Coverage

Industry	Frequency	Percentage
Basic Industries	692	14.10
Capital Goods	1 319	26.87
Consumer Durables	153	3.12
Consumer Non-Durables	791	16.12
Consumer Services	1 203	24.51
Energy	90	1.83
Health Care	175	3.57
Public Utilities	123	2.51
Technology	235	4.79
Transportation	127	2.59
Total	4 908	100.00

Table D2
Summary Statistics

	(1)	(2)	(3)	(4)
	mean	std. dev.	min	max
$\Delta k_{i,t}$	0.0959	0.1560	-0.7707	1.2294
$\frac{I_{i,t}}{K_{i,t}}$	0.1494	0.1273	-0.9498	0.7316
$\Delta y_{i,t}$	0.0467	0.1618	-1.0091	1.0373
$(k_{i,t} - y_{i,t})$	-1.0315	0.8372	-4.6187	2.5615
$Q_{i,t}$	1.4056	1.7729	-0.8603	13.4544
$\sigma_{i,t}$	1.5330	0.6586	0.4465	4.3567

Table D3
Correlation

	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\Delta y_{i,t}$	$(k_{i,t-1} - y_{i,t-1})$	$Q_{i,t}$	$\sigma_{i,t}$
	(1)	(2)	(3)	(4)		
$\Delta k_{i,t}$	1.0000					
$\frac{I_{i,t}}{K_{i,t}}$	0.9621	1.0000				
$\Delta y_{i,t}$	0.4537	0.4394	1.0000			
$(k_{i,t-1} - y_{i,t-1})$	-0.0730	-0.0526	0.0732	1.0000		
$Q_{i,t}$	0.2428	0.2741	0.2199	-0.2517	1.0000	
$\sigma_{i,t}$	-0.1540	-0.1172	-0.1598	0.0247	-0.0922	1.0000

1.13 Chapter 1 Estimation Results Using Restricted Instrument Set

Table A1
Error Correction Investment Specification: Instruments
For Equation in First Differences Lagged t-2:t-4

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	.011	-.022	-.036	-.044	-.014	-.031
	(.031)	(.038)	(.035)	(.035)	(.039)	(.034)
$\Delta y_{i,t-1}$	-.051	-.058	-.065	-.055	-.054	-.059
	(.029)*	(.032)*	(.032)**	(.030)*	(.030)*	(.033)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.154	-.101	-.072	-.152	-.154	-.068
	(.065)**	(.067)	(.078)	(.085)*	(.079)*	(.074)
$\Delta y_{i,t}$	.761	.582	.504	.611	.625	.505
	(.124)***	(.146)***	(.145)***	(.158)***	(.140)***	(.143)***
$(k_{i,t-1} - y_{i,t-1})$	-.484	-.141	-.064	-.038	-.091	-.084
	(.086)***	(.054)***	(.044)	(.028)	(.046)**	(.053)
$\Delta\sigma_{i,t}$	-.013	-.040	-.045	-.042	-.036	-.046
	(.015)	(.018)**	(.019)**	(.019)**	(.016)**	(.018)***
$\sigma_{i,t-1}$	-.014	-.042	-.053	-.051	-.036	-.057
	(.017)	(.023)*	(.022)**	(.024)**	(.016)**	(.021)***
Sargan/Hansen	.775	.247	.41	.255	.568	.443
DoF	136	147	147	148	148	147
AR1	-4.844	-8.375	-8.084	-8.684	-8.017	-8.048
AR2	-1.151	-.524	-.453	-.667	-.431	-.483
AR3	-.868	-.453	-.424	-.428	-.415	-.422
AR4	.538	.453	.467	.506	.461	.473
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\Delta y_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\sigma_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$		t-1:t-1				
$\Delta^2 y_{i,t}$			t-1:t-1			
$\Delta(k_{i,t-1} - y_{i,t-1})$				t-1:t-1		
$\Delta\sigma_{i,t}$					t-1:t-1	
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						t-1:t-1
Difference Sargan Test						
(1-p-value)		0.999	0.992	0.999	0.929	0.987

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table A2
Error Correction Investment Specification: Instruments
For Equation in First Differences Lagged t-3:t-4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\sigma_{i,t} * \Delta y_{i,t}$	-.216	-.313	-.295	-.251	-.302	-.306	-.207
	(.109)**	(.105)***	(.122)**	(.112)**	(.093)***	(.114)***	(.093)**
$\Delta y_{i,t}$	.687	.723	.727	.698	.739	.752	.715
	(.184)***	(.182)***	(.194)***	(.190)***	(.171)***	(.180)***	(.173)***
$(k_{i,t-1} - y_{i,t-1})$	-.326	-.119	-.041	-.022	-.084	-.071	-.049
	(.100)***	(.044)***	(.031)	(.025)	(.034)**	(.032)**	(.028)*
$\Delta\sigma_{i,t}$	-.024	-.053	-.059	-.066	-.047	-.053	-.030
	(.019)	(.022)**	(.022)***	(.021)***	(.018)***	(.020)***	(.018)*
$\sigma_{i,t-1}$	-.051	-.063	-.082	-.095	-.051	-.064	-.029
	(.026)*	(.037)*	(.036)**	(.036)***	(.020)**	(.031)**	(.018)
Sargan/Hansen	.665	.772	.729	.567	.751	.774	.397
DoF	92	102	112	113	113	112	133
AR1	-1.9	-3.669	-3.195	-3.173	-3.313	-3.395	-2.985
AR2	-2.132	-2.496	-1.903	-2.323	-2.248	-2.259	-1.424
AR3	-.67	-.168	-.101	-.031	-.088	-.122	-.121
AR4	.732	.53	.559	.55	.524	.55	.589
Instruments For Equations in First Differences							
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels							
$\Delta^2 k_{i,t}$		t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$			t-2:t-2				t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$				t-2:t-2			
$\Delta\sigma_{i,t}$					t-2:t-2		t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						t-2:t-2	t-2:t-2
Difference Sargan Test							
(1-p-value)		0.136	0.674	0.934	0.591	0.506	0.862

See note to Table A1.

Table A3

Average Q Investment Specifications: Instrument Selection

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\sigma_{i,t} * \Delta y_{i,t}$	-.077	-.094	-.058	-.098	-.088	-.061	-.032
	(.072)	(.067)	(.069)	(.061)	(.065)	(.068)	(.065)
$\Delta y_{i,t}$	.351	.380	.300	.398	.374	.311	.276
	(.124)***	(.116)***	(.119)**	(.110)***	(.113)***	(.117)***	(.114)**
$Q_{i,t}$	.033	.032	.030	.020	.029	.032	.019
	(.007)***	(.007)***	(.006)***	(.003)***	(.006)***	(.006)***	(.003)***
$\Delta\sigma_{i,t}$	-.019	-.023	-.025	-.019	-.029	-.025	-.025
	(.015)	(.014)	(.014)*	(.014)	(.012)**	(.014)*	(.013)*
$\sigma_{i,t-1}$	-.017	-.024	-.026	-.021	-.030	-.028	-.032
	(.015)	(.015)	(.014)*	(.014)	(.011)***	(.014)**	(.010)***
Sargan/Hansen	.725	.576	.448	.581	.507	.597	.41
DoF	154	166	177	178	178	177	212
AR1	-9.757	-9.789	-9.727	-9.865	-9.804	-9.731	-9.8
AR2	.045	.045	.032	-.126	.063	.062	-.087
AR3	-.208	-.195	-.263	-.096	-.18	-.254	-.178
AR4	.81	.808	.768	.759	.741	.791	.731
Instruments For Equations in First Differences							
$\frac{I_{i,t}}{K_{i,t}}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\Delta y_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$Q_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\sigma_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4	t-2:t-4
Instruments For Equations in Levels							
$\Delta\frac{I_{i,t}}{K_{i,t}}$		t-1:t-1	t-1:t-1	t-1:t-1	t-1:t-1	t-1:t-1	t-1:t-1
$\Delta^2 y_{i,t}$			t-1:t-1				t-1:t-1
$\Delta Q_{i,t}$				t-1:t-1			t-1:t-1
$\Delta\sigma_{i,t}$					t-1:t-1		t-1:t-1
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						t-1:t-1	t-1:t-1
Difference Sargan Test							
(1-p-values)		0.906	0.889	0.526	0.766	0.461	0.910

See note to Table A1.

Table A4
Average Q Investment Specification: Timing of Instruments

	(1)	(2)	(3)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.015
			(.103)
$\Delta y_{i,t-1}$			.033
			(.043)
$\sigma_{i,t} * \Delta y_{i,t}$	-.032	-.111	-.107
	(.065)	(.062)*	(.063)*
$\Delta y_{i,t}$	.276	.434	.415
	(.114)**	(.119)***	(.128)***
$Q_{i,t}$	.019	.020	.020
	(.003)***	(.004)***	(.005)***
$\Delta \sigma_{i,t}$	-.025	-.009	-.012
	(.013)*	(.014)	(.015)
$\sigma_{i,t-1}$	-.032	-.016	-.017
	(.010)***	(.012)	(.013)
Sargan/Hansen	.41	.739	.734
DoF	212	149	147
AR1	-9.8	-9.521	-4.528
AR2	-.087	-.174	-.709
AR3	-.178	-.058	-.262
AR4	.731	.897	.953
Instruments For Equations in First Differences			
$\frac{I_{i,t}}{K_{i,t}}$	t-2:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-2:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-2:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-2:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels			
$\Delta \frac{I_{i,t}}{K_{i,t}}$	t-1:t-1	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$			
$\Delta Q_{i,t}$	t-1:t-1	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-1:t-1	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-1:t-1	t-2:t-2	t-2:t-2
Difference Sargan Test			
(1-p-values)		0.902	

See note to Table A1.

Table A5
Alternative Instrumentation with Adjusted Uncertainty Measures

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.195	-.178		
	(.105)*	(.123)		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.111	-.078
			(.115)	(.109)
$\Delta y_{i,t-1}$	.110	.089	.068	.046
	(.051)**	(.050)*	(.046)	(.044)
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	-.357	-.215	-.146	-.073
	(.116)***	(.124)*	(.089)*	(.085)
$\Delta y_{i,t}$	.775	.667	.429	.347
	(.160)***	(.170)***	(.135)***	(.134)***
$(k_{i,t-1} - y_{i,t-1})$	-.064	-.051		
	(.028)**	(.030)*		
$Q_{i,t}$			.019	.019
			(.005)***	(.005)***
$\Delta(g_{i,t} * \sigma_{i,t})$	-.051	-.037	-.025	-.018
	(.023)**	(.023)	(.021)	(.021)
$g_{i,t-1} * \sigma_{i,t-1}$	-.058	-.045	-.026	-.024
	(.022)***	(.022)**	(.018)	(.017)
Sargan/Hansen	.729	.286	.584	.411
DoF	123	133	137	147
AR1	-3.114	-2.844	-3.686	-4.025
AR2	-2.396	-1.943	-1.41	-1.146
AR3	-.144	-.113	-.224	-.196
AR4	.388	.515	.811	.833
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t}}{K_{i,t}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$k_{i,t} - y_{i,t}$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta^2 y_{i,t}$		t-2:t-2		t-2:t-2
$\Delta\frac{I_{i,t}}{K_{i,t}}$			t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
Difference Sargan Test				
(1-p-value)		0.999		0.701

See note to Table A1.

TABLE A6
Error Correction Investment Specification -
Grid of Coefficients on $(k_{i,t-1} - y_{i,t-1})$ Terms

	(1)	(2)	(3)	(4)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.116	-.134	-.141	-.139	-.124
	(.131)	(.113)	(.112)	(.115)	(.120)
$\Delta y_{i,t-1}$	.078	.058	.037	.019	-.009
	(.051)	(.052)	(.053)	(.055)	(.058)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207	-.173	-.148	-.131	-.108
	(.093)**	(.096)*	(.102)	(.105)	(.107)
$\Delta y_{i,t}$	.715	.687	.656	.622	.569
	(.173)***	(.191)***	(.205)***	(.211)***	(.218)***
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.1	-.15	-.2	-.3
	(.028)*	(fit)	(fit)	(fit)	(fit)
$\sigma_{i,t-1}$	-.029	-.028	-.028	-.028	-.024
	(.018)	(.018)	(.019)	(.021)	(.024)
$\Delta\sigma_{i,t}$	-.030	-.028	-.025	-.022	-.015
	(.018)*	(.017)	(.018)	(.018)	(.019)
Sargan/Hansen	.397	.4	.393	.387	.371
DoF	133	134	134	134	134
AR1	-2.985	-3.318	-3.201	-3.033	-2.722
AR2	-1.424	-1.675	-1.709	-1.699	-1.654
AR3	-.121	-.199	-.282	-.363	-.548
AR4	.589	.597	.609	.614	.614
Goodness of Fit	.413	.332	.264	.212	.151
Instruments For Equations in First Differences					
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$					
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

See note to Table A1. Goodness of Fit reports the squared correlation between the dependent variable and the value predicted by the estimated model.

TABLE A7

Error Correction Investment Specification with Alternative Instruments - Grid of Coefficients on $(k_{i,t-1} - y_{i,t-1})$ Terms

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.145	-.147	-.147	-.150
	(.091)	(.091)	(.097)	(.115)
$\Delta y_{i,t-1}$	.105	.099	.089	.073
	(.049)**	(.049)**	(.050)*	(.055)
$\sigma_{i,t} * \Delta y_{i,t}$	-.313	-.300	-.286	-.268
	(.105)***	(.099)***	(.097)***	(.098)***
$\Delta y_{i,t}$	.723	.717	.715	.736
	(.182)***	(.180)***	(.179)***	(.185)***
$(k_{i,t-1} - y_{i,t-1})$	-.119	-.15	-.2	-.3
	(.044)***	(fit)	(fit)	(fit)
$\sigma_{i,t-1}$	-.063	-.058	-.049	-.037
	(.037)*	(.035)*	(.034)	(.036)
$\Delta\sigma_{i,t}$	-.053	-.048	-.041	-.031
	(.022)**	(.021)**	(.021)**	(.022)
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.00	0.00	0.00	0.02
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = 0$	0.00	0.00	0.00	0.01
H_0: $\Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.06	0.06	0.14	0.37
Sargan/Hansen	.772	.796	.786	.691
DoF	102	103	103	103
AR1	-3.669	-3.707	-3.249	-2.31
AR2	-2.496	-2.598	-2.543	-2.309
AR3	-.168	-.206	-.283	-.481
AR4	.53	.541	.557	.589
Goodness of Fit	.227	.202	.171	.136
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta\sigma_{i,t}$				
$\Delta\sigma_{i,t} * \Delta y_{i,t}$				

See note to Table A1.

TABLE A8
Average Q Investment Specification -
Grid of Coefficients on $Q_{i,t}$ Terms

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.015	-.140	-.227	-.298	-.402
	(.103)	(.114)	(.144)	(.163)*	(.208)*
$\Delta y_{i,t-1}$	.033	-.002	-.028	-.059	-.131
	(.043)	(.054)	(.064)	(.072)	(.096)
$\Delta y_{i,t}$	.415	.408	.289	.210	.131
	(.128)***	(.178)**	(.196)	(.218)	(.301)
$\sigma_{i,t} * \Delta y_{i,t}$	-.107	-.143	-.116	-.106	-.111
	(.063)*	(.083)*	(.085)	(.097)	(.148)
$Q_{i,t}$	.020	.1/Qav	.15/Qav	.2/Qav	.3/Qav
	(.005)***	(fit)	(fit)	(fit)	(fit)
$\Delta\sigma_{i,t}$	-.012	-.006	.003	.008	.021
	(.015)	(.015)	(.017)	(.020)	(.028)
$\sigma_{i,t-1}$	-.017	.012	.034	.056	.106
	(.013)	(.018)	(.022)	(.026)**	(.035)***
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.03	0.35	0.32	0.13	0.02
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = 0$	0.16	0.21	0.38	0.48	0.53
H_0: $\Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.40	0.63	0.27	0.07	0.01
Sargan/Hansen	.734	.162	.019	.004	.0004
DoF	147	148	148	148	148
AR1	-4.528	-3.319	-2.274	-1.758	-.989
AR2	-.709	-1.137	-1.39	-1.618	-1.703
AR3	-.262	-.938	-1.391	-1.709	-1.908
AR4	.953	1.088	.779	.25	-.548
Goodness of Fit	.455	.301	.242	.211	.187
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

See note to Table A1.

TABLE A9

Average Q Investment Specification with Alternative Instruments - Grid of Coefficients on $Q_{i,t}$ Terms

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.081	-.097	-.122	-.138	-.141
	(.126)	(.122)	(.131)	(.147)	(.193)
$\Delta y_{i,t-1}$	.057	.014	-.015	-.030	-.052
	(.050)	(.052)	(.059)	(.066)	(.081)
$\Delta y_{i,t}$	.476	.420	.349	.293	.205
	(.181)***	(.214)**	(.244)	(.277)	(.369)
$\sigma_{i,t} * \Delta y_{i,t}$	-.164	-.125	-.078	-.044	.016
	(.097)*	(.115)	(.126)	(.142)	(.194)
$Q_{i,t}$	.027	.1/Qav	.15/Qav	.2/Qav	.3/Qav
	(.009)***	(fit)	(fit)	(fit)	(fit)
$\Delta\sigma_{i,t}$	-.030	-.023	-.015	-.002	.032
	(.018)*	(.020)	(.024)	(.028)	(.038)
$\sigma_{i,t-1}$	-.036	-.010	.011	.041	.115
	(.029)	(.029)	(.036)	(.044)	(.059)*
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.06	0.33	0.67	0.63	0.18
H_0: $\sigma_{i,t}\Delta y_{i,t} = \Delta\sigma_{i,t} = 0$	0.04	0.18	0.62	0.95	0.70
H_0: $\Delta\sigma_{i,t} = \sigma_{i,t-1} = 0$	0.24	0.45	0.53	0.43	0.13
Sargan/Hansen	.803	.504	.188	.043	.003
AR1	-3.454	-3.638	-3.356	-2.948	-2.07
AR2	-1.04	-.785	-.624	-.481	-.185
AR3	-.386	-.833	-1.116	-1.314	-1.496
AR4	1.008	1.057	.858	.514	-.185
Goodness of Fit	.409	.335	.301	.278	.254
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$					
$\Delta Q_{i,t}$					
$\Delta\sigma_{i,t}$					
$\Delta\sigma_{i,t} * \Delta y_{i,t}$					

See note to Table A1.

Table 8*: Alternative Instruments
Error Correction Investment Specification 2nd Order Lags

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.246	-.145	-.212	-.158
	(.104)**	(.091)	(.086)**	(.093)*
$\Delta y_{i,t-1}$	.069	.105	.083	.096
	(.054)	(.049)**	(.051)	(.050)*
$\sigma_{i,t} * \Delta y_{i,t}$		-.313		-.346
		(.105)***		(.095)***
$\Delta y_{i,t}$	.314	.723	.260	.824
	(.106)***	(.182)***	(.110)**	(.181)***
$(k_{i,t-1} - y_{i,t-1})$	-.148	-.119	-.123	-.137
	(.049)***	(.044)***	(.044)***	(.047)***
$\Delta\sigma_{i,t}$		-.063	-.096	
		(.037)*	(.038)**	
$\sigma_{i,t-1}$		-.053	-.063	
		(.022)**	(.024)***	
Sargan/Hansen	.313	.772	.504	.633
DoF	105	102	103	104
AR1	-2.699	-3.669	-3.795	-3.394
AR2	-3.006	-2.496	-3.187	-2.829
AR3	.071	-.168	.041	-.103
AR4	.511	.53	.517	.653
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta\sigma_{i,t}$				
$\Delta\sigma_{i,t} * \Delta y_{i,t}$				

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 9*: Alternative Instruments
Error Correction Investment Specification 1st Order Lags

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta y_{i,t}$	.279	.694	.242	.776
	(.101)***	(.171)***	(.104)**	(.176)***
$\sigma_{i,t} * \Delta y_{i,t}$		-.274		-.303
		(.092)***		(.087)***
$(k_{i,t-1} - y_{i,t-1})$	-.142	-.134	-.137	-.138
	(.051)***	(.045)***	(.044)***	(.052)***
$\sigma_{i,t-1}$		-.061	-.076	
		(.029)**	(.030)**	
$\Delta\sigma_{i,t}$		-.048	-.053	
		(.021)**	(.022)**	
Sargan/Hansen	.659	.866	.782	.791
DoF	107	104	105	106
AR1	-7.729	-8.13	-8.106	-7.572
AR2	-.612	-.524	-.48	-.767
AR3	-.22	-.086	-.309	.018
AR4	.464	.282	.322	.501
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta\sigma_{i,t}$				
$\Delta\sigma_{i,t} * \Delta y_{i,t}$				

See note to Table 8*: Alternative Instruments.

Table 10*: Alternative Instruments
Average Q Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$			.073	-.081	-.090	-.085
			(.138)	(.126)	(.127)	(.116)
$\Delta y_{i,t-1}$			.022	.057	.056	.064
			(.059)	(.050)	(.050)	(.050)
$\Delta y_{i,t}$		.378	.325	.476	.197	.496
		(.100)***	(.108)***	(.181)***	(.083)**	(.164)***
$\sigma_{i,t} * \Delta y_{i,t}$				-.164		-.164
				(.097)*		(.086)*
$Q_{i,t}$	.020	.024	.023	.027	.028	.031
	(.011)*	(.009)***	(.010)**	(.009)***	(.009)***	(.009)***
$\Delta\sigma_{i,t}$				-.030	-.034	
				(.018)*	(.017)**	
$\sigma_{i,t-1}$				-.036	-.047	
				(.029)	(.028)*	
Sargan/Hansen	.617	.696	.654	.803	.728	.643
DoF	41	70	68	105	106	107
AR1	-10.149	-8.416	-3.874	-3.454	-3.457	-3.654
AR2	-1.022	.054	-.065	-1.04	-1.036	-1.282
AR3	.115	.028	-.209	-.386	-.206	-.268
AR4	-.167	.877	.933	1.008	.852	1.101
Instruments For Equations in First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$		t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta\frac{I_{i,t}}{K_{i,t}}$		t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta\sigma_{i,t}$						
$\Delta\sigma_{i,t} * \Delta y_{i,t}$						

See note to Table 8*: Alternative Instruments.

Table 12*: Alternative Instruments
Effects of Financial Leverage

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.145	-.153	-.166			
	(.091)	(.088)*	(.090)*			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.081	-.139	-.115
				(.126)	(.137)	(.120)
$\Delta y_{i,t-1}$	.105	.098	.086	.057	.067	.070
	(.049)**	(.049)**	(.050)*	(.050)	(.054)	(.052)
$\sigma_{i,t} * \Delta y_{i,t}$	-.313			-.164		
	(.105)***			(.097)*		
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$		-.366	-.385		-.139	-.129
		(.126)***	(.124)***		(.122)	(.113)
$\Delta y_{i,t}$	.723	.732	.794	.476	.384	.394
	(.182)***	(.184)***	(.187)***	(.181)***	(.188)**	(.172)**
$Q_{i,t}$				.027	.025	.030
				(.009)***	(.010)***	(.009)***
$(k_{i,t-1} - y_{i,t-1})$	-.119	-.124	-.139			
	(.044)***	(.044)***	(.048)***			
$\sigma_{i,t-1}$	-.063			-.036		
	(.037)*			(.029)		
$\Delta\sigma_{i,t}$	-.053			-.030		
	(.022)**			(.018)*		
$g_{i,t-1} * \sigma_{i,t-1}$		-.077			-.041	
		(.042)*			(.035)	
$\Delta(g_{i,t} * \sigma_{i,t})$		-.059			-.032	
		(.025)**			(.022)	
Sargan/Hansen	.772	.681	.543	.803	.283	.425
DoF	102	102	104	105	105	107
AR1	-3.669	-3.746	-3.525	-3.454	-3.026	-3.473
AR2	-2.496	-2.548	-2.855	-1.04	-1.339	-1.415
AR3	-.168	-.262	-.191	-.386	-.285	-.183
AR4	.53	.399	.541	1.008	.838	.953
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$k_{i,t} - y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$g_{i,t} * \sigma i, t$		t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta(k_{i,t} - y_{i,t})$						
$\Delta Q_{i,t}$ $\Delta\sigma_{i,t}$						
$\Delta\sigma_{i,t} * \Delta y_{i,t}$						
$\Delta(g_{i,t} * \sigma_{i,t})$						
$\Delta(g_{i,t} * \sigma_{i,t} * \Delta y_{i,t})$						

See note to Table 8*: Alternative Instruments.

Table 13*: Alternative Instruments
Weekend Effects and Weekly Standard Deviation in Stock Returns

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.164	-.230		
	(.093)*	(.100)**		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.100	-.134
			(.135)	(.126)
$\Delta y_{i,t-1}$	.108	.121	.060	.077
	(.050)**	(.052)**	(.052)	(.051)
$\sigma^w_{i,t} * \Delta y_{i,t}$	-.393		-.204	
	(.137)***		(.135)	
$w\sigma_{i,t} * \Delta y_{i,t}$		-.232		-.132
		(.105)**		(.092)
$\Delta y_{i,t}$	.724	.636	.466	.443
	(.187)***	(.199)***	(.193)**	(.193)**
$Q_{i,t}$			.028	.021
			(.009)***	(.010)**
$(k_{i,t-1} - y_{i,t-1})$	-.123	-.113		
	(.044)***	(.048)**		
$\sigma^w_{i,t-1}$	-.076		-.048	
	(.047)		(.039)	
$\Delta\sigma^w_{i,t}$	-.063		-.035	
	(.028)**		(.023)	
$w\sigma_{i,t-1}$		-.082		-.049
		(.034)**		(.028)*
$\Delta w\sigma_{i,t}$		-.052		-.028
		(.020)**		(.017)*
Sargan/Hansen	.762	.603	.79	.743
DoF	102	102	105	105
AR1	-3.503	-2.838	-3.137	-3.132
AR2	-2.634	-3.061	-1.112	-1.505
AR3	-.108	.2	-.341	.008
AR4	.475	.447	.982	.775
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4		
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$k_{i,t} - y_{i,t}$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma^w_{i,t}$	t-3:t-4		t-3:t-4	
$\sigma^w_{i,t} * \Delta y_{i,t}$	t-3:t-4		t-3:t-4	
$w\sigma_{i,t}$		t-3:t-4		t-3:t-4
$w\sigma_{i,t} * \Delta y_{i,t}$		t-3:t-4		t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta\frac{I_{i,t}}{K_{i,t}}$			t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta Q_{i,t}$				
$\Delta\sigma^w_{i,t}$				
$\Delta\sigma^w_{i,t} * \Delta y_{i,t}$				
$\Delta w\sigma_{i,t}$				
$\Delta w\sigma_{i,t} * \Delta y_{i,t}$				

See note to Table 8*: Alternative Instruments.

Table 14*: Alternative Instruments
$\Delta k_{i,t}$ Hybrid Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.145	-.170	-.181	-.182	-.175	-.174
	(.091)	(.096)*	(.088)**	(.085)**	(.101)*	(.127)
$\Delta y_{i,t-1}$	.105	.037	.062	.068	.076	.127
	(.049)**	(.054)	(.051)	(.054)	(.056)	(.065)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.313	-.223	-.200	-.222	-.190	-.267
	(.105)***	(.102)**	(.090)**	(.096)**	(.110)*	(.143)*
$\Delta y_{i,t}$	.723	.618	.613	.625	.601	.612
	(.182)***	(.186)***	(.167)***	(.174)***	(.194)***	(.269)**
$Q_{i,t}$		.039	.034	.040	.043	
		(.012)***	(.009)***	(.009)***	(.010)***	
$(k_{i,t-1} - y_{i,t-1})$	-.119	-.078	-.084			
	(.044)***	(.042)*	(.042)**			
$\Delta\sigma_{i,t}$	-.053	-.034	-.033	-.037	-.013	-.039
	(.022)**	(.021)	(.019)*	(.018)**	(.022)	(.025)
$\sigma_{i,t-1}$	-.063	-.047	-.047	-.045	-.024	-.067
	(.037)*	(.032)	(.031)	(.031)	(.031)	(.032)**
Sargan/Hansen	.772	.747	.765	.652	.755	.615
DoF	102	101	122	123	102	82
AR1	-3.669	-3.261	-3.56	-4.342	-3.769	-2.905
AR2	-2.496	-1.984	-2.328	-2.207	-1.976	-1.949
AR3	-.168	-.429	-.278	-.215	-.132	.203
AR4	.53	.817	.809	.799	.929	.648
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta\sigma_{i,t}$						
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						

See note to Table 8*: Alternative Instruments.

Table 15*: Alternative Instruments
$\frac{I_{i,t}}{K_{i,t}}$ Hybrid Investment Specification

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.081	-.084	-.115	-.122	-.113	-.095
	(.126)	(.124)	(.107)	(.116)	(.122)	(.147)
$\Delta y_{i,t-1}$	.057	.055	.061	.084	.073	.068
	(.050)	(.049)	(.046)	(.045)*	(.045)	(.054)
$\sigma_{i,t} * \Delta y_{i,t}$	-.164	-.156	-.133	-.144	-.181	-.178
	(.097)*	(.099)	(.073)*	(.080)*	(.088)**	(.106)*
$\Delta y_{i,t}$	.476	.477	.438	.483	.496	.433
	(.181)***	(.183)***	(.136)***	(.148)***	(.157)***	(.218)**
$Q_{i,t}$	.027	.025	.026			
	(.009)***	(.009)***	(.008)***			
$(k_{i,t-1} - y_{i,t-1})$		-.028	-.034	-.049	-.051	
		(.025)	(.028)	(.030)	(.031)	
$\Delta\sigma_{i,t}$	-.030	-.032	-.038	-.048	-.059	-.056
	(.018)*	(.017)*	(.016)**	(.016)***	(.017)***	(.024)**
$\sigma_{i,t-1}$	-.036	-.037	-.045	-.063	-.065	-.071
	(.029)	(.028)	(.027)*	(.028)**	(.030)**	(.034)**
Sargan/Hansen	.803	.826	.839	.846	.759	.769
DoF	105	104	125	126	105	85
AR1	-3.454	-3.374	-3.691	-3.369	-3.279	-2.923
AR2	-1.04	-1.095	-1.431	-1.631	-1.442	-1.098
AR3	-.386	-.418	-.41	-.247	-.447	-.349
AR4	1.008	.994	.97	.778	.763	.744
Instruments For Equations in First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$			t-3:t-4	t-3:t-4	t-3:t-4	
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4		
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels						
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta\sigma_{i,t}$						
$\Delta(\sigma_{i,t} * \Delta y_{i,t}$						

See note to Table 8*: Alternative Instruments.

Chapter 2

Capturing the Impact of Real Option Effects of Uncertainty on Firm Investment in Estimates of Error Correction and Average Q Specifications

2.1 Introduction

Results presented throughout Chapter 1 suggested that investment uncertainty relationships described in estimates of error correction and average q specifications were generally consistent when both specifications were estimated using a panel data set of UK firms. However, coefficients estimated on uncertainty sales growth interaction terms were larger in magnitude and more significant in estimates of error correction specifications. Previous empirical research into effects of uncertainty on firm level investment has focused on a single investment specification - popular choices being error correction and average q models. It is important to determine whether estimates of the former specifications yield consistent results regarding investment uncertainty relationships. Estimates of such specifications could be used to assess the implications of monetary or fiscal policy on firm investment, and it is meaningful to clarify whether estimates of a specific specification may provide a more accurate account of this effects of uncertainty.

Although investment uncertainty relationships were *generally* consistent across estimates of the two investment specifications in Chapter 1, the measure of investment used as the dependent variable, together with the inclusion of average q and error correction terms among the explanatory variables, appeared to have a significant effect on coefficients estimated on uncertainty sales growth interaction terms. The current chapter assesses these findings by comparing investment uncertainty relationships described by estimates of error correction and average q specifications with simulated panel data sets. The simulated data sets are generated by a MATLAB program written by Professor Nick Bloom of Stanford University, in which investment uncertainty relationships can be directly observed through varying the level of underlying uncertainty in demand/productivity conditions faced by firms. Firms in the simulation program face uncertain stochastic demand/productivity conditions and real option values to (partially) irreversible investment decisions. Empirically observable variables outputted by the simulation are used to estimate error correction and average q investment specifications in order to evaluate the capacity of each in describing the effects of real options on firm investment across simulated data sets.

Uncertainty in the simulation is defined as volatility in a stochastic index of demand and productivity conditions. Non-parametric Lowess plots of investment responses to underlying demand growth illustrate a negative real option effect of higher volatility(/uncertainty) on the investment responses to demand. The strength of these real option effects on investment is demonstrated to change with both the degree of irreversibility of investment, and volatility in the underlying demand/productivity index; consistent with the predictions of theoretical investment literature on real options[1]. Empirical proxies for the underlying uncertainty - included in estimates of the investment specifications - are constructed in the program based on within year volatility in monthly returns on the value function of a firm. These uncertainty proxies in the simulation program are intended to mimic empirical proxies based on volatility in stock returns. [2]

[1]Dixit and Pindyck (1994)

[2]Bloom, Bond and Van Reenen (2007) show that the negative real option effects of uncertainty on investment can be captured by a negative significant coefficient estimated on an interaction term between sales growth and the empirical uncertainty proxy, within an error correction specification.

Using the simulation program, a panel data set is generated in which error correction and average q specifications are able to identify lower investment responses to demand at higher levels of uncertainty with significant negative coefficients estimated on interaction terms between sales growth and the uncertainty proxy. As in the empirical data set, the inclusion of error correction and average q terms in their respective specifications played an important role in identifying coefficients estimated on uncertainty sales growth interaction terms with the simulated data. The measurement of investment also has a significant effect on coefficients estimated on uncertainty sales growth interaction terms in estimates of average q and error correction specifications with the simulated data.

From the parameterization of the simulation program that produced the former data set, simultaneously decreasing both volatility in demand conditions and non-convex adjustment costs causes coefficients on uncertainty sales growth interaction terms to become insignificant in estimates of both specifications. This suggests that in the simulated data neither specification has a tendency to falsely report - or significantly overstate - lower investment responses to demand at higher levels of uncertainty.

From the simulated data set that leads to similar descriptions of investment uncertainty relationships in estimates of error correction and average q specifications, two causes are identified which lead to inconsistencies between coefficients estimated on uncertainty terms between these two specifications. (i) As a result of decreasing both partial irreversibility of capital (differences between purchase and resale prices of capital) and fixed costs to changing the capital stock, significant coefficients estimated on uncertainty sales growth interaction terms in error correction specifications become insignificant; whereas the same coefficient remains strongly significant and an order of magnitude larger in estimates of the average q specifications. (ii) Measurement error in present discounted firm values and average q, can lead to a more reliable account of investment uncertainty relationships in estimates of error correction specifications. By introducing measurement error into firms' value functions within the simulated data set, it is possible to cause significant negative coefficients on uncertainty interaction terms in estimates of average q specifications to become insignificant when the specification is re-estimated with *noisy* measures of average q.

These results obtained with the simulated data may have implications for research into investment uncertainty relationships using empirical data with a similar data generating process. Results with the simulated data suggest instances in which either the error correction or average q specification may provide a more reliable description of investment uncertainty relationships. Regarding cases in which firms face "low" non-convex adjustment costs, the simulated data suggests that estimates of average q specifications may better capture real option effects of uncertainty on investment. However, noise, or measurement error in average q, possibly resulting from stock market measures of firm value, could lead to a more reliable description of effects of uncertainty in estimates of error correction specifications.

The remainder of the chapter is structured as follows: Section 2 briefly describes Professor Nick Bloom's MATLAB program, with a more detailed description of the investment model outlined in a Program Appendix; Section 3 reviews the error correction and average q specifications, discussing their underlying assumptions in relation to the investment model of the simulation program. Section 4 presents results from estimating the two investment specifications using 4 simulated data sets with varying levels of volatility in demand/productivity conditions, non-convex capital adjustment costs and real option values; Section 5 presents results from estimating the two investment specifications with measurement error introduced into the value functions of firms in the simulated data; Section 6 provides an overview of the results obtained with the simulated data, and concluding remarks.

2.2 Simulation Program

This section describes the MATLAB program and underlying investment model used to generate the simulated data analyzed in this chapter. The MATLAB program was written by Professor Nick Bloom of Stanford University, and the version described here was originally used to generate simulated data in Bloom, Bond and Van Reenen (2007).[3] No changes are made to the structure of the MATLAB program, which outputs the same format of data sets used in Bloom, Bond and Van Reenen (2007). Changes are made to the capital adjustment cost parameters, and parameters governing the variance of underlying demand conditions in order to generate simulated data sets with different real option values to investment decisions. An overview of the MATLAB code and investment model is outlined here, and a more detailed description is provided in the Program Appendix at the end of this Chapter.

The MATLAB code is used to generate a panel data set containing annual investment and output data for 10 000 firms over 15 years. Each firm is made up of 250 production units, or plants, that make monthly investment decisions in two types of capital based on their individual iso-elastic demand curves[4]The number of production units per firm is not changed from the Bloom, Bond and Van Reenen (2007) parameterization of the program. The number of production units was chosen in that paper by increasing the number until it no longer impacted their results. Stochastic demand and productivity conditions, faced by each plant, drive investment dynamics in the simulation. The investment model of each production unit is based on Eberly and Van Mieghem (1997) which assesses the real option effects of demand uncertainty on investment in multiple lines of capital goods. Each individual plant faces fixed and quadratic costs to adjusting the capital stock, and a re-sale price of capital that is lower than the purchase price (partially irreversible capital stock). The annual figures of each firm are aggregated over and across the monthly investment decisions and capital types of its individual production units. There is no debt built into the investment model.

Uncertainty, in the simulated data, varies over time and across plants and firms, and is de-

[3]The program is available for download from Professor Bloom's website http://www.stanford.edu/ñbloom/index_files/Page298.htm

[4].

fined as the volatility in the underlying productivity and demand conditions faced by individual production units. The stochastic process of the underlying demand conditions generates real option values to plant level investments, which are positively related to the volatility of the demand process and the magnitude of non-convex capital adjustment costs. Due to the fact that volatility in underlying demand/productivity conditions is changing over time for each production unit, the real option values to their investment decisions change as well. Long run, Hartman-Abel effects of uncertainty are not present in the simulated data used in this chapter, which focuses on short run effects of uncertainty on investment behaviour arising from real options.

An empirical corollary to the underlying demand uncertainty is generated in the simulated data as within year volatility of the monthly returns to a firm's value function. This measure of uncertainty is meant to resemble the volatility in share price returns used to proxy uncertainty in previous empirical investigations[5]. This empirical measure of uncertainty results from extensive aggregation of different levels of underlying demand volatility driving the real options of individual investment decisions in the model. The difference between underlying levels of volatility faced by production units in the simulation and its aggregated proxy reflects a similar aggregation over uncertainties faced by individual managers of a firm, into an overall level of volatility in share price returns used to proxy uncertainty over expected profitability in empirical data. The coefficient of correlation between average underlying levels of uncertainty across production units of firms within a year, and the empirical proxy in the simulated data is 0.708[6].

Bloom ,Bond and Van Reenen (2007) show that in this MATLAB simulation, the effects of real options on the investment decisions of individual production units result in lower annual, firm-level investment responses to demand growth, at higher levels of average annual underlying demand volatility across the production units of firms. In their paper this negative effect of uncertainty was described using non-parametric Lowess plots using actual volatility in underlying demand conditions, as well as First Differenced GMM estimates of an error correction model between log capital and log sales, including an interaction term between the empirical *proxy*

[5]Bloom, Bond and Van Reenen (2007), Leahy and Whited (1996), Bulan (2005), Bond and Cummins (2004).

[6]This coefficient is calculated using Simulated Data Set 1, and is of the same magnitude in other simulated data sets used to produce the results in Sections 4 and 5.

measure of uncertainty and sales growth.

The simulation program is run at the level of individual production units of firms, making monthly investment decisions into their capital stocks. The production technology of each unit is described by a Cobb Douglas production function, facing an iso-elastic demand curve. Labor is costlessly adjusted and optimized out of the revenue function of the individual plants. Stochastic demand and productivity conditions are defined as an index in the production units' revenue functions, based on multiplicative plant level and firm level shocks, which introduce uncertainty at the level of individual plants, but tie investment decisions of plants together based on firm wide shocks. Production units face partial irreversibility adjustment costs in the form a wedge between the purchase and re-sale price of capital, fixed costs to adjusting the capital stock, and quadratic costs which increase exponentially with the size of adjustment to the capital stock.

The Bellman equation for each firm production unit is solved numerically in MATLAB, the value function solution and optimal policy correspondences produced for each unit are then combined with firm and production unit level demand-productivity conditions to simulate data for investment, sales, capital stocks and firm values[7]. Before aggregating across 250 firm production units and 12 time periods to produce firm year observations, the simulation is run for 240 monthly periods to produce an initial ergodic distribution. The annual investment figures for firm i in year t ($I_{i,t}$) are aggregated over the 12 monthly investments in the two types of capital at each plant. Annual values of the capital stock and the level of demand conditions for firm i in year t ($K_{i,t}$ and $\Sigma_{i,t}$) are generated by summing across the production units (j) within each firm at the end of every year. Sales of firm i in year t ($Y_{i,t}$) is obtained by summing the monthly revenues of production units (j) within each firm (i) and year (t). Annual firm level uncertainty ($var_{i,t}$) is measured as the within year average of volatility in the stochastic process defining the demand/productivity index of each plant (σ_{i,j,t_m})[8]; this average is calculated over all 250 production units of each firm. The empirical measure of uncertainty ($\sigma_{i,t}$) is calculated as the within year standard deviation in the monthly returns to a firm's value function.

[7]For more information see the Program Appendix.
[8]See appendix for more details.

Differences in real option values of investments at the level of individual production units have significant effects on the aggregated investment dynamics, based on annual firm level observations. Real option values can be changed by adjusting the levels of volatility in demand/productivity conditions over time. The magnitude of real options can also be changed with the level of non-convex capital adjustment costs faced by individual production units. Figure 1 below shows Lowess[9] plots of annual average investment rates ($\frac{I_{i,t}}{K_{i,t-1}}$), against the average annual percentage change in the underlying demand conditions faced by firms ($\Delta log(\Sigma_{i,t})$). Each Lowess plot corresponds to a different level of underlying uncertainty in the sample.[10].

The Lowess plot corresponding to average annual investment undertaken at the highest level of uncertainty has the smallest slope, representing lower average investment responses to growth in demand, arising from more valuable real options of the investment decisions of individual production units at higher levels of uncertainty. The Lowess plots of investments undertaken at the progressively lower levels of uncertainty in the data have proportionately larger slopes, corresponding to larger investment responses to demand at lower levels of uncertainty.

[FIGURE 1 HERE]

In the simulated data used to generate Figure 1 above, partial irreversibility adjustment costs[11] are imposed on production units, whereby capital is re-sold for 25% (partial capital adjustment cost of 75 %) of the purchase price, and fixed costs of 7.5% of annual revenue are paid each time capital stocks are adjusted[12]. Figure 2 below illustrates the effect of lower real

[9]Lowess smoothing estimates a linear regression at each data point, using Cleveland's (1979) tricube weighting over a moving window of 5% of the data, to generate a non-parametrically smoothed data series. Lowess is similar to Kernel smoothing, but uses information on both the mean and the slope of the data and so is more efficient in estimating functions with continuous first derivatives, which the aggregated data have asymptotically (in the number of production units).

[10]The 5 levels of uncertainty correspond to $var_{i,t} <= 0.11$, $0.11 < var_{i,t} <= 0.22$, $0.22 < var_{i,t} <= 0.33$, $0.33 < var_{i,t} <= 0.44$, $0.44 < var_{i,t}$, in the firm level annual panel data set produced by the simulation program. These intervals were chosen because they contain 5 points around which values of $var_{i,t}$ cluster in the aggregated simulated data. These are the same points used in Bloom, Bond and Van Reenen (2007) to construct the Lowess plots in that paper

[11]For more information on adjustment costs faced by production units in the simulation program, refer to the Program Appendix.

[12]These parameters were set to 50% and 5% in the original parameterization of the MATLAB code in Bloom, Bond and Van Reenen (2007).

option values on investment responses to demand with Lowess plots generated from simulated data with lower capital adjustment costs. Relative to the case of Figure 1, partial irreversibility capital adjustment costs are decreased from 75% (re-sale price 25% of purchase price) to 25% (re-sale price is 75% of purchase price), and fixed capital adjustment costs are decreased to 2.5% of annual revenues. The Lowess plots in Figure 2 correspond to investment responses to demand at the same levels of underlying uncertainty as in Figure 1 above. The lower real option values in the simulated data in Figure 2 result in larger slopes of the Lowess plots of the investment responses to demand, relative to Figure 1, and the level of uncertainty has less effect on the slopes of these plots.

[FIGURE 2 HERE]

Real option values to the investment decisions of production units can also be adjusted through the variance of demand conditions in the simulation program. In Figures 1 and 2 the variance of the underlying productivity/demand index described in the program appendix takes on 5 values evenly spaced between 0.1 and 0.5. Figure 3 below contains Lowess plots of firm investment responses to demand based on a simulation in which the variance of the underlying productivity/demand index takes on 5 values between 0.02 and 0.1; and adjustment costs are the same as in Figure 1 above. As would be expected, annual average changes in underlying demand are much smaller in Figure 3 relative to Figure 1, due to the lower variance of the underlying demand/productivity index. Figure 4 plots the regions of the Lowess plots in Figure 1 corresponding to the changes in average annual demand and axes in Figure 3. Comparing the Lowess plots in Figures 3 and 4, smaller slopes of the Lowess plots in Figure 4 result from more valuable real options faced by individual production units with greater variance in their underlying demand/productivity indexes.

[FIGURE 3 HERE]

[FIGURE 4 HERE]

Comparison across the Lowess plots in Figures 1 to 4 illustrates the effect of adjustment costs and variance in underlying demand/productivity conditions on real option values; which result in lower investment responses to changes in demand at higher levels of uncertainty or variance in underlying demand/productivity indexes. Section 4 presents results from estimating investment specifications using 4 simulated data sets, across which the magnitude of real options are varied with the non-convex adjustment costs and variance of underlying demand/productivity indexes. The simulated data set in which real option values are the highest, Simulated Data Set 1, sets partial irreversibility adjustment costs to 20% [13], and fixed adjustment costs to 2% of annual revenue, and allows the variance of the underlying demand/productivity indexes to take on 5 values from 0.1 to 0.5 (as in Figures 1 and 2, and in the simulated data used by Bloom, Bond and Van Reenen (2007)). Real option values are lowered from this parameterization in 3 ways across 3 different data sets: (i) in Simulated Data Set 2, by lowering both the variance of underlying demand/productivity indexes to take on 5 values from 0.075 to 0.375, and by decreasing partial and fixed adjustment costs to 15% and 1.5% of annual revenue respectively; (ii) in Simulated Data Set 3 by only decreasing the variance of underlying demand/productivity indexes to take on 5 values from 0.075 to 0.375 relative to Simulated Data Set 1; and (iii) in Simulated Data Set 4 by only decreasing partial and fixed adjustment costs to 15% and 1.5% of annual revenue relative to Simulated Data Set 1.

[13] Capital can be resold for 80% of its purchase price.

2.3 Investment Specifications in the Simulated Data

2.3.1 Error Correction Specification

The formulation of the error correction specification for the simulated data follows Bloom, Bond and Van Reenen (2007), which assumes a co-integrating relationship between the natural logarithms of a firm's capital stock under adjustment costs and the frictionless capital stock that would be chosen in the absence of adjustment costs:

$$log(K_{i,t}) = log(K^*_{i,t}) + e_{i,t} \tag{2.1}$$

Where $K_{i,t}$ is actual capital stock, $K^*_{i,t}$ is optimal capital stock in the absence of adjustment costs and $e_{i,t}$ is a stationary error term. Bloom, Bond and Van Reenen (2007) formulate the optimal frictionless capital stock as Equation (2.2) below.

$$log(K^*_{i,t}) = log(Y_{i,t}) + A^*_i + B^*_t \tag{2.2}$$

The formulation of actual capital stock $K_{i,t}$ in terms of optimal frictionless capital stock with Equations (2.1) and (2.2) gives rise to the same type of error correction specification between the natural logarithms of capital and sales that was estimated in Chapter 1. Beginning with an expression for the natural logarithm of capital stock ($k_{i,t}$) in terms of log sales ($y_{i,t}$) and the error term $e_{i,t}$, additional lagged terms $k_{i,t-1}$ and $y_{i,t-1}$ can be added as in Chapter 1, resulting in an ADL[2,2] specification for the natural logarithm of capital ($k_{i,t}$) in terms of sales ($y_{i,t}$):

$$k_{it} = \beta_1 k_{i,t-1} + \beta_2 k_{i,t-2} + \alpha_0 y_{it} + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-2} + \hat{b}_t + \hat{a}_i + \epsilon_{it} \tag{2.3}$$

Additional terms in $k_{i,t}$ and $y_{i,t}$ can added and subtracted, and then re-arranged to the form of the error correction specification below:

$$\Delta k_{it} = \Big(\alpha_0 + \alpha_1 + \alpha_2 - (\theta)(1 - \beta_1 - \beta_2)\Big) y_{i,t-1} - \beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} \tag{2.4}$$

$$+\alpha_0 \Delta y_{i,t} - \big(1 - \beta_1 - \beta_2\big)\big(k_{i,t-1} - \theta y_{i,t-1}\big) + \hat{b}_t + \hat{a}_i + \epsilon_{i,t}$$

Imposing the condition $\theta = \frac{\alpha_0+\alpha_1+\alpha_2}{1-\beta_1-\beta_2} = 1$ on the terms of the ADL[2,2] specification (Equation (2.3)) will simplify Equation (2.4) into an error correction specification, as the coefficient on $y_{i,t-1}$ is set to zero. As discussed in Chapter 1, this condition on the terms of the ADL[2,2] specification imposes an equilibrium capital stock that is consistent with Equations (2.1) and (2.2):

$$k_{i,t} - \beta_1 k_{i,t-1} - \beta_2 k_{i,t-2} = \alpha_0 y_{i,t} + \alpha_1 y_{i,t-1} + \alpha_2 y_{i,t-2} + \hat{a}_i + \hat{b}_t + \epsilon_{i,t} \tag{2.5}$$

$$(1 - \beta_1 - \beta_2)\, k = (\alpha_0 + \alpha_1 + \alpha_2)\, y + \hat{a}_i + \hat{b}_t + \epsilon_{i,t} \tag{2.6}$$

The validity of this restriction can be evaluated with a t-test of the coefficient estimated on $y_{i,t-1}$ in Equation (2.4). An estimated coefficient on this term that is not significantly different from zero implies that the data supports the restriction of the coefficients of the ADL[2,2] specification to the error correction specification below.

$$\Delta k_{it} = -\beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} \tag{2.7}$$

$$+\alpha_0 \Delta y_{i,t} - \big(1 - \beta_1 - \beta_2\big)\big(k_{i,t-1} - y_{i,t-1}\big) + \hat{b}_t + \hat{a}_i + \epsilon_{i,t}$$

Bloom, Bond and Van Reenen (2007) note that the error correction specification they estimate[14] is derived from the investment decisions of a single production unit with one type of capital; as shown in the section on investment specifications in Chapter 1. However, Bloom, Bond and Van Reenen (2007) report evidence of co-integration between firm time series of log capital and log sales which are based on the aggregate investment decisions of many production units in the simulated data. The current Chapter presents estimates of re-arranged ADL[2,2] specifications of the form of Equation (2.4) with simulated data sets produced from various parameterizations of the program. In each set of results coefficients estimated on $y_{i,t-1}$ terms are statistically insignificant, supporting the error correction specification and the underlying co-integrating relationship assumed between the natural logarithms of capital and sales. Estimates of AR models of $k_{i,t}$, $y_{i,t}$, $\Delta k_{i,t}$, $\Delta y_{i,t}$ and $(k_{i,t} - y_{i,t})$ presented for the simulated data in Section 4, also support the co-integrating relationship between $k_{i,t}$ and $y_{i,t}$.

[14]Based on Chetty (2007).

2.3.2 Average Q Specification

Working with empirical data in Chapter 1, values of average q ($Q_{i,t}$) are obtained by taking the ratio of the firm's stock market value, to the replacement cost of its capital stock. In the simulated data set, values of average q are obtained in a similar manner by taking the ratio of the firm's value function to its capital stock at the beginning of each annual period t. [15] The dependent variable of the average q specification is constructed in the simulated data by the ratio of current period investment to capital stock: $\frac{I_{i,t}}{K_{i,t}}$. Using these variables constructed in the simulated data the same investment specification from Chapter 1 - based on the Hayashi (1982) average q model - is re-estimated using the various simulated data sets in this Chapter.

$$\frac{I_{i,t}}{K_{i,t}} = \lambda_1 Q_{i,t} + \lambda_2 \frac{I_{i,t-1}}{K_{i,t-1}} + \lambda_3 \Delta y_{i,t-1} + \lambda_4 \Delta y_{i,t} + a_i + b_t + \epsilon_{i,t} \tag{2.8}$$

The investment specification described in Hayashi (1982) is mis-specified in the simulated data sets due to imperfect competition and non-convex, discontinuous capital adjustment costs. However, obtaining estimates of average q specifications with these simulated data sets is informative of the role of additional explanatory variables when average q is known not to be a sufficient statistic for marginal q and the investment rate. Although it may not necessarily be due to similar non-convex capital adjustment costs, or degrees of imperfect competition as in the simulated data, the Hayashi (1982) often appears mis-specified in empirical data sets based on the significance of explanatory variables in addition to average q.[16]

Both the average q and error correction specifications are appended with similar uncertainty terms to those used in Chapter 1 - constructed with the empirical uncertainty proxy calculated in the simulated data: $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$.

[15] This measure is not calculated automatically by the simulation program, but constructed with the panel data output.

[16] See for example Bond and Cummins (2004), Bond and Cummins (2001), Bond et al (2004) or Bulan (2005).

2.4 Results: Real Options

This section presents results from estimating error correction and average q specifications using several simulated panel data sets with varying levels of real option values to investment opportunities. In estimates of error correction and average q specifications with Simulated Data Set 1, coefficients estimated on uncertainty sales growth interaction terms are significant and negative, and are of comparable magnitude and significance across the two specifications. Consistent with results obtained for the empirical data set in Chapter 1, the inclusion of average q and error correction terms in these investment specifications has a substantial influence on coefficients estimated on uncertainty sales growth interaction terms. In the simulated data, as in the empirical data, the measurement of investment in estimates of the average q and error correction specifications also has a significant effect on coefficients on uncertainty sales growth interaction terms.

When the strength of real options are decreased between Simulated Data Sets 1 and 2, by lowering both the volatility in demand/productivity conditions, and non-convex adjustment costs, coefficients estimated on uncertainty sales growth interaction terms become insignificant in both error correction and average q specifications. This implies that below a certain level, *weaker* real option effects cannot be detected by coefficients estimated on uncertainty sales growth interaction terms in either specification. Furthermore, these results suggest that neither specification appears to be falsely reporting, or overstating lower investment responses to demand at higher uncertainty arising from real option values in the simulated data.

In Simulated Data Sets 3 and 4 the strength of real option values are set at intermediate levels between Simulated Data Sets 1 and 2, by only decreasing either non-convex adjustment costs or volatility in demand/productivity conditions. Relative to Simulated Data Set 1, the strength of real option effects is decreased by lowering the volatility in demand/productivity conditions in Simulated Data Set 3. The lower real option values to investment in Simulated Data Set 3 cause coefficients on uncertainty sales growth interaction terms to become only marginally significant in estimates of average q and error correction specifications. However, coefficients on these terms remain similar across estimates of both specifications, describing consistent investment uncertainty relationships.

Decreasing the strength of real options relative to Simulated Data Set 1, by lowering non-convex capital adjustment costs in Simulated Data Set 4, results in inconsistent investment uncertainty relationships described in estimates of error correction and average q specifications. Decreasing the magnitude of non-convex adjustment costs in Simulated Data Set 4 from Simulated Data Set 1, causes the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to become insignificant in the error correction specification; whereas the same coefficient remains strongly significant in the average q specification. These results suggest that estimating average q specifications may yield a more reliable description of investment uncertainty relationships than estimates of error correction specifications in simulated data with lower non-convex capital adjustment costs.

2.4.1 Simulated Data Set 1

Tables 1 and 2 below present OLS estimates of simple auto-regressive (AR) models for the variables used to estimate the error correction and average q specifications with Simulated Data Set 1. Coefficient estimates across these tables demonstrate that these variables have the time series properties assumed by the investment specifications in the simulated data. Columns 1 and 3 of Table 1 present OLS estimates of AR[3] and AR[4] models of the natural logarithms of capital $k_{i,t}$ and sales $y_{i,t}$ respectively. Coefficients estimated on $k_{i,t-1}$ and $y_{i,t-1}$ represent the sum of the AR coefficients, indicating that each series is approximately unit root.[17] Columns 2 and 4 present OLS estimates of the AR[1] models of the series $\Delta k_{i,t}$ and $\Delta y_{i,t}$, in which coefficients on $\Delta k_{i,t-1}$ and $\Delta y_{i,t-1}$ are well below 1, implying stationarity in these series. Column 5

[17] Although the hypothesis that these series are unit roots is formally rejected by the standard errors of coefficients estimated on $k_{i,t-1}$ and $y_{i,t-1}$, these series, and the underlying process driving them, are defined as unit root processes in the MATLAB program. The OLS coefficient estimates that are marginally above one in Table 1 are resulting from extensive aggregation across production units and over time, as well as the level of volatility in the underlying demand/productivity index in the revenue function of individual production units. In simulated panel data sets with no aggregation over time or across production units of firms, as well as lower volatility in demand/productivity conditions, OLS estimates of similar AR models were able to identify the unit roots in the series $k_{i,t}$ and $y_{i,t}$. For the purposes of this investigation the level of aggregation and volatility in demand/productivity conditions was not changed from the Bloom, Bond and Van Reenen (2007) version of the MATLAB program; and the nature of the relationship between the upward bias in OLS estimates of AR models for these series, and degree of aggregation and demand/productivity volatility in Professor Nick Bloom's program is left open to future investigation.

presents estimates of an AR[1] model for the series $(k_{i,t} - y_{i,t})$, which also appears to be stationary. Together the coefficient estimates presented throughout Table 1, support the underlying assumptions of the error correction investment specification and the co-integrating relationship between the series $k_{i,t}$ and $y_{i,t}$, which behave like $I(1)$ variables in the simulated data.

[TABLE 1 HERE]

[TABLE 2 HERE]

Table 2 above presents OLS estimates of AR[1] models for the series $\frac{I_{i,t}}{K_{i,t}}$, $Q_{i,t}$ and $\sigma_{i,t}$ in the simulated data. Coefficient estimates on the lagged dependent variables of these models suggest that they are all stationary series.

Tables 3 and 4 below present First Differenced GMM estimates of the error correction and average q investment specifications using Simulated Data Set 1.[18] Coefficient estimates on uncertainty sales growth interaction terms $\sigma_{i,t} * \Delta y_{i,t}$ are significant and negative in estimates of both investment specifications.

Column 1 of Table 3 below presents estimates of an unrestricted ADL[2,2] specification between $k_{i,t}$ and $y_{i,t}$, re-arranged to the form of an error correction model. The coefficient estimated on $y_{i,t-1}$ is insignificant, implying that the necessary restriction between the series $k_{i,t}$ and $y_{i,t}$ imposed by the error correction specification is not rejected by the simulated data. Column 2 restricts the coefficient estimated on $y_{i,t-1}$ to zero, resulting in no significant change to coefficients estimated on the remaining terms. Relative to the specification in Column 2, Column 3 adds an uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$, on which a significant and negative coefficient is estimated. Column 4 drops the uncertainty sales growth interaction term from Column 3 and adds linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$; a positive, statistically significant coefficient is estimated on the latter term, whereas the coefficient estimated on the former term

[18]The use of First Differenced GMM estimates with the simulated data sets follows Bloom, Bond and Van Reenen (2007) which found it difficult to obtain suitable instruments for equations in levels for the error correction specification in simulated data. This difficulty was also encountered in Simulated Data Sets 1 to 4, when searching for valid instruments for equations in levels for the error correction specification, and also for the specification based on average q.

is statistically insignificant. At the current parameterization of the simulation program, this coefficient is likely detecting a positive hangover effect of uncertainty and partial irreversibility of investment, similar to the effect described in Abel and Eberly (1999). This effect occurs when the accumulation of irreversible (or partially irreversible) capital, during times of positive demand growth, leaves a firm with excess (or above optimal) levels of capital once demand subsides.[19] Column 5 includes both the linear and non-linear controls for uncertainty, on which coefficients are not statistically different from Columns 3 and 4.

[TABLE 3 HERE]

The results in Columns 3 through 5 of Table 3 emphasize the importance of using interaction terms between uncertainty proxies and sales growth to capture the effects of real options on investment behaviour. Including only linear terms in the uncertainty proxies in the error correction investment specification estimated with this simulated data would provide no evidence of real options. Figure 5 below presents Lowess plots of the investment responses to demand at the different levels of underlying uncertainty in the simulated data illustrating the effect of real options captured by the coefficients estimated on the term $\sigma_{i,t} * \Delta y_{i,t}$ in Columns 3 and 5 of Table 3. The greater slopes of the Lowess plots at lower levels of uncertainty demonstrates larger investment responses to demand at lower levels of uncertainty implied by the underlying real option values in the simulation program.

[FIGURE 5 HERE]

Table 4 below presents First Differenced GMM estimates of an average q investment specification obtained from Simulated Data Set 1. Coefficient estimates on uncertainty terms across the columns of Table 4 are consistent with the effects of uncertainty described in estimates of

[19] Such positive coefficients on linear uncertainty terms were not found in Bloom, Bond and Van Reenen (2007), however relative to the parameterization of the simulations in Bloom, Bond and Van Reenen (2007), adjustment costs have been significantly altered in Simulated Data Sets 1 through 4. Abel and Eberly (1999) notes that the relative strength of user cost and hangover effects was relatively ambiguous in the investment model considered in that paper, and was sensitive to the choice of parameter values.

the error correction specification in Table 3 above. Comparing coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ across Tables 3 and 4, they have similar t-ratios and their magnitudes are very similar, within one standard deviation of each other.

Column 1 of Table 4 presents estimates of the Hayashi q model, in which the investment rate is a linear function of average q and no other explanatory variables. Column 2 adds a sales growth term $\Delta y_{i,t}$, on which the coefficient estimate is significant and positive. Column 3 adds additional terms $\frac{I_{i,t-1}}{K_{i,t-1}}$ and $\Delta y_{i,t-1}$ on which coefficients are individually insignificant, but jointly significant according to a Wald test which rejects the null hypothesis of joint insignificance with a p-value of 0.001. Column 4 adds the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$, on which the estimated coefficient is significant and negative. Column 5 drops the uncertainty sales growth interaction term and adds the linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$. Only the coefficient estimated on the latter of the two linear terms is significant, and describes a positive effect on the investment rate. Column 6 includes both linear and non-linear uncertainty terms, on which coefficient estimates are not significantly different from Columns 3 and 4. As discussed in the case of Table 3, only coefficients estimated on uncertainty sales growth interaction terms show evidence of the effect of real options on investment behaviour in estimates of the average q specification with this data set. Including only linear controls for the effects of uncertainty would overlook the effects of real options on investment behaviour described by the average q investment specification in this simulated data set.

[TABLE 4 HERE]

Tables 5 to 7 below present estimates of hybrid and accelerator investment specifications, which were used in Chapter 1 to determine the influence of error correction and average q terms, as well as the measurement of investment, on coefficients estimated on uncertainty terms. As in results presented in Chapter 1 for empirical data, the measurement of investment had a significant effect on coefficients estimated on uncertainty sales growth interaction terms in hybrid specifications, and in the less general error correction and average q specifications. The inclusion/exclusion of error correction and average q terms has a significant effect on coefficients estimated on uncertainty sales growth interaction terms in the hybrid, error correction and average q investment specifications; a result which was also found with the empirical data.

Table 5 below presents estimates of error correction, hybrid and average q investment specifications, with the dependent variable specified as $\Delta k_{i,t}$. Column 1 presents estimates of the error correction specification from Column 5 of Table 3, which includes all uncertainty terms. Column 2 adds a $Q_{i,t}$ term to the specification, withholding it from the instrument set, resulting in no significant changes to coefficients on the terms of the error correction specification from Column 1, and an insignificant coefficient on $Q_{i,t}$ itself. Column 3 adds $Q_{i,t}$ to the instrument set from Columns 1 and 2, increasing the positive coefficient on $Q_{i,t}$, which becomes statistically significant; and causing the coefficient on $\sigma_{i,t-1}$ to become statistically insignificant. Column 4 drops $(k_{i,t-1} - y_{i,t-1})$ from the specification in Column 3, but retains its lagged value in the instrument set. The result is a much less significant coefficient on $\sigma_{i,t} * \Delta y_{i,t}$, however, the point estimate on which remains similar to the those in the previous columns of Table 5. Dropping $(k_{i,t} - y_{i,t})$ from the instrument set in Column 5 causes the point estimate on $\sigma_{i,t} * \Delta y_{i,t}$ to increase in magnitude - becoming significant; and causes the positive coefficient on $\sigma_{i,t-1}$ to become significant. The coefficient on $Q_{i,t}$ also doubles between Columns 4 and 5. Whereas adding $Q_{i,t}$ to the error correction specification and instrument set over the first 3 columns of Table 5 seemed to have little impact on coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$, dropping $(k_{i,t-1} - y_{i,t-1})$ from the hybrid specification had a significant impact on the estimated coefficient.

[TABLE 5 HERE]

The specification in Column 5 of Table 5 is the average q specification in Column 6 of Table 4, with $\frac{I_{i,t}}{K_{i,t}}$ replaced with $\Delta k_{i,t}$ in the specification and instrument set. Comparing coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ between the latter columns, replacing $\frac{I_{i,t}}{K_{i,t}}$ with $\Delta k_{i,t}$ in the average q specification causes the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ to increase in magnitude, with the change slightly larger than either of the standard deviations of this coefficient in the tables.

Table 6 below presents estimates of the average q, hybrid and error correction investment specifications with the dependent variable parameterized as $\frac{I_{i,t}}{K_{i,t}}$. Column 1 presents estimates of the average q specification from Column 6 of Table 4. Column 2 of Table 6 adds $(k_{i,t-1} - y_{i,t-1})$ to the specification but not the instrument set, decreasing the significance of all coefficients from the specification in Column 1, and causing coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ and $Q_{i,t}$ to become insignificant. Adding $(k_{i,t} - y_{i,t})$ to the instrument set in Column 3, results in very little change to coefficient estimates from Column 2. The only difference between the hybrid specifications in Columns 3 of Tables 5 and 6, is the measurement of investment as $\Delta k_{i,t}$ in the former and as $\frac{I_{i,t}}{K_{i,t}}$ in the latter. The difference between coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ between the two columns is quite substantial; moving from Table 5 to 6, the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 3 decreases by a factor of roughly 10 and becomes statistically insignificant.[20] In column 4 of Table 6 $Q_{i,t}$ is dropped from the specification in Column 3 but is kept in the instrument set. Coefficients on the remaining terms remain quite stable across Columns 3 and 4. Column 5 drops $Q_{i,t}$ from the instrument set in Column 4 resulting in small increases in the magnitudes of coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ and $\sigma_{i,t-1}$, however the coefficient on the former remains statistically insignificant.

[TABLE 6 HERE]

The specification in Column 5 of Table 6 is the error correction specification from Column 1 of Table 5 (and Column 5 of Table 3), with $\Delta k_{i,t}$ substituted with $\frac{I_{i,t}}{K_{i,t}}$ in the specification and

[20]In comparing Column 3 in Tables 5 and 6 it is important to note that given the paramaterization of the simulation program firms can make large changes to their capital stocks in response to commensurately large changes in demand conditions. Given small changes in the capital stock $\Delta k_{i,t} \approx \frac{I_{i,t}}{K_{i,t-1}} - \delta$, and specifications in Column 3 of Tables 5 and 6 should be quite similar. However, in the simulated data, for firms making large changes to their capital stocks $\frac{I_{i,t}}{K_{i,t}} - \delta$ and $\frac{I_{i,t}}{K_{i,t}}$ are poor approximations for $\Delta k_{i,t}$. The 75th, 90th and 95th percentiles of $\Delta k_{i,t}$ are 0.03, 0.13 and 0.21 respectively. Taking the absolute value of the difference between $\frac{I_{i,t}}{K_{i,t}} - 0.1$ (δ is set to 0.1 in the simulation program) and $\Delta k_{i,t}$, the 75th, 90th and 95th percentiles of that difference are 0.01, 0.02 and 0.04. The 75th, 90th and 95th percentiles of the percentage difference between $\frac{I_{i,t}}{K_{i,t}} - \delta$ and $\Delta k_{i,t}$ $\left(\frac{|\frac{I_{i,t}}{K_{i,t}} - \delta - \Delta k_{i,t}|}{|\Delta k_{i,t}|}\right)$ are 0.14, 0.26 and 0.47. This implies that for at 25% of the sample there is at least a 14% difference between $\frac{I_{i,t}}{K_{i,t}} - 0.1$ and $\Delta k_{i,t}$. This difference is sufficient enough to result in significant changes to coefficient estimates and Sargan/Hansen test statistics when substituting $\frac{I_{i,t}}{K_{i,t}}$ for $\Delta k_{i,t}$ in the specification and instrument set between Tables 5 and 6 in Column 3. In the current simulated data set the specification for the variance of demand and productivity conditions has not been changed from Bloom, Bond and Van Reenen (2007), and is contributing to the large values of $\Delta k_{i,t}$.

instrument set. As a result of this substitution, the point estimate of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ decreases by more than half, and its standard error increases slightly, causing the coefficient to become statistically insignificant. In the results presented in Chapter 1 for the empirical data set, the same substitution in this investment specification decreased the magnitude of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$, however the coefficient remained statistically significant.

Table 7 below contrasts error correction and average q specifications, with accelerator investment specifications with their dependent variables specified as $\Delta k_{i,t}$ and $\frac{I_{i,t}}{K_{i,t}}$ respectively. Dropping $(k_{i,t-1} - y_{i,t-1})$ and $Q_{i,t}$ from the error correction and average q specifications in Table 7, causes coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to become statistically insignificant in both specifications. The same effect of dropping these controls for investment dynamics was also observed with the empirical data set. This suggests that controlling for investment dynamics with average q and error correction terms is important for capturing effects of uncertainty on investment behaviour.

Column 1 of Table 7 below presents estimates of the error correction specification from Column 1 of Table 5, with $\Delta k_{i,t}$ as the dependent variable. Dropping $(k_{i,t-1} - y_{i,t-1})$ from the error correction specification, but retaining it in the instrument set in Column 2 causes the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ to become statistically insignificant, and increases the magnitude of the coefficient estimated on $\sigma_{i,t-1}$. In Column 3, Dropping $(k_{i,t} - y_{i,t})$ from the instrument set of Column 2, causes very little change to coefficient estimates.

[TABLE 7 HERE]

Column 4 of Table 7 above presents estimates of the average q specification from Column 1 of Table 6 (and Column 6 of Table 4). Column 5 of Table 7 drops $Q_{i,t}$ from the specification in Column 4, but retains it in the instrument set; as a result the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 5 becomes insignificant. Column 6 drops $Q_{i,t}$ from the instrument set in Column 5, resulting in no significant change to coefficient estimates, except for the coefficient estimated on $\sigma_{i,t-1}$ which increases by roughly two standard deviations.

2.4.2 Simulated Data Set 2

Tables 8 and 9 below present estimates of the error correction and average q specifications obtained from Simulated Data Set 2, in which real option values have been decreased by lowering both non-convex adjustment costs and volatility of underlying demand/productivity indexes, relative to Simulated Data Set 1. Both tables follow the same format as Tables 3 and 4, in which $\sigma_{i,t} * \Delta y_{i,t}$ terms are added to estimates of the base specifications, then terms in $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ are added to the base specifications, then both non-linear and linear uncertainty terms are included in the investment specifications. Coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms are insignificant in estimates of both the error correction and average q specifications in Tables 8 and 9; providing no evidence of lower investment responses to demand at higher levels of uncertainty. The only evidence of effects of uncertainty controlled for by terms in $\sigma_{i,t}$ is in a marginally significant negative coefficient estimated on $\Delta\sigma_{i,t}$ in the average q specification in Column 3 of Table 9; all other coefficients on terms in $\sigma_{i,t}$ were insignificant across Tables 8 and 9. The insignificant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms in Tables 8 and 9, shows that sufficiently weak real option effects may go undetected by including such terms in error correction and average q specifications. These results suggest that coefficients estimated on uncertainty sales growth interaction terms in error correction or average q specifications will not have a tendency to falsely report lower investment responses to demand at higher levels of uncertainty; at least in data sets with similar data generating process to the simulation program, and in which proxies for uncertainty accurately describe volatility in firm's discounted present values.

[TABLE 8 HERE]

[TABLE 9 HERE]

Figure 6 below presents Lowess plots of average investment responses to average annual changes in demand at different levels of uncertainty, across the firms in Simulated Data Set 2. Based on the Lowess plots illustrated in Figure 6 below, there appears to be some heterogeneity in investment responses to demand at different levels of uncertainty that is not being detected by coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms in estimates of the average q and error correction specifications obtained with Simulated Data Set 2. Comparing the Lowess plots generated with Simulated Data Sets 1 and 2, presented in Figures 5 and 6 respectively, differences between the effects of real options on investment responses to demand between these two data sets can appear quite subtle. The key differences between the two sets of Lowess plots lies in the investment responses corresponding to the 3 lowest levels of uncertainty (the Lowess Plots with the 3 highest slopes). Decreasing volatility in demand/productivity conditions and non-convex adjustment costs between the two data sets causes considerably more investment in response to demand shocks at higher levels of uncertainty. The latter effect is represented by the considerably shorter Lowess plot in Figure 6 corresponding to the lowest level of uncertainty. Whereas in Figure 5, the latter plot was much longer with a steeper slope, representing considerably more investment activity at the lowest level of uncertainty, much of which is relegated to times of higher relative uncertainty in Simulated Data Set 2. This difference can also be seen in the greater slopes of Lowess Plots corresponding to the 2nd and 3rd lowest levels of uncertainty in Simulated Data Set 1.

[FIGURE 6 HERE]

2.4.3 Simulated Data Set 3

The sets of tables presented throughout the remainder of this section present estimation results of the error correction and average q specifications obtained with Simulated Data Sets 3 and 4, in which real option values are set at intermediate levels between those in Simulated Data Sets 1 and 2. Although estimates of the error correction and average q specifications described consistent investment uncertainty relationships in Simulated Data Sets 1 and 2, coefficients estimated on uncertainty terms are significantly different between estimates of these specifications obtained with Simulated Data Set 4. Results obtained with Simulated Data Sets 3 and 4 suggest that it is possible for descriptions of investment-uncertainty relationships to be influenced by the choice of underlying investment specification being estimated.

Tables 10 and 11 below present results obtained from estimating the error correction and average q specifications with Simulated Data Set 3, in which the real option values have been decreased relative to Simulated Data Set 1, by lowering the variance of underlying demand/productivity conditions. As a result, the significance of coefficients estimated on uncertainty terms is greatly reduced. The coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ are only marginally significant in estimates of both specifications. Point estimates on these coefficients are quite similar and, compared by their standard errors, are not significantly different between the two specifications. Although real options have been reduced as a result of lower volatility in demand/productivity conditions in the simulation, relative to Simulated Data Set 1, both specifications continue to describe consistent effects of uncertainty on investment behaviour.

Table 10 below presents estimates of the error correction specification, using Simulated Data Set 3, in which demand/productivity volatility and real option values are lower relative to Simulated Data Set 1.[21] Column 1 presents estimates of the ADL[2,2] specification between $k_{i,t}$ and $y_{i,t}$, re-arranged to the form of an error correction specification. The coefficient estimated on $y_{i,t-1}$ is insignificant in Column 1 and is dropped in the error correction specification in Column 2. Column 3 adds the uncertainty interaction term $\sigma_{i,t} * \Delta y_{i,t}$, on which the estimated coefficient is only significant at the 10% level. Column 4 drops the uncertainty sales growth interaction term and adds the linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$, resulting in a rejection of the hypothesis that the instrument set is valid, according to a Sargan/Hansen test statistic. Column 5 adds $\sigma_{i,t} * \Delta y_{i,t}$ to Column 4, however the validity of the instrument set is still rejected by the Sargan/Hansen test statistic. Thus the preferred error correction specification for Simulated Data Set 2 is that presented in Column 3.

[21] The First Differenced GMM estimates in Table 10 use $t-4$ lagged instruments, as opposed to the $t-3$ lagged instrument set from Table 3. This is due to 3rd order serial correlation in the first differenced residuals detected by the Arellano-Bond test statistics reported in the bottom of Table 10. In the appendix to this chapter, Differenced Sargan/Hansen tests reject the hypothesis that $t-3$ lags of the instruments are valid relative to the null Hypothesis that only moment conditions based on $t-4$ lags are valid.

[TABLE 10 HERE]

Table 11 below reproduces the results in Table 4, using Simulated Data Set 3. Column 1 presents estimates of the average q specification from Column 3 of Table 4, in which coefficients estimated on $\frac{I_{i,t-1}}{K_{i,t-1}}$ and $\Delta y_{i,t-1}$ are individually insignificant but the hypothesis that they are jointly insignificant is rejected by a Wald test based on a p-value of 0.001. Based on the Arellano-Bond test for serial correlation in the differenced residuals in Column 1, Column 2 presents estimates of the specification in Column 1 using $t-2$ lags, instead of $t-3$ lags, of instruments for equations in first differences. However, in Column 2 the Arellano-Bond test rejects the hypothesis of no 2nd order serial correlation in the differenced residuals of the estimated average q investment specification. Column 3 uses $t-3$ lagged instruments, as in Column 1, and adds the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$ to the average q specification. Although the coefficient estimated on the term $\sigma_{i,t} * \Delta y_{i,t}$ is not significant, it is within one standard deviation of the significant coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ in the error correction specification in Table 10 and the average q specification in Table 4. Column 4 of Table 11 drops the $\sigma_{i,t} * \Delta y_{i,t}$ term from Column 3, and adds the linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$, on which coefficients are individually insignificant, but the hypothesis that they are jointly insignificant is rejected by a Wald test based on a p-value of 0.000. Column 5 adds the interaction term $\sigma_{i,t} * \Delta y_{i,t}$ to the specification in Column 4, however the coefficient on this term remains statistically insignificant. As in Column 4 coefficients estimated on $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ were individually insignificant, but the hypothesis that they are jointly insignificant is rejected by a Wald test based on a p-value of 0.0001.

[TABLE 11 HERE]

Column 6 of Table 11 uses longer lags of instruments, as in estimates of the error correction specification in Table 10 above. Although Arellano Bond tests for serially correlated residuals did not reject the hypothesis of no third order serial correlation in the residuals of Column 5, this hypothesis is rejected for the results in Column 6. As a result of using the longer lagged instruments in Column 6, the magnitude and standard error of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ increase, causing the coefficient to become statistically significant. The coefficient estimated on the latter term in Column 6 is not significantly different (by standard errors) from coefficients in Column of the same table, or from coefficients in Table 10. The negative coefficient on $\Delta\sigma_{i,t}$ also becomes statistically significant as a result of using the longer lagged instruments in Column 6.

2.4.4 Simulated Data Set 4

Tables 12 and 13 below reproduce the estimation results in Tables 3 and 4 for the error correction and average q investment specifications, using Simulated Data Set 4, in which non-convex capital adjustment costs and real option values are lower relative to Simulated Data Set 1. As a result of decreasing the capital adjustment costs in this simulated data set, coefficients estimated on uncertainty sales growth interaction terms become insignificant in the error correction specification; however coefficients estimated on these terms in the average q specification remain strongly significant and negative. Unlike in the previous sets of results obtained with Simulated Data Sets 1,2 and 3, coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ are of a significant order of magnitude higher in the average q specification as compared to the error correction specification. Estimates of each specification imply significantly different investment-uncertainty relationships in the data.

Table 12 below presents First Differenced GMM estimates[22] of the error correction specification using Simulated Data Set 4. Column 1 presents estimates of an ADL[2,2] model between $k_{i,t}$ and $y_{i,t}$, re-arranged to the form of an error correction model, and Column 2 drops the $y_{i,t-1}$ term from Column 1 resulting in an error correction specification. Arellano-Bond test statistics reported at the bottom of Column 2 reject the hypothesis of no 4th order serial correlation in the differenced residuals, in the presence of which it may be inappropriate to use $t-4$ lags of the dependent variable as instruments for equations in differences. Column 3 reproduces the results of Column 2 with $t-5$ lags of the dependent variable as instruments for equations in first differences, resulting in almost no change in the estimated coefficients from Column 2. Column 4 adds the uncertainty interaction term $\sigma_{i,t} * \Delta y_{i,t}$ to the specification in Column 3[23], on which the coefficient is statistically insignificant. Column 5 drops the $\sigma_{i,t} * \Delta y_{i,t}$ term and adds linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$, on which only the coefficient on the latter was

[22]Based on Arellano-Bond test statistics for serially correlated differenced residuals, $t-4$ lags of the instruments are used, as in the case of results presented in Table 10 above.

[23]The Arellano-Bond test statistic in this column does not reject the hypothesis of no 4th order serial correlation in the differenced residuals, and $t-4$ lags of the dependent variable are used as instruments for equations in first differences.

significant and had a positive effect on investment in the error correction specification. Column 6 includes the non-linear uncertainty term $\sigma_{i,t} * \Delta y_{i,t}$ as well as the linear terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$; coefficients in Column 6 are not significantly different from those in Columns 4 or 5.

[TABLE 12 HERE]

Table 13 below presents First Difference GMM estimates of the average q investment specification using Simulated Data Set 4, in which real option values are lower relative to Simulated Data Set 1 due to lower non-convex capital adjustment costs. Column 1 presents estimates of the average q specification excluding any uncertainty terms. Column 2 adds the uncertainty interaction term $\sigma_{i,t} * \Delta y_{i,t}$, on which the coefficient is significant and negative. Column 3 uses earlier $t-3$ lagged instruments to estimate the same specification in Column 2 (which used $t-4$ lagged instruments), Arellano-Bond test statistics do not reject the hypothesis of no 3rd order serial correlation in the differences residuals in Column 3. Column 4 drops the $\sigma_{i,t} * \Delta y_{i,t}$ term and adds the linear uncertainty terms $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$, on which a significant coefficient was only estimated on the latter. Column 5 includes both linear and non-linear uncertainty terms from Columns 3 and 4, on which estimated coefficients are not significantly different from the previous columns. Column 6 uses $t-4$ lags of the instruments, as in estimates of the error correction specification in Table 12 above, resulting in no significant change in coefficient estimates relative to Column 5.

[TABLE 13 HERE]

Results presented throughout this section demonstrate that the significance of coefficients estimated on uncertainty sales growth interaction terms is related to the strength of real options in the simulated data sets. Beginning with Simulated Data Set 1, in which coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms were significant in both investment specifications, decreasing real option values to the level in Simulated Data Set 2 causes coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ to become insignificant in both error correction and average Q specifications. Decreasing only the level of volatility in demand/productivity conditions in Simulated Data Set 3, relative to Simulated Data set 1, had a uniform effect on coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms. Unlike the case of Simulated Data Set 2, negative coefficients estimated on the latter terms remained marginally significant in estimates of error correction and average q specifications obtained with Simulated Data Set 3.

Unlike estimates obtained using Simulated Data Sets 1-3, estimates of error correction and average q specifications did not provide consistent descriptions of real option effects in Simulated Data Set 4. Discrepancies between coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms between the two specifications estimated with Simulated Data Set 4 would appear to be the result of lower non-convex capital adjustment costs. Estimates of error correction specifications using Simulated Data Set 4 resulted in insignificant coefficients estimated on uncertainty sales growth interaction terms. Whereas estimates of the average q investment specification yielded strongly significant, negative coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms; which were an order of magnitude larger than coefficients estimated on corresponding terms in the error correction specification. These results suggest that in Simulated Data Sets with *low* partial irreversibility in investment and low fixed adjustment costs to changing the capital stock, estimates of average q specifications may provide a more reliable description of real option effects of uncertainty on investment.

2.5 Measurement Error in Average Q

This section presents estimation results of the error correction and average q investment specifications obtained from Simulated Data Set 1, in which measurement error is introduced into monthly firm value functions, affecting measures of average q and uncertainty proxies $\sigma_{i,t}$ in the simulated data. The introduction of measurement error into firm value functions in the simulated data creates a measure analogous to noisy stock market valuations of firms which may include information which is not related to a firm's fundamental discounted expected value. As a result of introducing measurement error into the value functions of firms in the simulated data, coefficients estimated on uncertainty sales growth interaction terms become insignificant in the average q specification, but remain significant and negative in the error correction specification. This result appears to hold across estimates of average q and error correction specifications which use the original $\sigma_{i,t}$ uncertainty proxy, and a noisy measure that results from measurement error in firm value. This set of results raises concern over consistency between investment uncertainty relationships described in estimates of error correction and average q investment specifications. Although it did not appear to be an issue in the empirical data set analyzed in Chapter 1, the set of results presented here suggests that noisy measures of firm value and average q could lead to the failure of estimated average q investment specifications to capture lower investment responses to demand at higher levels of uncertainty.

The noisy measure of firm value in the simulated data set is obtained by multiplying the *true* firm value by a measurement error: $V^n_{i,t} = V_{i,t} * (1 + MA_{i,t})$. The measurement error component $MA_{i,t}$ is a moving average of three independently and identically distributed noise components that are normally distributed with mean 0.5 and variance 0.4[24]: $ma_{i,t} \sim N[0.5, 0.4]$.

$$MA_{i,t} = \sum_{j=0}^{2} ma_{i,t-j} \tag{2.9}$$

Using the noisy measure of firm value, $V^n_{i,t}$, to construct average q in the simulated data set results in the noisy measure of average q $Q^n_{i,t}$. Table 14 below presents estimates of average q

[24]The mean and variance of the normally distributed measurement errors were chosen as the minimum values that resulted in insignificant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ and a significant coefficient estimated on the noisy measure of $Q_{i,t}$, $Q^n_{i,t}$ in the average q investment specification.

specifications using both $Q^n_{i,t}$ and $Q_{i,t}$ as controls for average q, in Simulated Data Set 1. The original uncertainty proxy $\sigma_{i,t}$ is used in Table 14 to illustrate the effect of noisy measures of average q on coefficients estimated on uncertainty interaction terms that could be constructed using alternative uncertainty proxies which do not rely on noisy stock market measures of firm value. As a result of using the noisy measure of average q, coefficients estimated on uncertainty sales growth interaction terms become insignificant. The first two columns of Table 14 present estimates of the average q specification using $Q_{i,t}$, including both linear and non-linear uncertainty terms in Column 1 and only the non-linear $\sigma_{i,t} * \Delta y_{i,t}$ term to control for uncertainty in Column 2. The specifications in these Columns correspond to those in Columns 4 and 6 of Table 4. Estimates of the specifications in Columns 3 and 4 of Table 14 replace $Q_{i,t}$ in the average q specifications in Columns 1 and 2, with the noisy measure $Q^n_{i,t}$; as a result, coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ become insignificant in both Columns 3 and 4.

[TABLE 14 HERE]

The MA[3] measurement error introduced into the firm value functions of the simulated data implies that the monthly firm value functions used to construct the uncertainty proxy $\sigma_{i,t}$ (the within year standard deviation of monthly returns to firm value functions), are also subject to measurement error. Where $\sigma_{i,t}$ and $\sigma^n_{i,t}$ are the uncertainty proxies constructed with true and noisy measures of V_{i,t_m} (where the additional subscript m indicates the month within year t)[25].

$$\sigma_{i,t} = \sqrt{VAR_t[\Delta_m log(V_{i,t_m})]}$$

$$\sigma^n_{i,t} = \sqrt{VAR_t[\Delta_m log(V_{i,t_m} * (1 + MA_{i,t_m}))]}$$

The measurement error MA_{i,t_m} above is the monthly value of the annual measure $MA_{i,t}$. The monthly frequency of MA_{i,t_m} implies that $ma_{i,t}$ in Equation (2.9) is the sum of 12 monthly independently and identically distributed random variables n_{i,t_m}, each with $N[0.5/12, 0.4/12]$ distributions.

[25] In Prof. Nick Bloom's MATLAB program monthly returns to firm value functions is calculated as $\frac{V_{i,tm}}{V_{i,tm-1}} - 1$, however this is approximated by $\Delta_m log(V_{i,t_m})$ in order to simplify the construction of the noisy uncertainty proxy $\sigma^n_{i,t}$.

$$MA_{i,t_m} = \sum_{j=0}^{35} n_{i,t_{m-j}} \tag{2.10}$$

The noisy measure of uncertainty in the simulated data $\sigma^n_{i,t}$ can be simplified to the square root of the sum of $VAR_t[\Delta_m log(V_{i,t_m})]$ and a constant, this is shown with the following algebra.

$$(\sigma^n_{i,t})^2 = VAR_t[\Delta_m log(V_{i,t_m} * (1 + MA_{i,t_m}))]$$

Due to the fact that the measurement errors are independent of V_{i,t_m} by construction, the above expression can be re-written as,

$$(\sigma^n_{i,t})^2 = VAR_t[\Delta_m log(V_{i,t_m})] + VAR_t[\Delta_m log(*(1 + MA_{i,t_m}))]$$

Through an application of the Delta Method, Equation (2.11), $VAR_t[\Delta_m log((1 + MA_{i,t_m}))]$ can be re-written in the form of Equation (2.12) below, where the random variables X and Y are given by MA_{i,t_m} and $MA_{i,t_{m-1}}$ and $f(X, Y)$ is given by $\Delta_m log(1 + MA_{i,t_m}) = log(1 + MA_{i,t_m}) - log(1 + MA_{i,t_{m-1}})$.

$$\begin{aligned} VAR[f(X,Y)] = (f_X(E[X], E[Y]))^2 VAR[X] + 2f_X(E[X], E[Y])f_Y(E[X], E[Y])COV[X, Y] \\ +(f_Y(E[X], E[Y]))^2 VAR[Y] \end{aligned} \tag{2.11}$$

$$\begin{aligned} VAR_t[\Delta_m log(1 + MA_{i,t_m})] = \left(\frac{1}{1 + E_t[MA_{i,t_m}]}\right)^2 VAR_t[MA_{i,t_m}] \\ -2\left(\frac{1}{1 + E_t[MA_{i,t_{m-1}}]}\right)\left(\frac{1}{1 + E_t[MA_{i,t_{m-1}}]}\right) COV_t[MA_{i,t_m}, MA_{i,t_{m-1}}] \\ +\left(\frac{1}{1 + E_t[MA_{i,t_{m-1}}]}\right)^2 VAR_t[MA_{i,t_{m-1}}] \end{aligned} \tag{2.12}$$

Equation (2.12) above can be simplified by the facts that $E_t[MA_{i,t_m}] = E_t[MA_{i,t_{m-1}}] = 1.5$, $VAR_t[MA_{i,t_m}] = VAR_t[MA_{i,t_{m-1}}] = 1.2$ and $COV_t[MA_{i,t_m}, MA_{i,t_{m-1}}] = 1.167$[26], and re-

[26] This is due to the fact that MA_{i,t_m} and $MA_{i,t_{m-1}}$ have only two uncommon elements: n_{i,t_m} and $n_{i,t_{m-36}}$, and thus $COV_t[MA_{i,t_m}, MA_{i,t_{m-1}}] = 34 * VAR[n_{i,t_m}] = 1.167$

written as Equation (2.13) below.

$$2\left(\frac{1}{1+E_t[MA_{i,t_m}]}\right)^2\left(VAR_t[MA_{i,t_m}]-COV_t[MA_{i,t_m},MA_{i,t_{m-1}}]\right)=0.01056 \quad (2.13)$$

Thus $\sigma_{i,t}^n$ can be re-written in terms of $\sigma_{i,t}$ and a constant:

$$\sigma_{i,t}^n=\sqrt{(\sigma_{i,t})^2+0.01056} \quad (2.14)$$

Table 15 below presents estimates of the average q and error correction specifications, using the uncertainty proxy $\sigma_{i,t}^n$, constructed according to Equation (2.14), implied by the measurement error in firm value functions which was introduced to $Q_{i,t}^n$ in Table 14 above. Replacing $\sigma_{i,t}$ with $\sigma_{i,t}^n$, constructed with the noisy monthly firm value functions, results in no significant change in coefficients estimated on uncertainty sales growth interaction terms in average q and error correction specifications. Coefficients estimated on uncertainty sales growth interaction terms $\sigma_{i,t}^n * \Delta y_{i,t}$ are significant and negative in estimates of the average q specification using $Q_{i,t}$ in Columns 1 and 2, and in estimates of the error correction specifications in Columns 5 and 6. However, coefficients on $\sigma_{i,t}^n * \Delta y_{i,t}$ become insignificant in Columns 3 and 4 when $Q_{i,t}$ is replaced with $Q_{i,t}^n$ in estimates of the average q specification.

[TABLE 15 HERE]

These results suggest that in an empirical data set (with a similar data generating process to Professor Bloom's MATLAB program) measurement error in firms' value functions, which led to the construction of noisy measures of average q, could prevent estimates of average q specifications from identifying lower investment responses to demand at higher levels of uncertainty. Such noisy measures of average q could result in an empirical data set which used stock market valuations of firms containing information unrelated to firms discounted expected values. Comparing results in Tables 14 and 15 suggests that this issue is chiefly related to noise in average q, and would not necessarily be resolved by using alternative uncertainty proxies not based on noisy stock market valuations of firms.

2.6 Conclusion

Results presented in Chapter 1 confirmed that estimates of error correction and average q investment specifications described similar investment uncertainty relationships in an empirical data set of UK firms. Specifically, coefficients estimated on interaction terms between sales growth and uncertainty proxies in each specification implied similar negative effects of uncertainty on investment responses to changes in demand. Coefficients on the latter terms being considerably larger in magnitude in estimates of error correction specifications, the measurement of investment rates in the error correction and average q specifications appeared to have a significant effect on coefficients estimated on uncertainty sales growth interaction terms. The inclusion of error correction or average q terms in investment specifications were also found to have a significant effect on coefficients estimated on uncertainty sales growth interaction terms using the empirical data.

Using simulated data, the current chapter continued the comparison of investment uncertainty relationships described in estimates of error correction and average q specifications from Chapter 1. The advantage of using the simulated data is that uncertainty, in the form of volatility over demand/productivity conditions, is directly observable. The real option effects of uncertainty on investment behavior are also observable in the simulated data through Lowess Plots of investment responses to demand at varying levels of uncertainty. Although, error correction and average q investment specifications described consistent effects of uncertainty when estimated with several simulated data sets, specific changes to the simulation program produced data sets for which estimated error correction and average q specifications yielded inconsistent coefficients on uncertainty sales growth interaction terms.

Similar to results presented in Chapter 1 for empirical data, error correction and average q specifications were estimated with simulated data[27] in which negative coefficients on uncertainty sales growth interaction terms were significant in both specifications. As in the results of Chapter 1, the measurement of investment in estimates of hybrid (containing both average q and error correction terms) investment specifications had a significant effect on the coefficients

[27]Specifically, using Simulated Data Set 1.

estimated on uncertainty sales growth interaction terms. In the simulated data measuring investment as $\Delta k_{i,t}$ as opposed to $\frac{I_{i,t}}{K_{i,t}}$ in hybrid and average q specifications, resulted in larger and more significant coefficients on uncertainty sales growth interaction terms. Measuring investment as $\frac{I_{i,t}}{K_{i,t}}$ in hybrid and error correction specifications resulted in insignificant coefficients on uncertainty sales growth interaction terms. The inclusion of average q and error correction terms in investment specifications also had a significant effect on coefficients estimated on uncertainty sales growth interaction terms in the simulated data; this feature of the results was also found with the empirical data in Chapter 1. The latter result suggests that controls for investment dynamics are important for identifying effects of uncertainty on investment in estimates of firm level investment specifications.

Estimates of the investment specifications were shown to describe consistent effects of uncertainty at lower parameterizations of volatility in underlying demand/productivity conditions. Decreasing both volatility in demand/productivity conditions and non-convex adjustment costs illustrated that when real option values are low enough, neither estimates of error correction nor average q specifications could detect effects of real options with significant coefficients on uncertainty sales growth interaction terms in the simulated data.

Lowering only non-convex adjustment costs in the simulated data resulted in inconsistent investment uncertainty relationships described by estimates of the error correction and average q specifications. Coefficients estimated on uncertainty sales growth interaction terms were only significant in estimates of the latter specification. Conversely, introducing measurement error into firm value functions, and measures of average q, can cause significant negative coefficients on uncertainty interaction terms to become insignificant in estimates of the average q specification. In the presence of such measurement error, estimates of error correction specifications yielded a more reliable description of the investment uncertainty relationship in the simulated data.

Estimation results presented in Chapters 1 and 2, with empirical and simulated data, both imply that the measurement of dependent variables, as well as the inclusion of controls for investment dynamics have a significant effect on coefficients estimated on uncertainty sales growth interaction terms in estimates of average q and error correction specifications. Estimation results obtained with the simulated data demonstrated several instances in which estimates of error correction and average q specifications yielded significantly different coefficients on uncertainty terms, implying different relationships between investment and uncertainty. These findings suggest that future investigations into the effects of uncertainty on firm level investment should pay careful attention to the choice of underlying investment specification; and ideally confirm the robustness of results across alternative investment specifications.

2.7 Program Appendix

2.7.1 Revenue Function

To generate the simulated data analyzed in this chapter, each firm in the MATLAB code was made up of 250 production units, each facing unique series' of shocks to the demand/productivity indexes in their revenue functions. [28] The production technologies of each unit are identical across the simulation program and are described for the production unit j of firm i in a given monthly period m of year t[29] by a Cobb Douglas Production function with labor L_{i,j,t_m} and two types of capital K_{k,i,j,t_m} where $k = 1, 2$, with the production share of capital types given by β.

$$Q_{i,j,t_m} = A_{i,j,t_m} L^{1-2\beta}_{i,j,t_m} K^{\beta}_{1,i,j,t_m} K^{\beta}_{2,i,j,t_m} \tag{2.15}$$

$$Q_{i,j,t_m} = A_{i,j,t_m} L^{1-2\beta}_{i,j,t_m} K^{\beta}_{i,j,t_m} \qquad where \qquad K_{i,j,t_m} = K_{1,i,j,t_m} K_{2,i,j,t_m}$$

The equations of motion are the same for each capital type $k = 1, 2$, and are defined as follows where I_{k,i,j,t_m} is investment by unit j of firm i in year t month m in capital type k, and δ is a depreciation rate.

$$K_{k,i,j,t_m} = (1-\delta)K_{k,i,j,t_m-1} + I_{k,i,j,t_m}$$

Each production unit faces its own iso-elastic demand curve, which contains a stochastic component X_{i,j,t_m}.

$$Q_{i,j,t_m} = X_{i,j,t_m} P^{-\epsilon}_{i,j,t_m} \tag{2.16}$$

It is assumed that labour can be costlessly adjusted, which allows the short term revenue function (net of variable costs) of each production unit to be written in terms of capital and demand conditions after labor is optimized out. Below, L^*_{i,j,t_m} is the amount of labour that maximizes equation (2.17). Substituting L^*_{i,j,t_m} into (2.17) yields equation (2.19).

[28] The number of production units was left unchanged from that chosen in Bloom, Bond and Van Reenen (2007).

[29] Where each year has 12 monthly periods denoted by subscript m on the year t (t_m), and month 12 of year $t-1$ ($(t-1)_{12}$) precedes month 1 of year t (t_1)

$$R_{i,j,t_m} = X_{i,j,t_m}^{1/\epsilon} Q_{i,j,t_m}^{1-1/\epsilon} - wL_{i,j,t_m} \tag{2.17}$$

$$R_{i,j,t_m} = max_L \big(X_{i,j,t_m}^{1/\epsilon} A_{i,j,t_m}^{1-1/\epsilon} L_{i,j,t_m}^{(1-2\beta)(1-1/\epsilon)} (K_{1,i,j,t_m} K_{2,i,j,t_m})^{\beta(1-1/\epsilon)} - wL_{i,j,t_m} \big) \tag{2.18}$$

$$L_{i,j,t_m}^{*} = \big[w \frac{\gamma\epsilon}{\gamma\epsilon - 1} \big]^{-\gamma\epsilon} X^{\gamma} A_{i,j,t_m}^{(1-\epsilon)\gamma} (K_{1,i,j,t_m} K_{2,i,j,t_m})^{1/2(1-\gamma)}$$

where γ is defined as $\frac{1}{1+2\beta(\epsilon-1)}$

$$R_{i,j,t_m} = \big[w^{1-\gamma\epsilon} \gamma\epsilon^{-1-\gamma\epsilon} (\gamma\epsilon - 1)^{\gamma\epsilon} \big] X_{i,j,t_m}^{\gamma} A_{i,j,t_m}^{(1-\epsilon)\gamma} (K_{1,i,j,t_m} K_{2,i,j,t_m})^{1/2(1-\gamma)} \tag{2.19}$$

This revenue function is simplified by combining demand and productivity conditions into one index

$$Z_{i,j,t_m} \equiv \big[w^{1/\gamma-\epsilon} \gamma\epsilon^{-1/\gamma-\epsilon} (\gamma\epsilon - 1)^{\epsilon} \big] X_{i,j,t_m} A_{i,j,t_m}^{(1-\epsilon)}$$

It is then normalized to be homogeneous to the first degree in K_{1,i,j,t_m}, K_{2,i,j,t_m} and $\Sigma_{i,j,t_m} = Z_{i,j,t_m}^{\frac{\gamma}{1-2\alpha}}$, where $\alpha = 1/2(1-\gamma)$.

$$R(Z_{i,j,t_m}, K_{1,i,j,t_m}, K_{2,i,j,t_m}) = Z_{i,j,t_m}^{\gamma} (K_{1,i,j,t_m} K_{2,i,j,t_m})^{1/2(1-\gamma)}$$

$$R(\Sigma_{i,j,t_m}, K_{1,i,j,t_m}, K_{2,i,j,t_m}) = \Sigma_{i,j,t_m}^{1-2\alpha} (K_{1,i,j,t_m} K_{2,i,j,t_m})^{\alpha} \tag{2.20}$$

2.7.2 Uncertainty/Volatility in Underlying Demand/Productivity

The demand/productivity index Σ_{i,j,t_m} faced by each production unit is comprised of a firm level component (Σ_{i,j,t_m}^{F}) and a plant level (Σ_{i,j,t_m}^{P}) component: $\Sigma_{i,j,t_m} = \Sigma_{i,j,t_m}^{P} * \Sigma_{i,j,t_m}^{F}$. This allows for individual production units to be exposed to idiosyncratic productivity shocks that don't affect other production units; whereas the firm specific shocks jointly affect all the production units, linking their investment behaviour through common demand shocks and firm level uncertainty. Both plant level productivity Σ_{i,j,t_m}^{P} and the firm demand Σ_{i,j,t_m}^{F} evolve over time as augmented geometric random walks with a common mean drift μ and stochastic variance

σ^2_{i,j,t_m}.

$$\Sigma^F_{i,j,t_m} = \Sigma^F_{i,j,t_{m-1}}(1 + \mu + \sigma_{i,j,t_m} V^F_{i,j,t_m}) \qquad V^F_{i,j,t_m} \sim N[0,1] \tag{2.21}$$

$$\Sigma^P_{i,j,t_m} = \Sigma^P_{i,j,t_{m-1}}(1 + \mu + \sigma_{i,j,t_m} V^P_{i,j,t_m}) \qquad V^P_{i,j,t_m} \sim N[0,1] \tag{2.22}$$

The variance of these productivity and demand conditions varies over time, converging to the long run mean σ^* at a rate of ρ_σ, according to the process described by equation (2.23) below. The variance of the shocks to σ_{i,j,t_m} is σ^2_σ.

$$\sigma_{i,j,t_m} = \sigma_{i,j,t_{m-1}} + \rho_\sigma(\sigma^* - \sigma_{i,j,t_m-1}) + \sigma_\sigma W_{i,j,t_m} \qquad W_{i,j,t_m} \sim N[0,1] \tag{2.23}$$

In the simulation program σ_{i,j,t_m} is varied by a symmetric monthly transition matrix across 5 values 0.1, 0.2, 0.3, 0.4, and 0.5, with 0.3 set as the long run mean for the process[30]. As noted in Bloom, Bond Van Reenen (2007), this process results in a cluster around these values, of the average annual underlying demand volatility outputted in the panel data set $var_{i,t}$. The Lowess plots in Figures 1 through 4 use the clustering around these values of $var_{i,t}$ to describe the investment responses to demand at the 5 different levels of underlying uncertainty. In Figure 3, these 5 values are uniformly decreased to lower the variance of the underlying demand/productivity conditions, and consequently the real option values faced by the individual production units.

2.7.3 Adjustment Costs

Each production unit of a firm faces a combination of three types of adjustment costs for each type of capital: fixed, partial irreversibility and quadratic. The MATLAB program is set up to allow the adjustment costs to differ for each type of capital, however, for the purposes of the analysis in this chapter the two capital types are treated symmetrically. It is by changing the adjustment costs parameters c_f and c_p below, that real option values faced by production units

[30]These are the values used to produce the simulated data sets in Bloom, Bond and Van Reenen (2007)

are varied across simulated data sets.

Fixed adjustment costs are imposed as a fixed proportion of revenue, whenever a production unit alters the stock of a type of capital.

$$C_{F,i,j,t_m} = \sum_{k=1}^{2} c_f * R(\Sigma_{i,j,t_m}, K_{1,i,j,t_m}, K_{2,i,j,t_m}) I[I_{k,i,j,t_m}]_{(+)}$$

where $I[x]_{(+)}$ is an indicator function that takes the value of 1 when $x \neq 0$ and 0 when $x = 0$.

Partial adjustment costs are imposed in the same way as in Abel and Eberly (1996) in the form of a wedge between the purchase and resale price of capital; ie when selling capital that was purchased at price p_k, production units only receive $(1 - c_p) * p_k$ for each unit of capital.

$$C_{p,i,j,t_m} = \sum_{k=1}^{2} I_{k,i,j,t_m}(1 - c_p) * p_k I[I_{k,i,j,t_m}]_{(-)}$$

Where the subscript k denotes capital type 1 or 2, and $I[x]_{(-)}$ is an indicator function that takes the value of 1 when $x < 0$ and 0 when $x > 0$.

Quadratic adjustment costs make higher rates of adjustment to the capital stock more costly. This is meant to reflect disproportionately higher costs to large overhauls/changes to the capital stock, compared to minor additions and maintenance/replacement.

$$C_{q,k,i,j,t_m} = c_q(1 - \delta)K_{k,i,j,t_m-1}\left(\frac{I_{k,i,j,t_m}}{(1 - \delta)K_{k,i,j,t_m-1}}\right)^2$$

2.7.4 Solving the Investment Problems

The optimization problem of each production unit (j) of each firm (i) can be written in the form of the Bellman equation shown below (Equation (2.24)), in which δ and r, the depreciation and discount rate are both set to 0.1 annually. I_{k,i,j,t_m} is investment in period t_m in capital type $k = 1, 2$. K_{k,i,j,t_m} is the stock of type $k = 1, 2$ capital of production unit (j) in firm (i) in period t_m, and $E[.]$ is the expectations operator.

$$V(\Sigma_{i,j,t_m}, K_{1,i,j,t_m-1}, K_{2,i,j,t_m-1}, \sigma_{i,j,t_m}) = max_{I_{1,i,j,t_m}, I_{2,i,j,t_m}} \big(R(\Sigma_{i,j,t_m}, (1-\delta)K_{1,i,j,t_m-1} \tag{2.24}$$

$$+I_{1,i,j,t_m}, (1-\delta)K_{2,i,j,t_m-1} + I_{2,i,j,t_m}) - C(\Sigma_{i,j,t_m}, I_{1,i,j,t_m}, I_{2,i,j,t_m}, K_{1,i,j,t_m-1}, K_{2,i,j,t_m-1})$$

$$+\frac{1}{1+r} E\left[V(\Sigma_{i,j,t_{m+1}}, K_{1,i,j,t_m}, K_{2,i,j,t_m}, \sigma_{i,j,t_{m+1}}) \right] \big)$$

where $C(I_{1,i,j,t_m}, I_{2,i,j,t_m}, K_{1,i,j,t_m}, K_{2,i,j,t_m})$ is the sum of adjustment costs over both types of capital.

In order to simplify the solution process to this optimization problem, the joint homogeneity of the revenue function, adjustment cost functions, depreciation schedules and expectations operators in ($\Sigma_{i,j,t_m}, K_{1,i,j,t_m-1}$ and K_{2,i,j,t_m-1}) can be used to re-parameterize equation (2.24) in terms of 3 state variables instead of 4.

$$K_{1,i,j,t_m-1} V(\Sigma^*_{i,j,t_m}, 1, K^*_{2,i,j,t_m-1}, \sigma_{i,j,t_m}) = max_{I^*_{1,i,j,t_m}, I^*_{2,i,j,t_m}} \big(K_{1,i,j,t_m-1} R(\Sigma^*_{i,j,t_m}, (1-\delta) \tag{2.25}$$

$$+I^*_{1,i,j,t_m}, (1-\delta)K^*_{2,i,j,t_m-1} + I^*_{2,i,j,t_m}) - K_{1,i,j,t_m-1} C(\Sigma^*_{i,j,t_m}, I^*_{1,i,j,t_m}, I^*_{2,i,j,t_m}, 1, K^*_{2,i,j,t_m-1})$$

$$+\frac{K_{1,i,j,t_m}}{1+r} E\left[V(\Sigma^*_{i,j,t_{m+1}}, 1, K^*_{2,i,j,t_m}, \sigma_{i,j,t_{m+1}} \right] \big)$$

Where $K^*_{2,i,j,t_m-1} = \frac{K_{2,i,j,t_m-1}}{K_{1,i,j,t_m-1}}$, $\Sigma^*_{i,j,t_m} = \frac{\Sigma_{i,j,t_m}}{K_{1,i,j,t_m-1}}$, $I^*_{1,i,j,t} = \frac{I_{1,i,j,t_m}}{K_{1,i,j,t_m-1}}$, $I^*_{2,i,j,t_m} = \frac{I_{2,i,j,t_m}}{K_{1,i,j,t_m-1}}$

After normalizing by type 1 capital the new Bellman equation is given by

$$V(\Sigma^*_{i,j,t_m}, 1, K^*_{2,i,j,t_m-1}, \sigma_{i,j,t_m}) = max_{I^*_{1,i,j,t_m}, I^*_{2,i,j,t_m}} \big(R(\Sigma^*_{i,j,t_m}, (1-\delta)+I^*_{1,i,j,t_m}, (1-\delta)K^*_{2,i,j,t_m-1}+I^*_{2,i,j,t_m}) \tag{2.26}$$

$$(1-\delta)K^*_{2,i,j,t_m-1} + I^*_{2,i,j,t_m}) - C(\Sigma^*_{i,j,t_m}, I^*_{1,i,j,t_m}, I^*_{2,i,j,t_m}, 1, K^*_{2,i,j,t_m-1})$$

$$+\frac{(1-\delta)+I^*_{1,i,j,t_m}}{1+r} E\left[V(\Sigma^*_{i,j,t_{m+1}}, 1, K^*_{2,i,j,t_m}, \sigma_{i,j,t_{m+1}}) \right] \big)$$

The program sets up this optimization problem in MATLAB on a state space of (100,100,5) for $(\Sigma^*_{i,j,t_m}, K^*_{2,i,j,t_m-1}, \sigma_{i,j,t_m})$ and an optimal control space of (100,100) for $(I^*_{1,i,j,t_m}, I^*_{2,i,j,t_m})$. Then it runs successive iterations of contraction mapping on the value function to solve the Bellman equation. A single iteration begins with an initial guess for the value function, then expectations of the next period's value function are generated based on the current guess. The program then solves for the optimal investment levels for the revenue function and the current guess of next period's value function. The optimal investment levels are substituted back into the revenue function and the current iteration's guess of the value function, in order to form a guess of the value function for the next iteration of contraction mapping. The iterations continue until a convergence criteria for the value function is reached, producing the optimal investment rates at each point in the state space.

For further details please refer to Professor Nick Bloom's website:
$http://www.stanford.edu/\ nbloom/index_files/Page298.htm$

2.7.5 Varying the Real Option Values

The simulated data used throughout this chapter is generated directly from the version of the MATLAB program that is available for download on Professor Nick Bloom's website, listed above. The core of the program is completely unchanged from that which produced the simulated data in Bloom, Bond and Van Reenen (2007). The only changes that are made to the program are to some adjustment cost and volatility parameters that impact the real option values faced by the individual production units in the simulation. Parameters governing non-convex adjustment costs c_p and c_f are adjusted to change the magnitude of partial and fixed adjustment costs faced by production units[31]; and the 5 values taken on by σ_{i,j,t_m} are reduced from the values in Bloom, Bond and Van Reenen (2007), to decrease the volatility of underlying demand/productivity conditions and the real option values faced by production units. Relative to the parameterization of the program available on Professor Bloom's Website (the same used to generate simulated data in Bloom, Bond and (2007)) the latter parameters are varied accordingly in the simulated data sets used to generate figures and estimation results:

Figures:

1. In Figure 1, c_f and c_p are increased to 0.075 and 0.75 respectively, to create more valuable real option values faced by production units
2. In Figure 2, c_f and c_p are decreased to 0.025 and 0.25 respectively to create less valuable real options relative to the above parameterization and the default parameterization from Bloom, Bond and Van Reenen (2007).
3. In Figure 3, c_f and c_p are set to 0.075 and 0.75 respectively, and 5 values taken on by σ_{i,j,t_m} are decreased from [0.1, 0.2, 0.3,0.4,0.5] with long run mean 0.3, to [0.02,0.04,0.06,0.08,0.1] with long run mean 0.06.

Results:

1. Simulated Data Set 1, with the highest real option values, sets c_f and c_p to 0.02 and 0.2 respectively, and leaves the values of σ_{i,j,t_m} as the Bloom, Bond and VanReenen (2007) default ([0.1, 0.2, 0.3,0.4,0.5]).
2. In Simulated Data Set 2, real option values are at their lowest, with c_f and c_p set to 0.015 and 0.15 respectively, and values of σ_{i,j,t_m} taking on values of [0.075, 0.15, 0.225, 0.3, 0.375].
3. In Simulated Data Set 3, the real option values are lowered relative to Simulated Data Set 1 by decreasing the values of σ_{i,j,t_m} to [0.075, 0.15, 0.225, 0.3, 0.375] from [0.1, 0.2, 0.3,0.4,0.5]

[31]The weighting of the quadratic adjustment costs c_q was also changed from a value of 0.3 in Bloom, Bond Van Reenen (2007), to 0.2 across all the simulated data sets, because the Bloom, Bond Van Reenen (2007) default parameterization produced unrealistically high values of average q, several magnitudes beyond values observed in the empirical data set of Chapter 1

4. The real option values are also lowered by decreasing c_f and c_p to 0.015 and 0.15 respectively in Simulated Data Set 4, but leaving the values of σ_{i,j,t_m} as the Bloom, Bond and VanReenen (2007) default ([0.1, 0.2, 0.3,0.4,0.5]).

2.8 Instrument Appendix

Table A1 below asses the validity of earlier instruments in First Differenced GMM estimates of the error correction specification from Column 3 of Table 10 based on instruments lagged $t-4$. Differenced Sargan/Hansen tests are used to evaluate the null hypothesis that additional $t-3$ lags of each instrument are valid relative to the alternative hypothesis that only the $t-4$ lagged instruments are valid in estimates of the specification in Column 3 of Table 10. The results show that the data does not support the use of $t-3$ lagged instruments, in First Differenced GMM estimates of the error correction specification. Column 1 of Table A1 below reproduces the First Differenced GMM estimates of the specification from Column 3 of Table 10 based on instruments lagged $t-4$. Column 2 presents estimates of the same specification obtained by adding $k_{i,t-3}$ to the instrument set in Column 1 of Table A1. At the bottom of Column 2 the value of 1 minus the p-value is reported for a Differenced Sargan/Hansen test evaluating the null hypothesis that $k_{i,t-3}$ is a valid instrument against the alternative hypothesis that only the subset of instruments from Column 1 are valid in the First Differenced Estimates of the investment specification; the null hypothesis is rejected. Columns 3 through 5 repeat the exercise in Column 2, individually adding $y_{i,t-3}$, $(k_{i,t-3} - y_{i,t-3})$ and $\sigma_{i,t-3} * \Delta y_{i,t-3}$ to the instrument set in Column 1. At the bottom of each column the value of 1 minus the p-value is reported for Differenced Sargan/Hansen tests evaluating the null hypotheses that the additional instruments are valid against the null hypothesis that only the subset of instruments from Column 1 are valid in the First Differenced GMM estimates of the error correction investment specification. In Columns 3 through 5 each null hypothesis is rejected by the Differenced Sargan/Hansen tests.

[TABLE A1 HERE]

2.9 Figures and Tables

FIGURE 1

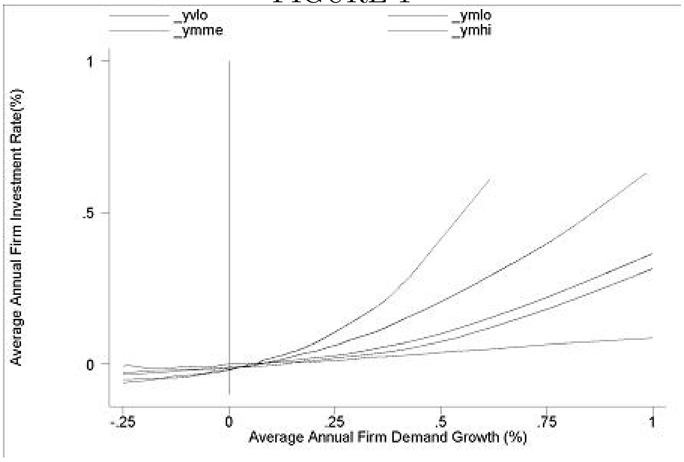

FIGURE 2

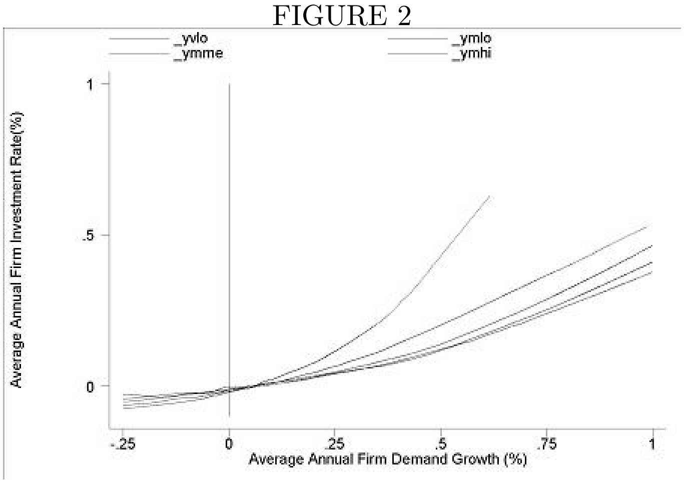

FIGURE 3

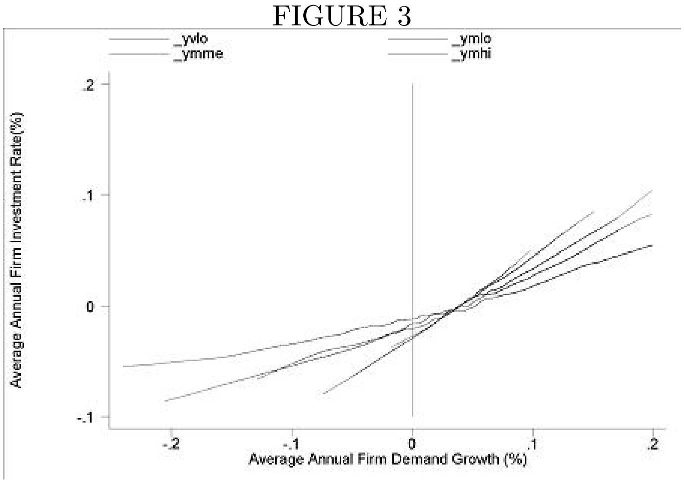

FIGURE 4

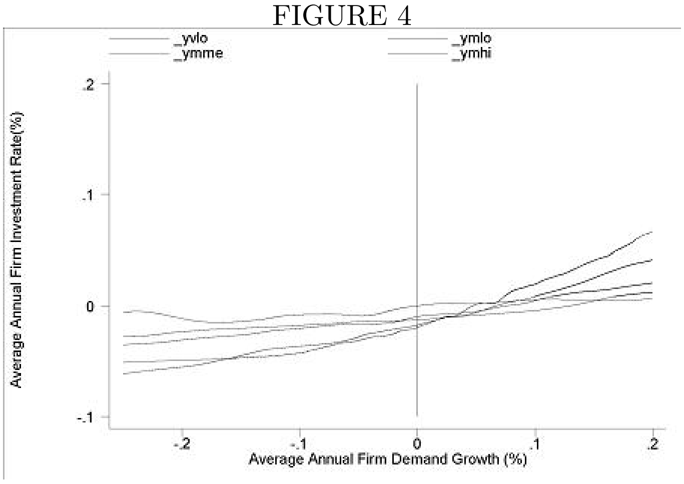

FIGURE 5

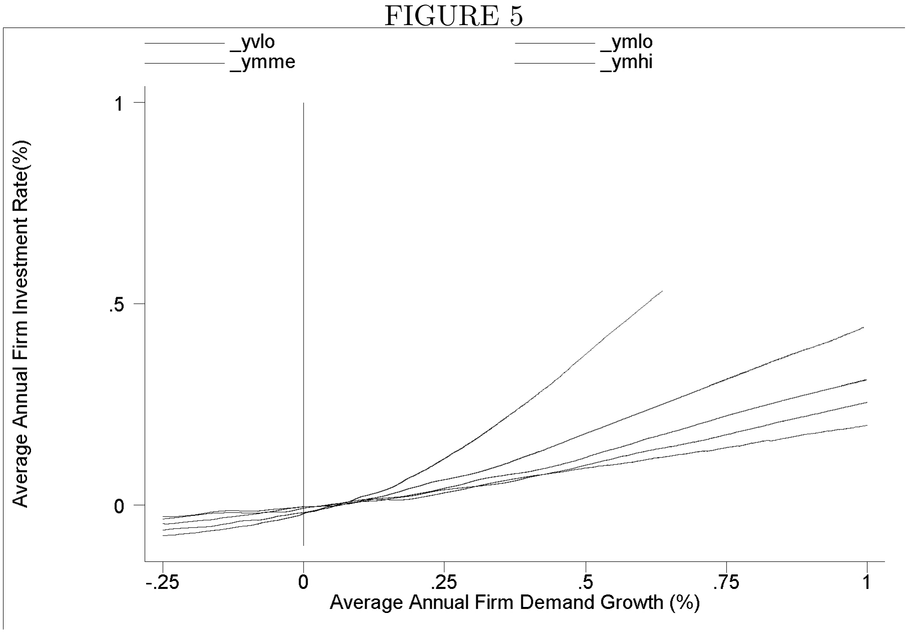

FIGURE 6

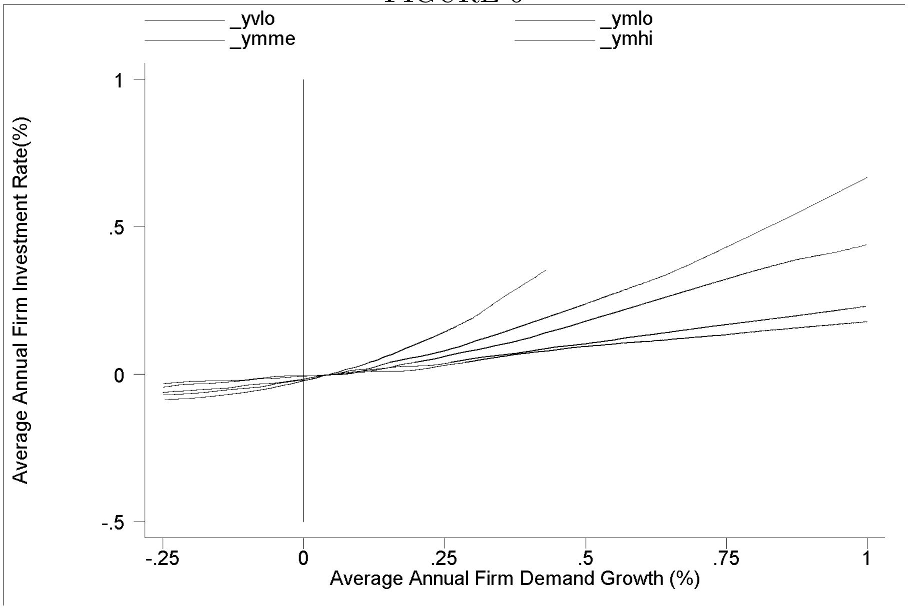

TABLE 1
Autoregressive Models

	(1)	(2)	(3)	(4)	(5)
	$k_{i,t}$	$\Delta k_{i,t}$	$y_{i,t}$	$\Delta y_{i,t}$	$(k_{i,t} - y_{i,t})$
$k_{i,t-1}$	1.003 (.0003)***				
$\Delta k_{i,t-1}$	.689 (.004)***	.695 (.003)***			
$\Delta k_{i,t-2}$	-.033 (.005)***				
$\Delta k_{i,t-3}$	.034 (.004)***				
$\Delta k_{i,t-4}$					
$y_{i,t-1}$			1.004 (.0003)***		
$\Delta y_{i,t-1}$			.730 (.004)***	.688 (.003)***	
$\Delta y_{i,t-2}$			-.131 (.005)***		
$\Delta y_{i,t-3}$			.091 (.005)***		
$\Delta y_{i,t-4}$			-.019 (.004)***		
$(k_{i,t-1} - y_{i,t-1})$					.697 (.003)***

TABLE 2
Autoregressive Models

	(1)	(2)	(3)
	$\frac{I_{i,t}}{K_{i,t}}$	$\sigma_{i,t}$	$Q_{i,t}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	.698 $(.003)^{***}$		
$\sigma_{i,t-1}$		.750 $(.002)^{***}$	
$Q_{i,t-1}$			.788 $(.004)^{***}$

TABLE 3
Error Correction Investment Specification (Simulated Data Set 1)

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	.022				
	(.027)				
$\Delta k_{i,t-1}$	-.271	-.324	-.278	-.350	-.290
	(.106)**	(.084)***	(.066)***	(.077)***	(.062)***
$\Delta y_{i,t-1}$	.128	.151	.125	.160	.126
	(.049)***	(.040)***	(.030)***	(.038)***	(.028)***
$\sigma_{i,t} * \Delta y_{i,t}$			-.425		-.399
			(.172)**		(.155)***
$\Delta y_{i,t}$	1.015	.989	1.103	1.011	1.115
	(.071)***	(.064)***	(.079)***	(.057)***	(.074)***
$(k_{i,t-1} - y_{i,t-1})$	-.781	-.695	-.633	-.655	-.589
	(.129)***	(.074)***	(.056)***	(.070)***	(.055)***
$\Delta \sigma_{i,t}$				.003	.015
				(.066)	(.058)
$\sigma_{i,t-1}$				.086	.078
				(.031)***	(.027)***
Sargan/Hansen	.721	.752	.814	.347	.374
DoF	29	30	40	40	50
AR1	-1.854	-1.988	-3.367	-2.326	-3.881
AR2	-2.514	-2.573	-2.598	-2.77	-2.664
AR3	-.419	-.553	.128	-.626	.076
AR4	.097	-.221	-.405	-.295	-.477
Instruments For Equations In First Differences					
$\Delta k_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$(k_{i,t} - y_{i,t})$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$			t-3:t-3		t-3:t-3
$\sigma_{i,t}$				t-3:t-3	t-3:t-3

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

TABLE 4

Average Q Investment Specification (Simulated Data Set 1)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.246	-.405	-.420	-.395
			(.154)	(.087)***	(.125)***	(.080)***
$\Delta y_{i,t-1}$			.051	.149	.149	.138
			(.089)	(.049)***	(.074)**	(.044)***
$\sigma_{i,t} * \Delta y_{i,t}$				-.751		-.544
				(.302)**		(.269)**
$\Delta y_{i,t}$		.918	1.021	1.142	.998	1.130
		(.027)***	(.082)***	(.087)***	(.074)***	(.081)***
$Q_{i,t}$	.081	.007	.013	.020	.015	.015
	(.002)***	(.002)***	(.005)***	(.003)***	(.004)***	(.003)***
$\Delta\sigma_{i,t}$					.024	.055
					(.101)	(.083)
$\sigma_{i,t-1}$					.263	.252
					(.059)***	(.047)***
Sargan/Hansen	.336	.222	.224	.149	.317	.226
DoF	10	29	30	40	40	50
AR1	-32.951	-31.984	-4.24	-6.227	-4.29	-6.626
AR2	-13.674	6.305	-.07	-1.441	-1.014	-1.502
AR3	-2.998	2.76	.711	-.058	.978	1.036
AR4	-.739	.419	-.565	-.167	-.459	-.121
Instruments For Equations In First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-4:t-4	t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$		t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$Q_{i,t}$		t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$				t-3:t-3		t-3:t-3
$\sigma_{i,t}$					t-3:t-3	t-3:t-3

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

TABLE 5

$\Delta k_{i,t}$ Hybrid Investment Specification (Simulated Data Set 1)

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.290	-.286	-.313	-.316	-.533
	(.062)***	(.063)***	(.061)***	(.105)***	(.111)***
$\Delta y_{i,t-1}$	.126	.126	.128	.035	.185
	(.028)***	(.027)***	(.027)***	(.044)	(.055)***
$\sigma_{i,t} * \Delta y_{i,t}$	-.399	-.371	-.465	-.469	-.928
	(.155)***	(.169)**	(.167)***	(.284)*	(.318)***
$\Delta y_{i,t}$	1.115	1.110	1.118	1.440	1.461
	(.074)***	(.074)***	(.066)***	(.106)***	(.107)***
$(k_{i,t-1} - y_{i,t-1})$	-.589	-.604	-.514		
	(.055)***	(.085)***	(.048)***		
$Q_{i,t}$		-.001	.007	.008	.016
		(.005)	(.002)***	(.003)***	(.003)***
$\Delta \sigma_{i,t}$	.015	.022	-.076	-.124	-.065
	(.058)	(.063)	(.051)	(.090)	(.093)
$\sigma_{i,t-1}$	.078	.088	.011	.062	.101
	(.027)***	(.044)**	(.029)	(.050)	(.051)**
Sargan/Hansen	.374	.253	.251	.068	.302
DoF	50	49	60	61	49
AR1	-3.881	-3.536	-5.115	-26.712	-9.697
AR2	-2.664	-2.649	-2.38	.848	-1.623
AR3	.076	.095	.377	1.243	-.212
AR4	-.477	-.361	-1.137	-1.85	-1.253
Instruments For Equations In First Differences					
$\Delta k_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$(k_{i,t} - y_{i,t})$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	
$Q_{i,t}$			t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3

TABLE 6

$\frac{I_{i,t}}{K_{i,t}}$ Hybrid Investment Specification (Simulated Data Set 1)

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.395	-.127	-.126	-.117	-.152
	(.080)***	(.075)*	(.049)**	(.042)***	(.057)***
$\Delta y_{i,t-1}$	.138	.036	.038	.035	.050
	(.044)***	(.037)	(.021)*	(.018)*	(.025)**
$\sigma_{i,t} * \Delta y_{i,t}$	-.544	-.061	-.047	-.017	-.136
	(.269)**	(.219)	(.180)	(.160)	(.182)
$\Delta y_{i,t}$	1.130	.909	.898	.892	.932
	(.081)***	(.072)***	(.063)***	(.059)***	(.074)***
$(k_{i,t-1} - y_{i,t-1})$		-.522	-.547	-.558	-.522
		(.086)***	(.053)***	(.051)***	(.057)***
$Q_{i,t}$	.015	.001	.0008		
	(.003)***	(.003)	(.002)		
$\Delta\sigma_{i,t}$	.055	-.016	-.002	.002	.045
	(.083)	(.063)	(.055)	(.052)	(.062)
$\sigma_{i,t-1}$	.252	.079	.081	.080	.145
	(.047)***	(.043)*	(.031)***	(.032)**	(.031)***
Sargan/Hansen	.226	.093	.088	.04	.38
DoF	50	49	60	61	49
AR1	-6.626	-5.088	-5.177	-5.24	-4.37
AR2	-1.502	-1.041	-1.524	-1.512	-1.58
AR3	1.036	-.475	-.702	-.714	-.668
AR4	-.121	-.008	.176	.216	.526
Instruments For Equations In First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$(k_{i,t} - y_{i,t})$			t-3:t-3	t-3:t-3	t-3:t-3
$Q_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3

TABLE 7

Accelerator Investment Specification (Simulated Data Set 1)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.290	-.170	-.270			
	(.062)***	(.122)	(.142)*			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.395	-.172	-.356
				(.080)***	(.073)**	(.108)***
$\Delta y_{i,t-1}$	.126	-.035	.023	.138	-.017	.088
	(.028)***	(.048)	(.071)	(.044)***	(.033)	(.060)
$\sigma_{i,t} * \Delta y_{i,t}$	-.399	-.057	-.197	-.544	.136	-.188
	(.155)***	(.308)	(.369)	(.269)**	(.263)	(.306)
$\Delta y_{i,t}$	1.115	1.349	1.407	1.130	1.142	1.241
	(.074)***	(.142)***	(.153)***	(.081)***	(.098)***	(.108)***
$(k_{i,t-1} - y_{i,t-1})$	-.589					
	(.055)***					
$Q_{i,t}$				.015		
				(.003)***		
$\Delta\sigma_{i,t}$	.015	-.036	-.020	.055	.108	.139
	(.058)	(.109)	(.133)	(.083)	(.101)	(.119)
$\sigma_{i,t-1}$	.078	.122	.151	.252	.268	.376
	(.027)***	(.050)**	(.072)**	(.047)***	(.057)***	(.073)***
Sargan/Hansen	.374	.436	.457	.226	.179	.293
DoF	50	51	39	50	51	40
AR1	-3.881	-24.689	-9.814	-6.626	-13.516	-7.967
AR2	-2.664	2.128	.067	-1.502	.24	-1.876
AR3	.076	2.384	1.545	1.036	2.055	.988
AR4	-.477	-1.548	-1.41	-.121	-.767	-.59
Instruments For Equations In First Differences						
$\Delta k_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3			
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$(k_{i,t} - y_{i,t})$	t-3:t-3	t-3:t-3				
$Q_{i,t}$				t-3:t-3	t-3:t-3	
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3

TABLE 8

Error Correction Investment Specification (Simulated Data Set 2)

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	.047				
	(.041)				
$\Delta k_{i,t-1}$	-.006	.043	.016	.021	-.002
	(.061)	(.050)	(.047)	(.051)	(.046)
$\Delta y_{i,t-1}$	.012	-.021	-.005	-.013	-.002
	(.038)	(.026)	(.024)	(.027)	(.024)
$\sigma_{i,t} * \Delta y_{i,t}$			.240		-.147
			(.390)		(.357)
$\Delta y_{i,t}$	.983	.876	.846	.915	.939
	(.105)***	(.062)***	(.078)***	(.059)***	(.076)***
$(k_{i,t-1} - y_{i,t})$	-.751	-.511	-.547	-.486	-.503
	(.229)***	(.070)***	(.064)***	(.074)***	(.065)***
$\Delta\sigma_{i,t}$				-.166	-.121
				(.124)	(.100)
$\sigma_{i,t-1}$				.012	.039
				(.063)	(.054)
Sargan/Hansen	.421	.572	.725	.612	.63
DoF	28	29	39	39	49
AR1	-2.058	-5.574	-5.93	-5.154	-5.837
AR2	-.291	1.052	.674	1.269	1.118
AR3	1.587	1.914	2.044	1.96	1.936
AR4	-.187	-.3	-.335	-.693	-.658
Instruments For Equations In First Differences					
$\Delta k_{i,t}$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$(k_{i,t} - y_{i,t})$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$			t-3:t-3		t-3:t-3
$\sigma_{i,t}$				t-3:t-3	t-3:t-3

TABLE 9

Average Q Investment Specification (Simulated Data Set 2)

	(1)	(2)	(3)	(4)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	.026	-.235	-.231	-.254
	(.161)	(.110)**	(.125)*	(.092)***
$\Delta y_{i,t}$	-.095	.045	.048	.055
	(.081)	(.053)	(.060)	(.043)
$\sigma_{i,t} * \Delta y_{i,t}$		-.252		-.721
		(.512)		(.459)
$\Delta y_{i,t}$	.966	.875	.880	.977
	(.100)***	(.089)***	(.081)***	(.091)***
$Q_{i,t}$	.035	.095	.088	.088
	(.035)	(.023)***	(.026)***	(.019)***
$\Delta\sigma_{i,t}$			-.268	-.175
			(.153)*	(.131)
$\sigma_{i,t-1}$			.040	.083
			(.084)	(.074)
Sargan/Hansen	.566	.478	.316	.442
DoF	30	40	40	50
AR1	-5.198	-6.656	-7.206	-8.494
AR2	2.37	1.436	1.759	1.997
AR3	1.018	.596	.907	.75
AR4	-.574	.222	-.298	.042
Instruments For Equations In First Differences				
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$Q_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$		t-3:t-3		t-3:t-3
$\sigma_{i,t}$			t-3:t-3	t-3:t-3

TABLE 10

Error Correction Investment Specification (Simulated Data Set 3)

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	.024				
	(.018)				
$\Delta k_{i,t-1}$	-.362	-.458	-.335	-.284	-.244
	(.171)**	(.161)***	(.112)***	(.153)*	(.112)**
$\Delta y_{i,t-1}$	.206	.286	.210	.200	.173
	(.112)*	(.100)***	(.073)***	(.093)**	(.072)**
$\sigma_{i,t} * \Delta y_{i,t}$			-.733		-.419
			(.424)*		(.400)
$\Delta y_{i,t}$	1.080	1.071	1.142	.985	1.033
	(.077)***	(.076)***	(.093)***	(.071)***	(.081)***
$(k_{i,t-1} - y_{i,t-1})$	-.709	-.537	-.446	-.442	-.405
	(.174)***	(.101)***	(.091)***	(.098)***	(.081)***
$\Delta \sigma_{i,t}$				-.241	-.114
				(.132)*	(.111)
$\sigma_{i,t-1}$				.129	.146
				(.088)	(.072)**
Sargan/Hansen	.135	.136	.462	.009	.006
DoF	26	27	36	36	45
AR1	-1.3	-1.592	-2.287	-2.715	-3.001
AR2	-1.664	-2.07	-1.587	-.814	-1.028
AR3	.676	2.69	2.845	2.869	2.928
AR4	-1.118	-.075	-.43	-1.631	-1.412
Instruments For Equations In First Differences					
$\Delta k_{i,t}$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$\Delta y_{i,t}$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$(k_{i,t} - y_{i,t})$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$\sigma_{i,t} * \Delta y_{i,t}$			t-4:t-4		t-4:t-4
$\sigma_{i,t}$				t-4:t-4	t-4:t-4

TABLE 11

Average Q Investment Investment Specification (Simulated Data Set 3)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{k_{i,t}}$	$\frac{I_{i,t}}{k_{i,t}}$	$\frac{I_{i,t}}{k_{i,t}}$	$\frac{I_{i,t}}{k_{i,t}}$	$\frac{I_{i,t}}{k_{i,t}}$	$\frac{I_{i,t}}{k_{i,t}}$
$\frac{I_{i,t-1}}{k_{i,t-1}}$	-.143	-.091	-.222	-.195	-.191	-.434
	(.156)	(.113)	(.098)**	(.127)	(.095)**	(.157)***
$\Delta y_{i,t-1}$	-.011	.002	.030	.017	.014	.251
	(.074)	(.021)	(.042)	(.056)	(.040)	(.095)***
$\sigma_{i,t} * \Delta y_{i,t}$			-.507		-.599	-.988
			(.414)		(.402)	(.541)*
$\Delta y_{i,t}$	.865	.433	.905	.934	1.013	.999
	(.087)***	(.066)***	(.080)***	(.082)***	(.087)***	(.113)***
$Q_{i,t}$	.060	.121	.074	.052	.051	.069
	(.026)**	(.010)***	(.015)***	(.022)**	(.017)***	(.016)***
$\Delta\sigma_{i,t}$				-.257	-.145	-.343
				(.166)	(.135)	(.134)**
$\sigma_{i,t-1}$				.078	.119	.043
				(.104)	(.086)	(.119)
Sargan/Hansen	.378	.329	.347	.662	.447	.59
DoF	30	32	40	40	50	45
AR1	-5.041	-13.678	-8.578	-6.926	-8.566	-6.328
AR2	1.446	3.81	1.809	2.186	2.594	-.584
AR3	1.118	-1.143	.846	1.261	1.139	1.964
AR4	-1.025	-.805	-.586	-1.624	-1.336	.049
Instruments For Equations In First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-3	t-2:t-2	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$\Delta y_{i,t}$	t-3:t-3	t-2:t-2	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$Q_{i,t}$	t-3:t-3	t-2:t-2	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$\sigma_{i,t} * \Delta y_{i,t}$			t-3:t-3		t-3:t-3	t-4:t-4
$\sigma_{i,t}$				t-3:t-3	t-3:t-3	t-4:t-4

TABLE 12
Error Correction Investment Specification (Simulated Data Set 4)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$y_{i,t-1}$	.043					
	(.029)					
$\Delta k_{i,t-1}$	-.354	-.436	-.414	-.335	-.447	-.333
	(.119)***	(.107)***	(.105)***	(.090)***	(.087)***	(.077)***
$\Delta y_{i,t-1}$	.254	.316	.312	.254	.305	.237
	(.076)***	(.063)***	(.063)***	(.055)***	(.055)***	(.051)***
$\sigma_{i,t} * \Delta y_{i,t}$				-.081		-.117
				(.212)		(.197)
$\Delta y_{i,t}$	1.152	1.096	1.071	1.072	1.093	1.072
	(.074)***	(.070)***	(.084)***	(.095)***	(.054)***	(.073)***
$(k_{i,t-1} - y_{i,t-1})$	-.986	-.656	-.699	-.570	-.659	-.578
	(.241)***	(.109)***	(.116)***	(.094)***	(.097)***	(.091)***
$\Delta\sigma_{i,t}$					-.080	-.011
					(.074)	(.063)
$\sigma_{i,t-1}$					.113	.106
					(.040)***	(.037)***
Sargan/Hansen	.45	.281	.381	.115	.488	.134
DoF	26	27	26	36	36	45
AR1	-.924	-2.041	-1.618	-2.753	-2.674	-2.813
AR2	-3.957	-3.495	-3.305	-2.886	-3.579	-2.839
AR3	1.932	4.794	4.963	4.847	3.992	4.108
AR4	1.337	1.75	1.289	.586	1.121	.21
Instruments For Equations In First Differences						
$\Delta k_{i,t}$	t-4:t-4	t-4:t-4	t-5:t-5	t-4:t-4	t-4:t-4	t-4:t-4
$\Delta y_{i,t}$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$(k_{i,t} - y_{i,t})$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$\sigma_{i,t} * \Delta y_{i,t}$				t-4:t-4		t-4:t-4
$\sigma_{i,t}$					t-4:t-4	t-4:t-4

TABLE 13

Average Q Investment Specification (Simulated Data Set 4)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.632	-.369	-.436	-.315	-.448	-.428
	(.172)***	(.144)**	(.109)***	(.161)**	(.094)***	(.123)***
$\Delta y_{i,t-1}$	.486	.279	.140	.080	.152	.323
	(.127)***	(.109)**	(.063)**	(.099)	(.054)***	(.096)***
$\sigma_{i,t} * \Delta y_{i,t}$		-.870	-.850		-.766	-.699
		(.294)***	(.317)***		(.288)***	(.275)**
$\Delta y_{i,t}$	1.121	1.299	1.353	1.101	1.299	1.249
	(.079)***	(.114)***	(.103)***	(.080)***	(.094)***	(.099)***
$Q_{i,t}$	.014	.010	.027	.016	.022	.007
	(.004)***	(.004)**	(.006)***	(.008)**	(.005)***	(.003)**
$\Delta\sigma_{i,t}$				.041	.014	-.040
				(.120)	(.093)	(.083)
$\sigma_{i,t-1}$				.275	.287	.156
				(.087)***	(.056)***	(.072)**
Sargan/Hansen	.755	.366	.351	.636	.346	.533
DoF	27	36	40	40	50	45
e(ar1)	-2.419	-3.742	-6.936	-3.938	-7.032	-3.688
e(ar2)	-3.477	-1.815	-1.075	-.017	-1.031	-2.293
e(ar3)	2.943	3.254	.435	1.841	1.243	3.902
e(ar4)	-.484	-.916	-1.271	-1.672	-1.133	-.598
Instruments For Equations In First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-4:t-4	t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$\Delta y_{i,t}$	t-4:t-4	t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$Q_{i,t}$	t-4:t-4	t-4:t-4	t-3:t-3	t-3:t-3	t-3:t-3	t-4:t-4
$\sigma_{i,t} * \Delta y_{i,t}$		t-4:t-4	t-3:t-3		t-3:t-3	t-4:t-4
$\sigma_{i,t}$				t-3:t-3	t-3:t-3	t-4:t-4

TABLE 14
Measurement Error In Average Q

	(1)	(2)	(3)	(4)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.395	-.405	-.341	-.393
	(.080)***	(.087)***	(.089)***	(.104)***
$\Delta y_{i,t-1}$	.138	.149	.078	.109
	(.044)***	(.049)***	(.049)	(.057)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.544	-.751	-.182	-.354
	(.269)**	(.302)**	(.284)	(.310)
$\Delta y_{i,t}$	1.130	1.142	1.208	1.254
	(.081)***	(.087)***	(.092)***	(.100)***
$Q_{i,t}$	.015	.020		
	(.003)***	(.003)***		
$Q^n_{i,t}$			.002	.003
			(.0004)***	(.0006)***
$\Delta\sigma_{i,t}$	.055		.062	
	(.083)		(.096)	
$\sigma_{i,t-1}$	.252		.307	
	(.047)***		(.058)***	
Sargan/Hansen	.226	.149	.498	.231
DoF	50	40	50	40
AR1	-6.626	-6.227	-8.507	-7.828
AR2	-1.502	-1.441	-1.354	-1.986
AR3	1.036	-.058	.975	-.403
AR4	-.121	-.167	-.81	-.898
Instruments For Equations In First Differences				
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$Q_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$Q^n_{i,t}$			t-3:t-3	t-3:t-3
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma_{i,t}$	t-3:t-3		t-3:t-3	

TABLE 15

Measurement Error In Average Q and Uncertainty Proxies

	(1)	(2)	(3)	(4)	(5)	(6)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.395	-.407	-.348	-.397		
	(.079)***	(.086)***	(.088)***	(.103)***		
$\Delta k_{i,t-1}$					-.306	-.289
					(.061)***	(.066)***
$\Delta y_{i,t-1}$	.136	.147	.082	.109	.131	.129
	(.043)***	(.048)***	(.048)*	(.056)*	(.028)***	(.030)***
$\sigma^n_{i,t} * \Delta y_{i,t}$	-.614	-.906	-.235	-.475	-.388	-.418
	(.296)**	(.331)***	(.312)	(.340)	(.183)**	(.200)**
$\Delta y_{i,t}$	1.171	1.214	1.228	1.301	1.138	1.113
	(.092)***	(.098)***	(.105)***	(.114)***	(.082)***	(.089)***
$Q_{i,t}$	.014	.019				
	(.003)***	(.003)***				
$Q^n_{i,t}$			.002	.003		
			(.0004)***	(.0005)***		
$(k_{i,t-1} - y_{i,t-1})$					-.614	-.653
					(.057)***	(.055)***
$\Delta\sigma^n_{i,t}$	.052		.061		-.020	
	(.089)		(.104)		(.064)	
$\sigma^n_{i,t-1}$	.267		.334		.047	
	(.051)***		(.063)***		(.032)	
Sargan/Hansen	.252	.159	.525	.235	.375	.816
DoF	50	40	50	40	50	40
AR1	-6.812	-6.496	-8.537	-8.073	-3.713	-3.224
AR2	-1.482	-1.446	-1.387	-2.055	-2.66	-2.798
AR3	.922	-.17	.912	-.459	-.484	-.366
AR4	-.202	-.194	-.835	-.917	-.709	-.412
Instruments For Equations In First Differences						
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3		
$\Delta k_{i,t-1}$					t-3:t-3	t-3:t-3
$\Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$Q_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3		
$Q^n_{i,t}$			t-3:t-3	t-3:t-3		
$(k_{i,t} - y_{i,t})$					t-3:t-3	t-3:t-3
$\sigma^n_{i,t} * \Delta y_{i,t}$	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3	t-3:t-3
$\sigma^n_{i,t}$	t-3:t-3		t-3:t-3		t-3:t-3	t-3:t-3

Table A1

Instrument Choice Error Correction Investment Specification (Simulated Data Set 3)

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.335	-.076	-.032	-.193	-.078
	(.112)***	(.066)	(.056)	(.096)**	(.049)
$\Delta y_{i,t-1}$	.210	.014	.0005	.074	.036
	(.073)***	(.030)	(.027)	(.055)	(.022)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.733	-.886	-1.079	-.639	-1.104
	(.424)*	(.384)**	(.401)***	(.360)*	(.394)***
$\Delta y_{i,t}$	1.142	1.090	1.094	1.125	1.117
	(.093)***	(.084)***	(.086)***	(.074)***	(.090)***
$(k_{i,t-1} - y_{i,t-1})$	-.446	-.383	-.334	-.437	-.328
	(.091)***	(.075)***	(.075)***	(.081)***	(.065)***
Sargan/Hansen	.462	.057	.127	.162	.167
DoF	36	47	47	48	47
AR1	-2.287	-5.331	-5.781	-3.701	-6.915
AR2	-1.587	1.269	1.631	-.017	1.247
AR3	2.845	1.331	1.482	2.106	1.932
AR4	-.43	-1.312	-1.081	-1.499	-.969
Instruments for Equations in First Differences					
$\Delta k_{i,t}$	t-4:t-4	t-3:t-4	t-4:t-4	t-4:t-4	t-4:t-4
$\Delta y_{i,t}$	t-4:t-4	t-4:t-4	t-3:t-4	t-4:t-4	t-4:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-4:t-4	t-4:t-4	t-4:t-4	t-3:t-4	t-4:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-4:t-4	t-4:t-4	t-4:t-4	t-4:t-4	t-3:t-4
Differenced Sargan Test					
(1-p-value)		0.996	0.976	0.956	0.957

Chapter 3

Comparing Effects of Stock Return Volatility and the Capital Asset Pricing Model β on Firm Investment Behavior

3.1 Introduction

The results presented in this Chapter address two issues related to the effects of Capital Asset Pricing Model (CAPM) βs on investment behaviour in the sample of UK firms: i.) to determine whether or not the effects of stock return volatility ($\sigma_{i,t}$) on investment behaviour, described in the previous chapters, proxy for effects of covariance between firm and market returns described in CAPM β terms; and ii.) whether there is additional information relevant to investment behaviour that is not contained in within year volatility in daily stock returns, but may be captured by time varying, firm specific CAPM β terms. In the contexts of a CAPM framework, β captures covariance between firm and market returns, representing undiversifiable systematic risk in firm returns from the perspective of a well diversified shareholder. Whereas the CAPM β can be interpreted as a measure of financial risk, volatility in share prices capture uncertainty in expected operating environments and the future profitability of a firm, which can theoretically affect optimal investment behaviour independently of any risk premium in the contexts of models with real option or Hartman Able effects.

Within year firm specific CAPM β terms are included in estimates of the error correction and average q investment specifications, first on their own and then jointly with controls for the effects of within year volatility in daily stock returns. The results provide no evidence to support significant effects of CAPM βs on user costs of capital in estimates of the error correction specification. Similarly, estimates of the average q specification implied no significant effects of controls for CAPM β on investment behaviour. Evidence presented throughout this chapter emphasizes the importance of firm specific uncertainty, captured by within year volatility in stock returns, over systemic measures of risk to investors described in the CAPM, in controlling for firm level investment behaviour. One possible explanation for such results lies with the risk exposure of managers to firm returns, and the dominance of their risk aversion over investors' risk weighted required rates of return described in the CAPM model. The results in this chapter are consistent with the possibility that when making investment decisions, uncertainty over future firm performance (the livelihood of firm managers) receives more weight than the risk exposure of diversified investors.

Time varying firm specific CAPM βs ($\beta_{i,t}^{CAPM}$) are calculated as OLS coefficients from the regression of daily firm returns on daily returns to the FTSE 100 index. Both linear and sales growth interaction terms in $\beta_{i,t}^{CAPM}$ are included in estimates of error correction and average q investment specifications obtained using the UK data set from Chapter 1. In the contexts of the error correction specification, linear terms in $\beta_{i,t}^{CAPM}$ will allow for the covariance of firms' stock returns with the market to influence investment through the required rate of return and the user cost of capital. The sign and significance of coefficients estimated on these terms can provide evidence of the extent to which firm managers may be following CAPM motivated investment rules dictated by risk adjusted required rates of return. Additionally, linear terms in $\beta_{i,t}^{CAPM}$ are added to the average q specification to control for effects on the user cost of capital and marginal q that are not captured by controls for average q. In both specifications sales growth interaction terms with $\beta_{i,t}^{CAPM}$ will also allow the covariance between firm and market returns to influence firms' responses to demand growth, as was shown in Chapter 1 for volatility in firm returns ($\sigma_{i,t}$).

The comparison of within year firm specific CAPM βs with within year volatility of firms' stock returns follows from work in Leahy and Whited (1996), discussed in the literature review section of Chapter 1. The latter study used US data to produce Generalized Method of Moments (GMM) estimates of a specification which described the investment rate as a linear function of an uncertainty proxy based on volatility in stock returns as well as annual CAPM βs calculated based on the covariance of daily stock returns to a value weighted index of daily market returns. Leahy and Whited (1996) found that the uncertainty proxy based on volatility in daily stock returns had a significant and negative effect on the investment rate, whereas the CAPM beta had no statistically significant effect. However, these effects of uncertainty were shown to affect investment through average Q. In so far as the author is aware, no prior study has compared the effect of CAPM βs to uncertainty proxies such as $\sigma_{i,t}$ in the contexts of an error correction investment specification using firm level investment data.

3.2 Uncertainty, Financial Risk and the User Cost of Capital

Theories of firm investment addressing concepts of uncertainty over future operating environments and asset pricing models - which emphasize financial risk from the perspective of investors - have different implications for the user cost of capital faced by a firm, and its relation to optimal investment behaviour. Models with real option and Hartman-Abel effects consider risk neutral firms, and emphasize the impact of idiosyncratic uncertainty over future operating conditions on the expected profitability of capital, and the desired level of capital investment. In such models the profit of the firm is endogenously determined, and assumed to be uncorrelated with exogenously determined discount factors. Real options values to investment decisions arise due to irreversibility in investment together with decreasing returns to scale in a firm's net revenue function (due to either imperfect competition, decreasing returns to scale in production technology, or a combination of both). Real option effects imply an uncertainty adjusted user cost of capital that is larger than traditional Jorgonsonian user costs of capital, due to the fact that firms have to give up the option value of investing an additional unit of capital when making (partially) irreversible investments. By Jensen's inequality, Hartman Abel effects influence the desired level of capital stocks through the nature (convex or concave) of the relationship between stochastic variables (such as output price) and the expected marginal revenue product of capital.

The CAPM class of asset pricing models[1] consider the perspective of risk averse investors in assets (or firms) with exogenously determined payoffs, which are correlated with returns to an investor's portfolio[2], and thus the discount rate. These models emphasize the covariance of a firm's return with the market portfolio, because higher correlation between these streams of payoffs implies greater exposure of investors to risky returns of that firm. Less capital is invested in riskier firms that are highly correlated with the market portfolio, which in turn provides higher rates of return to investors for holding undiversified risk. According to the CAPM the rate of return required by investors in a firm i over a period t ($r_{i,t}$) is given by the sum of the risk free rate (r_f) with the product of $\beta_{i,t}^{CAPM}$ (the covariance of returns of firm i with the returns of the market over period t, divided by the variance of market returns over period t) and the market risk premium, according to Equation (3.1) below. Thus the CAPM predicts that

[1] see Craine (1988)

[2] In the CAPM combinations of a risk free asset and the market portfolio are held by investors

firms with returns that are highly correlated with the market(higher β) face higher required rates of return and higher user costs of capital.

$$r_{i,t} = r_f + \beta_{i,t}^{CAPM}(r_m - r_f) \tag{3.1}$$

A key distinction to emphasize in comparing models with real option or Hartman-Abel effects, with the CAPM, is the role of the discount rate in the respective models. Hartman-Abel and real option effects impact investment decisions for a given discount rate. Whereas firm investment in the CAPM is affected *through* the discount rate which is determined by required rates of returns to investors.

Craine (1988) develops a general equilibrium Consumption CAPM model in which consumers/investors allocate capital to firms in which the marginal revenue product of capital is convex with respect to exogenous productivity shocks. Firms described in the model exhibit positive Hartman-Abel effects of uncertainty (in productivity shocks) on the expected marginal revenue product of capital. In this general equilibrium specification both the discount rate and the dividends paid out by firms are endogenously determined; the fact that consumption is a function of the wage bill and firm profits, contradicts the supposition that investors' discount factor is independent of firms' profits. With the solution to this model, Craine (1988) demonstrates that although the Hartman-Abel effects of uncertainty have a positive impact on the expected marginal revenue products of firms, the capital allocated to firms in equilibrium remains dependent on the risk of a firm's returns as defined by correlation with the market portfolio held by investors. This model illustrates that although the theories of firm investment and asset pricing models have traditionally emphasized different assumptions in defining relationships between user costs of capital and uncertainty or risk, the implications of these assumptions are not mutually exclusive. In the contexts of the model in Craine (1988) firm specific uncertainty can impact the expected marginal revenue products of capital through Hartman-Abel effects, while covariance of firm returns with market portfolios simultaneously rations investors' capital across firms.

If capital is afforded to firms in accordance with the general equilibrium model in Craine (1988), investors would instruct firms' managers to continue investing in projects until the return on the firm's marginal revenue product of capital satisfied an equilibrium condition that adjusts the return on capital for risk defined by the CAPM. If this were the case in the UK panel data set, controls for CAPM βs should have significant effects on investment behaviour, alongside the effects of $\sigma_{i,t}$, in estimated investment specifications. In the contexts of the CAPM models described in Craine (1988), if firms undertook investment as though their profit streams were uncorrelated with the discount rate of investors described in asset pricing models, controls for CAPM βs would have limited effects in estimates of firm level investment specifications. This type of investment behaviour could arise when the exposure of firm managers to idiosyncratic risk leads to investment behaviour that is dominated by managers' risk aversion over the interests of diversified investors described in the CAPM. This effect can be represented by the type of model described in Himmelberg, Hubbard and Love (2002), in which firms' user costs of capital, and investment decisions, are heavily influenced by undiversified/stake-holding managers' aversion to idiosyncratic firm specific risk; and capital is not allocated in accordance with investors' risk weighted required rates of return. Several factors can lead to a lack of diversification of a manager's income and the sub-optimal exposure of a manager to volatility in firm returns and performance: a significant portion of a manger's human capital may become firm specific due to idiosyncracies in the operation of firms, within and across industries; and high powered incentive contracts may leave managers over-exposed to uncertainty in firm returns. When the well being or livelihood of managers is heavily exposed to the performance of their firm, volatility in expected firm returns can lead to a divergence in the investment policies preferred by managers and those preferred by diversified shareholders. If managers had some independence (from shareholders) in making investment decisions, it is conceivable that managers may benefit from managing investments in a way that is not in the best interests of well diversified shareholders. Such circumstances provide some explanation as to why investment behaviour may be more sensitive to firm specific volatility than to shareholders' required rates of return described in CAPMs. Risk premia associated by managers to expected returns of investments may be more strongly influenced by firm specific volatility, than risk introduced to shareholders' portfolio returns.

3.2.1 Constructing β

The CAPM β included in the investment specifications in this section is calculated, following Leahy and Whited (1996), as the within year OLS coefficient from the regression of firms' daily stock returns on the daily returns of the FTSE 100 index and a constant ($\beta_{i,t}^{CAPM}$). This allows for CAPM βs to vary over time and creates a measure that is comparable to the uncertainty proxy $\sigma_{i,t}$, which is calculated as the within year standard deviation of daily stock returns. Table 1 below presents summary statistics for $\beta_{i,t}^{CAPM}$ alongside $\sigma_{i,t}$. Within the framework of the CAPM, the magnitude of $\beta_{i,t}^{CAPM}$ should capture covariance between a firm's returns and the market and be positively related to investor's required rates of return, which impose higher user costs and greater marginal revenue products of capital on firms.

[TABLE 1 HERE]

Table 2 below presents sample correlations of the variables used to estimate the average q and error correction specifications alongside $\beta_{i,t}^{CAPM}$. The latter measure has small and negative correlations with the dependent variables of the two specifications as well as with the $\Delta y_{i,t}$ the sales growth measure, which are correctly signed if $\beta_{i,t}^{CAPM}$ is positively related to user costs of capital. The positive correlation between $\beta_{i,t}^{CAPM}$ and the error correction term $(k_{i,t-1} - y_{i,t-1})$ is somewhat counter-intuitive, as higher required rates of return and user costs of capital should imply lower capital sales ratios. The positive correlation between $Q_{i,t}$ and $\beta_{i,t}^{CAPM}$ is also unexpected, given that higher required rates of return, dictated by larger values of $\beta_{i,t}^{CAPM}$, imply that greater discount rates should be applied to expected revenues yielding lower present discounted expected values of firms and lower values of average q.

[TABLE 2 HERE]

3.2.2 Investment Specification

In Section 1.3.1 of Chapter 1 it is shown that the natural logarithm of the user cost of capital enters linearly in the error correction specification, and is negatively related to $\Delta k_{i,t}$. Equation (3.2) describes the natural logarithm of the optimal desired level of frictionless capital stock ($k^*_{i,t}$), as a linear function of the natural logarithm of sales ($y_{i,t}$), and the natural logarithm of a time varying user cost of capital ($c_{i,t}$). The equation below corresponds to Equation (1.19) from Chapter 1, which was derived from the static factor demand model of a firm with Cobb-Douglas production technology, facing an iso-elastic demand curve.

$$k^*_{i,t} = a + y_{i,t} - c_{i,t} \tag{3.2}$$

In Section 1.3.1 of Chapter 1 the assumption that the difference between observed capital stocks and optimal frictionless capital stocks forms a stationary process, and the addition of lagged values of the natural logarithms of capital and sales were used to develop, Equation (3.2) into an error correction specification. Deriving the error correction specification in Section 1.3.1 of Chapter 1 the user cost of capital was controlled for by the inclusion of year dummies; unobserved firm specific effects in the error correction specification, also allowed this user cost term to vary across firms. In order to explicitly control for variation in the user cost of capital across firms, the term in $c_{i,t}$ from Equation (3.2) must be treated symmetrically with terms in $k_{i,t}$ and $y_{i,t}$ in the derivation of the error correction specification, which therefore includes terms in $\Delta c_{i,t}$, $\Delta c_{i,t-1}$ and $c_{i,t-1}$ in Equation (3.3) below. This is a more general form the specification represented in Equation (1.25) of Chapter 1.

$$\Delta k_{i,t} = -\beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} + \alpha_0 \Delta y_{i,t} + (1 - \beta_1 - \beta_2)(k_{i,t-1} - y_{i,t-1}) + \eta_0 \Delta c_{i,t} \tag{3.3}$$

$$+\eta_1 \Delta c_{i,t-1} + \eta_2 c_{i,t-1} + a_i + b_t + \epsilon_{i,t}$$

The equation for a time varying user cost of capital $c_{i,t}$ is given below in Equation (3.4), where p^I_t is the purchase price of capital goods, δ the depreciation rate, and $r_{i,t}$ the discount rate, or required rate of return on capital. Under the implicit assumption of a time invariant market risk premium and risk free rate, Equation (3.1) for the CAPM implies that the required rate of return and discount rate $r_{i,t}$ varies over time and across firms according to firm specific $\beta_{i,t}^{CAPM}$s.

$$c_{i,t} = log(C_{i,t}) \qquad where \qquad C_{i,t} = p_t^I \left(1 - \frac{1-\delta}{1+r_{i,t}} \frac{p_{t+1}^I}{p_t^I} \right) \tag{3.4}$$

In Equation (3.4) above $c_{i,t}$ is an increasing function of $r_{i,t}$ for small values of $r_{i,t}$, which would be inline with firms' required rates of return. Equation (3.1) describes a positive relationship between $\beta_{i,t}^{CAPM}$ and the required rate of return $r_{i,t}$ in order to compensate investors for their exposure to risk in firm returns. Assuming a constant risk free rate and market risk premium over the sample period, changes in the required rate of return over time and across firms are entirely determined by $\beta_{i,t}^{CAPM}$ in the CAPM. Thus Equations (3.4) and (3.1) together, predict a negative effect of $\beta_{i,t}^{CAPM}$ through the user cost of capital $c_{i,t}$ in the error correction specification given in Equation (3.3). To capture this effect terms in $c_{i,t}$ in Equation (3.3) are replaced with terms in $\beta_{i,t}^{CAPM}$ in Equation (3.5) below. However, in Equation (3.4) the relationship between $c_{i,t}$ and $r_{i,t}$ is non-linear. Thus it may be difficult to control for the effect of $\beta_{i,t}^{CAPM}$ on the user cost of capital with linear terms in the error correction specification shown in Equation (3.5). In order to better approximate the functional relationship between $\beta_{i,t}^{CAPM}$ and $c_{i,t}$ linear terms in the natural logarithm of $\beta_{i,t}^{CAPM}$ ($log(\beta_{i,t}^{CAPM})$ are included in the error correction specification, in Equation (3.5). However, as shown in the following section, substituting $\beta_{i,t}^{CAPM}$ for $log(\beta_{i,t}^{CAPM})$ in the error correction specification has almost no effect on estimated coefficients. Further experimentation with alternative non-linear functions of $\beta_{i,t}^{CAPM}$ (not reported in the following section) yielded no change to the results.

$$\Delta k_{i,t} = -\beta_2 \Delta k_{i,t-1} - \alpha_2 \Delta y_{i,t-1} + \alpha_0 \Delta y_{i,t} + (1 - \beta_1 - \beta_2)(k_{i,t-1} - \theta y_{i,t-1}) \tag{3.5}$$
$$+\eta_0 \Delta \beta_{i,t}^{CAPM} + \eta_1 \Delta \beta_{i,t-1}^{CAPM} + \eta_2 \beta_{i,t-1}^{CAPM} + a_i + b_t + \epsilon_{i,t}$$

Unlike the case of the error correction investment specification, the Hayashi (1982) average q investment model does not explicitly control for the user cost of capital. Changes in the user cost of capital affect investment through average q in that model. As average q is the ratio of the discounted present value of a firm to its replacement cost of capital, changes in the user cost of capital and the discount rate of future revenues should be controlled for implicitly by the stock market measures of firm values in this term. When the assumptions in Hayashi (1982) hold, additional controls for investment behaviour should not be significant, as average q is a sufficient statistic for investment. However, if the assumptions in Hayashi (1982) do not hold, or there is measurement error in average q originating from stock market measures of the discounted present value of firms, additional controls can be significantly related to investment. Estimates of the average q specification in Chapter 1 (which include significant coefficients on additional controls for investment behaviour), have shown that the measure of average q ($Q_{i,t}$), is not a sufficient statistic for investment in the UK data set. Therefore adding additional controls for $\beta_{i,t}^{CAPM}$ to the specification based on average q, could control for effects of higher required rates of return on marginal q, not captured by $Q_{i,t}$. As in the error correction specification, the positive effect of $\beta_{i,t}^{CAPM}$ on the required rate of return should have a negative effect in the average q specification, by imposing higher discount factors on expected marginal revenue products of capital.

Compared to the average q investment specification, the error correction specification - with explicit terms in the user cost of capital - offers slightly more guidance of how $\beta_{i,t}^{CAPM}$ impacts investment behaviour. Results are presented for estimates of average q specifications which include a single linear term in $\beta_{i,t}^{CAPM}$, as well as the set of terms $\Delta\beta_{i,t}^{CAPM}$, $\Delta\beta_{i,t-1}^{CAPM}$, $\beta_{i,t-1}^{CAPM}$ and the set of terms $\Delta log(\beta_{i,t}^{CAPM})$, $\Delta log(\beta_{i,t-1}^{CAPM})$, $log(\beta_{i,t-1}^{CAPM})$ which were included in the error correction specification. Alternative lag structures and functional forms were experimented with in controls for $\beta_{i,t}^{CAPM}$ in the average q specification with no significant changes to results.

In addition to linear controls for the effects of $\beta_{i,t}^{CAPM}$ in the investment specifications, sales growth interaction terms are also included in each specification. These non-linear controls for the effects of $\beta_{i,t}^{CAPM}$ have limited theoretical justification. However they are included in order to test whether significant negative coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms may be capturing effects of covariance between firm and market returns. Alternatively it is possible that investment decisions in response to changes in demand are delayed in firms whose investors have greater risk exposure to returns on that investment; i.e. managers may be more reluctant to allocate capital in response to changes in the market, when the firms' shareholders have greater exposure to the returns.

3.3 Results

This section presents results from including both controls for CAPM βs ($\beta_{i,t}^{CAPM}$) and proxies based on stock return volatility ($\sigma_{i,t}$) in estimates of the error correction and average q specifications from Chapter 1. The proxy $\sigma_{i,t}$ is taken from Chapter 1, and $\beta_{i,t}^{CAPM}$ is calculated as the OLS coefficient from regressing firm returns on market returns and a constant, following Leahy and Whited (1996). The effects of uncertainty on investment, controlled for by $\sigma_{i,t}$ in the error correction and average q specifications are discussed in detail in Chapter 1. Estimates of both investment specifications in Chapter 1 were consistent with the predictions of models with irreversible capital investment and real options, in which higher levels of uncertainty lead to lower investment responses to demand shocks. Including linear terms in $\beta_{i,t}^{CAPM}$ or $log(\beta_{i,t}^{CAPM})$ do not provide any evidence of a significant relationship between investment and $\beta_{i,t}^{CAPM}$ in estimates of the error correction or average q specification. Insignificant coefficients are also estimated on $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$ terms across the two specifications. These findings are robust to an adjustment of $\sigma_{i,t}$ and $\beta_{i,t}^{CAPM}$ for effects of financial leverage.

Table 3 below presents System GMM estimates of the error correction and average q investment specifications, excluding terms in $\sigma_{i,t}$ and including various controls for the effects of $\beta_{i,t}^{CAPM}$.[3] Column 1 includes linear controls for the effects of $\beta_{i,t}^{CAPM}$ on the user cost of capital in the error correction specification from Equation (3.5). Coefficients estimated on the terms of the error correction specification are similar to corresponding estimates of the specification in previous chapters. The coefficients estimated on $\beta_{i,t}^{CAPM}$ terms are small in magnitude and individually insignificant. A Wald test of the joint hypothesis that coefficients on $beta_{i,t}^{CAPM}$ terms are jointly insignificant is not rejected with a p-value of 0.96. Column 2 of Table 3 replaces the linear terms in $\beta_{i,t}^{CAPM}$ with terms in $log(\beta_{i,t}^{CAPM})$, which may better approximate the functional relationship between $\beta_{i,t}^{CAPM}$ and the natural logarithm of the user cost of capital in the error correction specification. Coefficients estimated on the controls for $\beta_{i,t}^{CAPM}$ are relatively unchanged by standard errors across Columns 1 and 2. A Wald test does not reject the joint hypothesis that coefficients on terms in $log(\beta_{i,t}^{CAPM})$ are jointly insignificant, the p-value of this hypothesis is 0.25. Column 3 excludes all linear controls for $\beta_{i,t}^{CAPM}$ and adds a sales growth interaction

[3]Instrument sets are based on preferred instrument sets from Chapter 1, which are appended with appropriately lagged values of $\beta_{i,t}^{CAPM}$ as instruments for equations in levels and for equations in differences.

term $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$. The coefficient estimated on the latter term is statistically insignificant, implying no effect of $\beta_{i,t}^{CAPM}$ on investment responses to changes in demand.

[TABLE 3 HERE]

Column 4 of Table 3 presents estimates of the average q specification, including a single linear term in $\beta_{i,t}^{CAPM}$ to control for effects of covariance of firm returns with the market on required rates of return, not captured by $Q_{i,t}$. The coefficient on $\beta_{i,t}^{CAPM}$ is statistically insignificant in Column 4, and appears to have no effect on investment behaviour, as described by the estimates of the average q specification. Column 5 adds to the average q specification the lagged differenced and level terms of $\beta_{i,t}^{CAPM}$ that were added to the error correction specification in Column 1. As in the case of Column 1 all coefficients estimated on $\beta_{i,t}^{CAPM}$ terms were individually and jointly insignificant. A Wald test does not reject the hypothesis that coefficients on $\beta_{i,t}^{CAPM}$ terms in Column 5 are jointly insignificant, with a p-value of 0.44. Column 6 of Table 3 includes terms in $log(\beta_{i,t}^{CAPM})$ from Column 3 of Table 3; coefficients on which are individually insignificant. A Wald test of the hypothesis that coefficients on $log(\beta_{i,t}^{CAPM})$ terms are jointly insignificant is not rejected with a p-value 0.38. Column 7 of Table 3 drops controls for linear effects of $\beta_{i,t}^{CAM}$ in the average q specification and adds a sales growth interaction term with $\beta_{i,t}^{CAPM}$, on which the estimated coefficient is correctly signed but statistically insignificant.

Table 4 below presents results from adding controls for $\beta_{i,t}^{CAPM}$ to estimates of the error correction and average q specifications, which include terms in $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$.[4] Columns 1 and 2 of Table 3 respectively add linear controls for effects of $\beta_{i,t}^{CAPM}$ and $log(\beta_{i,t}^{CAPM})$ on the user cost of capital, just as in the first two columns of Table 2. Estimated coefficients on terms in $\beta_{i,t}^{CAPM}$ and $log(\beta_{i,t}^{CAPM})$ are individually and jointly insignificant, just as in the first two columns of Table 3. Wald tests do not reject the hypotheses that the latter coefficients are jointly insignificant based on respective p-values of 0.40 and 0.39. Column 3 drops linear controls for the effects of $\beta_{i,t}^{CAPM}$ and adds a term in $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$, on which the coefficient estimate is insignificant. As a result of adding the latter term, the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ becomes insignificant; however, dropping $\sigma_{i,t} * \Delta y_{i,t}$ from the specification in Column 3 does not yield a significant coefficient on $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$. It is worth noting that when both

[4]Instrument sets are based on preferred instruments for the investment specifications from Chapter 1.

controls for effects of uncertainty and risk on investment behaviour are included in Column 3, it is not evident whether one is more informative than the other. A Wald test does not reject the hypothesis that coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ and $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$ are jointly insignificant, with a p-value of 0.39.

[Table 4 Here]

Column 4 of Table 4 above adds a linear term in $\beta_{i,t}^{CAPM}$ to the average q specification which includes linear and non-linear sales growth interaction terms in $\sigma_{i,t}$. The coefficient estimated on β^{CAPM} in Column 4 is statistically insignificant. Column 5 drops the linear term in $\beta_{i,t}^{CAPM}$ and adds the lagged differenced and level terms in $\beta_{i,t}^{CAPM}$ from Column 1 of Table 4, on which coefficients are individually and jointly insignificant. A Wald test of the hypothesis that coefficients on $\beta_{i,t}^{CAPM}$ terms in Column 5 are jointly insignificant is not rejected based on a p-value of 0.49. Column 6 replaces the terms in $\beta_{i,t}^{CAPM}$ in the specification from Column 5 with terms in $log(\beta_{i,t}^{CAPM})$. Coefficients on $log(\beta_{i,t}^{CAPM})$ are individually insignificant in Column 6, and a Wald test of the hypothesis that they are jointly insignificant is not rejected based on a p-value of 0.24. Column 7 drops controls for linear effects of $\beta_{i,t}^{CAPM}$ and adds the sales growth interaction term $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$, on which the coefficient is statistically insignificant. As in the case of the error correction specification, including the latter term in the average q specification in Column 7 results in an insignificant coefficient on $\sigma_{i,t} * \Delta y_{i,t}$. However, dropping $\sigma_{i,t} * \Delta y_{i,t}$ from the specification in Column 7 does not improve the significance of the coefficient estimated on $\beta_{i,t}^{CAPM} * \Delta y_{i,t}$.

3.3.1 Effects of Financial Leverage

The set of results presented in Tables 5 and 6 below, consider a potential impact of financial leverage on equity βs ($\beta_{i,t}^{CAPM}$). Hamada (1972) outlines the positive relationship between financial leverage and systematic risk of a firm's stock from the perspective of an investor in the CAPM, and higher required rates of return that would be demanded by investors in a highly levered firm. If two firms had the same values of $\beta_{i,t}^{CAPM}$ in the absence of leverage, one of the firms could increase its leverage, amplifying the covariance of its returns with the market. In the contexts of the capital asset pricing model, on one hand it may not be of any consequence to a shareholder whether a firm has a higher $\beta_{i,t}^{CAPM}$ due to greater systematic risk or higher levels of leverage since in both cases the shareholder's portfolio has more exposure to the returns of the firm. However, on the other hand un-levered measures of $\beta_{i,t}^{CAPM}$ may provide a more fundamental level of covariance between firm and market returns, reflecting a systematic level of risk that is independent of a firm's financing decisions. To produce the un-levered measures of CAPM β the values of $\beta_{i,t}^{CAPM}$ are adjusted by the gearing ratio used to adjust the uncertainty proxy $\sigma_{i,t}$ in chapter 1: the ratio of Total Assets to the sum of Total Assets, Long Term Debt and Borrowing. The un-levered CAPM β $g_{i,t} * \beta_{i,t}^{CAPM}$ is smaller than $\beta_{i,t}^{CAPM}$ the more highly levered the firm. Making this adjustment to $\beta_{i,t}^{CAPM}$ has almost no effect on coefficient estimates from Tables 3 and 4.

Table 5 below reproduces the columns of Table 3, replacing $\beta_{i,t}^{CAPM}$ with $g_{i,t} * \beta_{i,t}^{CAPM}$ where it appears in the specifications and instrument sets. Coefficients estimated on the adjusted controls for $\beta_{i,t}^{CAPM}$ are largely unchanged from Table 3, and not significantly different by standard errors. In Column 1 of Table 5, a Wald test does not reject the hypothesis that coefficients on $g_{i,t} * \beta_{i,t}^{CAPM}$ are jointly insignificant, based on a p-value of 0.86. Although the coefficient on $\Delta log(g_{i,t} * \beta_{i,t}^{CAPM})$ becomes marginally significant in Column 2 as a result of the gearing adjustment, the point estimate and standard error are very similar to those in Table 3. The hypothesis that the coefficients on $\Delta log(g_{i,t} * \beta_{i,t}^{CAPM})$, $\Delta log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$ and $log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$ are jointly insignificant in Column 2 of Table 5 is not rejected by a Wald test of the linear hypothesis, based on a p-value of 0.23. Moreover the coefficient estimated on $\Delta log(g_{i,t} * \beta_{i,t}^{CAPM})$ becomes statistically insignificant when controls for effects of $g_{i,t} * \sigma_{i,t}$ are added to the specification in Table 6 below. In Columns 5 and 6, which add differenced and lagged terms in $g_{i,t} * \beta_{i,t}^{CAPM}$ and $log(g_{i,g} * \beta_{i,t}^{CAPM})$ to the average q specification, Wald test do not reject the joint hypotheses that coefficients on these terms are jointly insignificant, based on respective p-values of 0.75 and 0.18.

[Table 5 Here]

Table 6 below reproduces the columns of Table 4, making the gearing adjustment to the terms in $\beta_{i,t}^{CAPM}$. Terms in $\sigma_{i,t}$ are also adjusted for financial leverage; replaced by $g_{i,t} * \sigma_{i,t}$ in the specifications and instrument sets. Coefficients estimated on $g_{i,t} * \beta_{i,t}^{CAPM}$ terms in Table 6 are all (individually and jointly) insignificant. Coefficients estimated on terms in $g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$ in Table 6 are much less significant than corresponding coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms in Table 4. However, the appendix to this chapter presents results obtained using alternative instrument sets, in which coefficients on $g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$ terms are statistically significant.[5]

[Table 6 Here]

[5]Coefficients on $\beta_{i,t}^{CAPM}$ remained insignificant in specification estimated with the alternative instrument set from the appendix.

3.4 Conclusion

This Section has presented estimates of error correction and average q specifications which allow for effects of systematic risk to shareholders (described in Capital Asset Pricing Models) on required rates of return and user costs of capital. Coefficients estimated on firm specific and time varying terms in $\beta_{i,t}^{CAPM}$ implied no significant effects in either the error correction or average q specification. Based on the findings in this chapter the effects of $\sigma_{i,t}$ on investment behaviour, documented in Chapter 1, could not have been proxying for any effects of covariance between firm and market returns described by $\beta_{i,t}^{CAPM}$. These results do not show any evidence of firms investing less capital in response to higher user costs of capital and higher rates of return required by the type of diversified investor described in the CAPM. The stronger effects of $\sigma_{i,t}$ on investment behaviour provides evidence of a more important effect of idiosyncratic, firm specific volatility on the investment behaviour of firms; as compared to the effects of correlation between shareholder portfolios and firm returns. The dominance of firm specific volatility in returns on investment behaviour, over CAPM investment rules, is consistent with the prevalence of managers' aversion to volatility in firm performance, over the interests and rates of return required by fully diversified shareholders described in the CAPM.

3.5 Appendix

This brief appendix presents results comparing alternative instrument sets used to estimate the error correction and average q specifications in Table 6. Results presented in Table 6 used $\Delta^2 y_{i,t-2}$ as instruments for equations in levels to estimate both the error correction and average q specifications. Comparisons based on Differenced Sargan/Hansen tests reported in Table A1 below suggest that the additional moment conditions for equations in levels used in Table 6 may be invalid. Coefficients estimated on uncertainty sales growth terms, which have been adjusted for effects of financial leverage, are much more significant when estimated using the restricted instrument set. This is similar to results presented in Chapter 1, for which Differenced Sargan/Hansen tests also did not support the validity of $\Delta^2 y_{i,t}$ as an instrument for equations in levels for specification in which uncertainty terms are adjusted for possible effects of financial leverage.

Column 1 of Table A1 presents estimates of the error correction specification from Column 1 of Table 6, which excludes $\Delta^2 y_{i,t-1}$ from the instrument set for equations in levels. Column 2 of Table A1 adds $\Delta^2 y_{i,t-2}$ as an instrument for equations in levels to the instrument set in Column 1, yielding the results from Column 1 of Table 6. A Differenced Sargan/Hansen test is used to evaluate the null hypothesis that the additional moment condition in Column 2 of Table A1 is valid against the alternative that only the moment conditions from Column 1 of Table A1 are valid. Given that the null is valid the Differenced Sargan/Hansen test statistic should follow a χ^2 distribution with degrees of freedom equal to the difference in the number of moment conditions in the two sets of estimates. The value of one less the p-value of the Differenced Sargan/Hansen test statistic is reported in the bottom of Column 2, which rejects the validity of the null hypothesis.

[TABLE A1 HERE]

Column 3 of Table A1 presents estimates of the average q specification from Column 4 of Table 6, excluding $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels. Column 4 uses the instrument set from Column 4 of Table 6. As in the case of the error correction specification a Differenced Sargan/Hansen test rejects the null hypothesis that the moment conditions in

Column 4 are valid, relative to the alternative that only the subset of moment conditions from Column 3 are valid.

3.6 Tables of Results

Table 1
Summary Statistics

	mean	standard deviation	min.	max.
$\sigma_{i,t}$	1.532	0.6586	0.446	4.357
$\beta_{i,t}$	0.492	0.4031	-0.611	2.457

Table 2

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\Delta y_{i,t}$	$(k_{i,t-1} - \theta y_{i,t-1})$	$Q_{i,t}$	$\sigma_{i,t}$	$\beta_{i,t}^{CAPM}$
Correlations	$\Delta k_{i,t}$	1.0000						
	$\frac{I_{i,t}}{K_{i,t}}$	0.9621	1.0000					
	$\Delta y_{i,t}$	0.4537	0.4394	1.0000				
	$(k_{i,t-1} - \theta y_{i,t-1})$	-0.0730	-0.0526	0.0732	1.0000			
	$Q_{i,t}$	0.2428	0.2570	0.2199	-0.2517	1.0000		
	$\sigma_{i,t}$	-0.1540	-0.1311	-0.1598	0.0247	-0.1033	1.0000	
	$\beta_{i,t}^{CAPM}$	-0.0096	-0.0287	-0.0806	0.0805	0.0233	0.2638	1.0000

Table 3
Effects of $\beta_{i,t}^{CAPM}$ on Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.173	-.300	-.225				
	(.116)	(.137)**	(.107)**				
$\frac{I_{i,t-1}}{K_{i,t-1}}$				.040	.011	-.146	-.055
				(.101)	(.104)	(.128)	(.104)
$\Delta y_{i,t-1}$	.069	.103	.079	.038	.047	.004	.054
	(.054)	(.071)	(.052)	(.043)	(.043)	(.061)	(.036)
$\beta_{i,t}^{CAPM} * \Delta y_{i,t}$			-.253				-.156
			(.174)				(.123)
$\Delta y_{i,t}$	.305	.307	.427	.191	.193	.328	.273
	(.106)***	(.097)***	(.114)***	(.068)***	(.073)***	(.088)***	(.097)***
$(k_{i,t-1} - y_{i,t-1})$	-.077	-.100	-.048				
	(.035)**	(.043)**	(.022)**				
$Q_{i,t}$				.016	.015	.015	.018
				(.004)***	(.004)***	(.005)***	(.004)***
$\Delta\beta_{i,t}^{CAPM}$	.003				.012		
	(.044)				(.034)		
$\Delta\beta_{i,t-1}^{CAPM}$	-.007				.008		
	(.018)				(.016)		
$\beta_{i,t-1}^{CAPM}$	-.007				-.031		
	(.042)				(.021)		
$\beta_{i,t}^{CAPM}$				-.021			
				(.020)			
$\Delta log(\beta_{i,t}^{CAPM})$		.021				.012	
		(.013)				(.012)	
$\Delta log(\beta_{i,t-1}^{CAPM})$		.005				.004	
		(.007)				(.006)	
$log(\beta_{i,t}^{CAPM})$		.004				-.011	
		(.021)				(.012)	
Sargan/Hansen	.431	.291	.571	.575	.608	.275	.728
DoF	94	94	125	120	118	118	149
AR1	-2.912	-1.803	-2.906	-4.815	-4.563	-3.139	-4.051
AR2	-1.968	-2.784	-2.423	-.444	-.68	-.94	-1.142
AR3	.199	-.256	.132	-.031	.061	-.448	-.027
AR4	.453	.533	.63	.773	.602	.549	.899
Instruments For Equations in First Differences							
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4				
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4				
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\beta_{i,t}^{CAPM} * \Delta y_{i,t}$			t-3:t-4				t-3:t-4
$\beta_{i,t}^{CAPM}$	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4		t-3:t-4
$log(\beta_{i,t}^{CAPM})$		t-3:t-4				t-3:t-4	
Instruments For Equations in Levels							
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2				
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\beta_{i,t}^{CAPM} * \Delta y_{i,t})$			t-2:t-2				t-2:t-2
$\Delta(\beta_{i,t}^{CAPM})$	t-2:t-2		t-2:t-2	t-2:t-2	t-2:t-2		t-2:t-2
$\Delta(log(\beta_{i,t}^{CAPM}))$		t-2:t-2				t-2:t-2	

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 4
Joint Effects of $\beta_{i,t}^{CAPM}$ and $\sigma_{i,t}$ on Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.169	-.203	-.263				
	(.112)	(.108)*	(.103)**				
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.150	-.156	-.196	-.224
				(.103)	(.102)	(.107)*	(.100)**
$\Delta y_{i,t-1}$	.083	.092	.085	.079	.078	.061	.074
	(.051)	(.063)	(.055)	(.039)**	(.038)**	(.047)	(.039)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.218	-.258	-.096	-.108	-.110	-.165	-.063
	(.099)**	(.099)***	(.094)	(.065)*	(.066)*	(.080)**	(.063)
$\beta_{i,t}^{CAPM} * \Delta y_{i,t}$			-.161				-.089
			(.180)				(.124)
$\Delta y_{i,t}$	.704	.719	.567	.399	.384	.456	.368
	(.193)***	(.188)***	(.215)***	(.131)***	(.130)***	(.144)***	(.131)***
$(k_{i,t-1} - y_{i,t-1})$	-.060	-.013	-.062				
	(.024)**	(.026)	(.025)**				
$Q_{i,t}$				.020	.020	.019	.021
				(.005)***	(.005)***	(.005)***	(.004)***
$\Delta\sigma_{i,t}$	-.010	-.025	-.009	.0003	-.0009	-.016	.002
	(.017)	(.020)	(.016)	(.013)	(.012)	(.015)	(.011)
$\sigma_{i,t-1}$	-.026	-.036	-.031	-.015	-.016	-.020	-.016
	(.019)	(.022)*	(.019)	(.015)	(.016)	(.016)	(.014)
$\Delta\beta_{i,t}^{CAPM}$	.050				.029		
	(.037)				(.028)		
$\Delta\beta_{i,t-1}^{CAPM}$	.016				.022		
	(.018)				(.015)		
$\beta_{i,t-1}^{CAPM}$	.036				.004		
	(.027)				(.019)		
$\beta_{i,t}^{CAPM}$				.005			
				(.019)			
$\Delta log(\beta_{i,t}^{CAPM})$		.019				.016	
		(.012)				(.010)*	
$\Delta log(\beta_{i,t-1}^{CAPM})$		.007				.014	
		(.007)				(.008)*	
$log(\beta_{i,t-1}^{CAPM})$		.004				-.006	
		(.015)				(.009)	
Sargan/Hansen	.138	.106	.174	.411	.452	.178	.316
DoF	162	162	192	178	176	176	207
AR1	-3.174	-2.872	-2.697	-3.647	-3.578	-3.01	-3.351
AR2	-2.171	-2.386	-2.921	-1.974	-2.056	-2.09	-2.493
AR3	-.144	-.212	.036	-.002	-.071	-.165	.061
AR4	.829	.839	.786	.975	.987	.849	1.007
Instruments For Equations in First Differences							
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4				
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4				
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\beta_{i,t}^{CAPM} * \Delta y_{i,t}$			t-3:t-4				t-3:t-4
$\beta_{i,t}^{CAPM}$	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4		t-3:t-4
$log(\beta_{i,t}^{CAPM})$		t-3:t-4				t-3:t-4	
Instruments For Equations in Levels							
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2				
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\beta_{i,t}^{CAPM} * \Delta y_{i,t})$			t-2:t-2				t-2:t-2
$\Delta(\beta_{i,t}^{CAPM})$	t-2:t-2		t-2:t-2	t-2:t-2	t-2:t-2		t-2:t-2
$\Delta(log(\beta_{i,t}^{CAPM}))$		t-2:t-2				t-2:t-2	

Note:

Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null

Table 5
Effects of $g_{i,t} * \beta_{i,t}^{CAPM}$ on Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.172	-.297	-.203				
	(.119)	(.138)**	(.102)**				
$\frac{I_{i,t-1}}{K_{i,t-1}}$				.037	-.011	-.133	-.059
				(.098)	(.110)	(.128)	(.099)
$\Delta y_{i,t-1}$	.076	.098	.072	.039	.048	.028	.049
	(.054)	(.072)	(.052)	(.043)	(.044)	(.053)	(.035)
$g_{i,t} * \beta_{i,t}^{CAPM} * \Delta y_{i,t}$			-.244				-.186
			(.215)				(.149)
$\Delta y_{i,t}$	.295	.323	.400	.197	.188	.234	.277
	(.107)***	(.100)***	(.115)***	(.067)***	(.072)***	(.070)***	(.095)***
$(k_{i,t-1} - y_{i,t-1})$	-.077	-.098	-.044				
	(.035)**	(.042)**	(.022)**				
$Q_{i,t}$				.015	.015	.016	.018
				(.004)***	(.005)***	(.005)***	(.004)***
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM})$	-.007				.007		
	(.051)				(.041)		
$\Delta(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$	-.018				.004		
	(.022)				(.019)		
$g_{i,t-1} * \beta_{i,t-1}^{CAPM}$	.008				-.028		
	(.052)				(.029)		
$g_{i,t} * \beta_{i,t}^{CAPM}$				-.016			
				(.026)			
$\Delta log(g_{i,t} * \beta_{i,t}^{CAPM})$		.023				.014	
		(.013)*				(.012)	
$\Delta log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$		.005				.008	
		(.007)				(.009)	
$log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$		.009				-.016	
		(.022)				(.011)	
Sargan/Hansen	.414	.262	.596	.535	.343	.173	.654
DoF	94	94	125	120	118	118	149
AR1	-2.867	-1.804	-3.124	-4.839	-4.206	-3.02	-4.181
AR2	-1.985	-2.67	-2.257	-.482	-.814	-1.129	-1.172
AR3	.246	-.309	.109	-.025	.036	-.236	-.047
AR4	.454	.616	.598	.756	.638	.521	.87
Instruments For Equations in First Differences							
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4				
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4				
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\beta_{i,t}^{CAPM} * \Delta y_{i,t}$			t-3:t-4				t-3:t-4
$\beta_{i,t}^{CAPM}$	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4		t-3:t-4
$log(\beta_{i,t}^{CAPM})$		t-3:t-4				t-3:t-4	
Instruments For Equations in Levels							
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2				
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\beta_{i,t}^{CAPM} * \Delta y_{i,t})$			t-2:t-2				t-2:t-2
$\Delta(\beta_{i,t}^{CAPM})$	t-2:t-2		t-2:t-2	t-2:t-2	t-2:t-2		t-2:t-2
$\Delta(log(\beta_{i,t}^{CAPM}))$		t-2:t-2				t-2:t-2	

Table 6
Joint Effects of $g_{i,t} * \beta_{i,t}^{CAPM}$ and $g_{i,t} * \sigma_{i,t}$ on Investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.194	-.203	-.260				
	(.108)*	(.102)**	(.097)***				
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.173	-.176	-.205	-.266
				(.101)*	(.100)*	(.106)*	(.097)***
$\Delta y_{i,t}$	.094	.088	.089	.081	.078	.066	.083
	(.051)*	(.062)	(.054)	(.040)**	(.040)*	(.048)	(.041)**
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	-.238	-.317	-.100	-.128	-.129	-.184	-.065
	(.135)*	(.141)**	(.118)	(.095)	(.095)	(.112)*	(.081)
$g_{i,t} * \beta_{i,t}^{CAPM} * \Delta y_{i,t}$			-.161				-.082
			(.226)				(.147)
$\Delta y_{i,t}$	.678	.725	.517	.390	.381	.423	.341
	(.200)***	(.203)***	(.222)**	(.151)***	(.151)**	(.164)***	(.145)**
$(k_{i,t-1} - y_{i,t-1})$	-.060	-.017	-.063				
	(.024)**	(.026)	(.025)**				
$Q_{i,t}$				.019	.019	.018	.021
				(.005)***	(.005)***	(.005)***	(.004)***
$\Delta(g_{i,t} * \sigma_{i,t})$	-.010	-.026	-.015	-.003	-.003	-.023	.0008
	(.020)	(.024)	(.020)	(.015)	(.014)	(.018)	(.013)
$g_{i,t-1} * \sigma_{i,t-1}$	-.037	-.034	-.039	-.019	-.020	-.023	-.019
	(.023)*	(.026)	(.022)*	(.019)	(.019)	(.019)	(.017)
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM})$	.031				.017		
	(.044)				(.034)		
$\Delta(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$	.006				.017		
	(.021)				(.017)		
$g_{i,t-1} * \beta_{i,t-1}^{CAPM}$	.043				.007		
	(.032)				(.023)		
$g_{i,t} * \beta_{i,t}^{CAPM}$				.006			
				(.022)			
$\Delta log(g_{i,t} * \beta_{i,t}^{CAPM})$		.013				.014	
		(.012)				(.010)	
$\Delta log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$		.004				.013	
		(.007)				(.008)*	
$log(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$		.002				-.006	
		(.014)				(.009)	
Sargan/Hansen	.084	.11	.14	.225	.216	.097	.138
DoF	162	162	193	178	176	176	207
AR1	-3.164	-3.08	-2.907	-3.531	-3.521	-2.95	-3.162
AR2	-2.392	-2.457	-3.001	-2.135	-2.19	-2.175	-2.852
AR3	-.143	-.329	.017	-.062	-.144	-.257	.042
AR4	.773	.743	.704	.885	.966	.775	.921
Instruments For Equations in First Differences							
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4				
$\frac{I_{i,t}}{K_{i,t}}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - \theta y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4				
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \beta_{i,t}^{CAPM} * \Delta y_{i,t}$			t-3:t-4				t-3:t-4
$g_{i,t} * \beta_{i,t}^{CAPM}$	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4		t-3:t-4
$log(g_{i,t} * \beta_{i,t}^{CAPM})$		t-3:t-4				t-3:t-4	
Instruments For Equations in Levels							
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2				
$\Delta \frac{I_{i,t}}{K_{i,t}}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM} * \Delta y_{i,t})$			t-2:t-2				t-2:t-2
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM})$	t-2:t-2		t-2:t-2	t-2:t-2	t-2:t-2		t-2:t-2
$\Delta(log(g_{i,t} * \beta_{i,t}^{CAPM}))$		t-2:t-2				t-2:t-2	

Table A1

$\Delta^2 y_{i,t-2}$ as an Instrument for Equations in Levels

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.199	-.194		
	(.090)**	(.108)*		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.236	-.173
			(.090)***	(.101)*
$\Delta y_{i,t-1}$	.113	.094	.109	.081
	(.051)**	(.051)*	(.041)***	(.040)**
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	-.369	-.238	-.190	-.128
	(.121)***	(.135)*	(.089)**	(.095)
$\Delta y_{i,t}$	.806	.678	.470	.390
	(.182)***	(.200)***	(.142)***	(.151)***
$(k_{i,t-1} - y_{i,t-1})$	-.070	-.060		
	(.024)***	(.024)**		
Q			.018	.019
			(.004)***	(.005)***
$\Delta(g_{i,t} * \sigma_{i,t})$	-.015	-.010	-.008	-.003
	(.021)	(.020)	(.015)	(.015)
$g_{i,t-1} * \sigma_{i,t-1}$	-.041	-.037	-.026	-.019
	(.022)*	(.023)*	(.019)	(.019)
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM})$	.015	.031		
	(.041)	(.044)		
$\Delta(g_{i,t-1} * \beta_{i,t-1}^{CAPM})$	.003	.006		
	(.021)	(.021)		
$g_{i,t-1} * \beta_{i,t-1}^{CAPM}$	.033	.043		
	(.034)	(.032)		
$g_{i,t} * \beta_{i,t}^{CAPM}$			-.0007	.006
			(.023)	(.022)
Sargan/Hansen	.364	.084	.389	.225
DoF	162	152	168	178
AR1	-3.656	-3.164	-3.516	-3.531
AR2	-2.9	-2.392	-2.903	-2.135
AR3	-.129	-.143	-.017	-.062
AR4	.675	.773	.885	.885
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t}}{K_{i,t}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - \theta y_{i,t-1})$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$g_{i,t} * \beta_{i,t}^{CAPM}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta^2 y_{i,t}$		t-2:t-2		t-2:t-2
$\Delta \frac{I_{i,t}}{K_{i,t}}$			t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \sigma_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(g_{i,t} * \beta_{i,t}^{CAPM})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
Difference Sargan Test				
(1-p-value)		0.999		0.957

Chapter 4

Comparing Effects of Firm Specific and Market Wide Volatility on Firm Investment in Estimates of Error Correction and Average Q Specifications

4.1 Introduction

This Chapter presents results from decomposing the uncertainty proxy $\sigma_{i,t}$ into various firm specific and market wide components; assessing the individual effects of each in the contexts of the error correction and average q investment specifications, estimated using the panel data set of UK firms from Chapter 1. This builds upon previous work in Bulan (2005), which decomposed a similar uncertainty proxy into volatility in market and industry returns, as well as firm specific volatility components in a panel data set of US firms; and previous work in Bloom, Bond and VanReenen (2007) which decomposed a stock return volatility based uncertainty proxy into firm specific (time invariant) and common (time varying) market wide components, as well as an idiosyncratic residual component varying over time and across firms. The results of these previous studies implied that idiosyncratic-residual measures of uncertainty had the most significant effects in estimated investment specifications. In Bulan (2005) the impact of each volatility measure on investment behaviour was evaluated by including linear controls for market, industry and firm volatility in Two Stage Least Squares (2SLS) estimates of an investment specification based on controls for average q. In estimates of the average q investment specification which included all linear uncertainty terms, coefficient estimates on the industry and firm specific terms were significant and negative; whereas coefficient estimates on linear market volatility terms were insignificant[1]. In Bloom, Bond and VanReenen (2007) interaction terms between sales growth and the individual uncertainty components were included in System GMM estimates of error correction investment specifications. The coefficients estimated on the aggregate component and time invariant firm specific component were insignificant, whereas coefficients estimated on the idiosyncratic uncertainty interaction term was significant and negative.

This chapter decomposes the uncertainty measure $\sigma_{i,t}$ - based on within year volatility in daily stock returns - into volatility in returns to the FTSE 100 index and a firm specific residual component, following the approach in Bulan (2005). The effects of these components are compared to those obtained by decomposing the uncertainty proxy following Bloom Bond and VanReenen (2007). Individual effects of these various uncertainty components are considered by including both linear and sales growth interaction terms in the error correction and average q investment specifications from Chapter 1. Whereas only linear uncertainty terms were included in the investment specification in Bulan (2005), coefficients estimated on the uncertainty sales growth interaction terms will determine to what extent the different components of the uncertainty proxy, $\sigma_{i,t}$, contribute to lower investment responses to demand at higher uncertainty. As discussed in the literature review, the most direct way of evaluating the unambiguous predictions of models with real options is with coefficients estimated on uncertainty-sales growth interaction terms, which allow for lower investment responses to changes in demand at higher levels of uncertainty. Bulan (2005) interprets significant negative coefficients estimated on linear uncertainty terms as evidence of the predictions of investment models with real options. In addition to documenting empirical firm level effects of uncertainty proxies on investment, this chapter provides a more thorough treatment of predictions from theoretical models with real options

[1]Whether included independently of, or jointly with the other components of volatility in firm stock returns.

by including both linear and sales growth interaction uncertainty terms in the error correction and average specifications estimated with the UK data.

The findings in this chapter are generally consistent with those in Bulan (2005) and Bloom, Bond and VanReenen (2007), in that volatility specific to firms is the most significant driver of the effect of $\sigma_{i,t}$ in estimates of the average q and error correction investment specifications. Coefficients estimated on the Bulan (2005) market volatility component implied a marginally significant negative effect on investment responses to demand growth when used as the sole proxy for uncertainty in estimates of the error correction specification. However, coefficients on this terms became insignificant when controls for the idiosyncratic firm specific component of $\sigma_{i,t}$ were added to the specifications. It is not clear whether these two components of $\sigma_{i,t}$ each contained unique information that was relevant to the investment behaviour of firms. The Bulan (2005) decomposed market volatility did not appear to contain any information that could not be controlled with its firm specific idiosyncratic counterpart.

4.2 Decomposing The Uncertainty Proxy $\sigma_{i,t}$

Following Bulan (2005) the uncertainty proxy $\sigma_{i,t}$ is decomposed into volatility in market returns (based on the FTSE 100) and residual volatility, based on the same OLS regression used to calculate $\beta_{i,t}^{CAPM}$ in Chapter 3. For each firm (i) year (t) observation in the panel data set, the daily (d) returns data $r_{i,t,d}$ used to construct the volatility measure $\sigma_{i,t}$, is regressed (by OLS) on daily returns to the FTSE 100 index ($r_{t,d}^{FTSE}$).

$$r_{i,t,d} = \alpha_{i,t} + \beta_{i,t}^{CAPM} r_{t,d}^{FTSE} + \epsilon_{i,t,d}^{r} \tag{4.1}$$

The coefficient estimate $\beta_{i,t}^{CAPM}$ and estimated residuals $\hat{\epsilon}_{i,t,d}^{r}$ are recorded for each firm year observation in the data set. Market volatility σ_t^{FTSE} and firm specific volatility $\sigma_{i,t}^{FIRM}$ are calculated as the within year standard deviations of $r_{t,d}^{FTSE}$ and $\epsilon_{i,t,d}^{\hat{r}}$ respectively (where $\bar{r}_t^{FTSE}$ denote mean values in year t).

$$\sigma_t^{FTSE} = \sqrt{\frac{1}{t_d}\sum_{d=1}^{t_d}(r_{t,d}^{FTSE} - \bar{r}_t^{FTSE})^2}$$

$$\sigma_{i,t}^{FIRM} = \sqrt{\frac{1}{t_d}\sum_{d=1}^{t_d}(\epsilon_{i,t,d}^{r})^2}$$

In addition to estimating Equation (4.1) for each firm year observation Bulan (2005) also estimated a similar equation, which regressed daily returns data on returns to market and industry indexes as explanatory variables; the analysis here omits the industry index returns data. Equation (4.1) can be interpreted as a CAPM in which terms in the risk free rate are assumed to be constant within years and amalgamated into the constant $\alpha_{i,t}$. The estimated coefficient on the $r_{t,d}^{FTSE}$ term in Equation (4.1) coincides with the $\beta_{i,t}^{CAPM}$ terms used to control for required rates of return predicted by the CAPM in Chapter 3. At this point it is worth while to note that although the estimation of $\beta_{i,t}^{CAPM}$ is the same as in Chapter 3, the incorporation of the term into the investment specifications in Chapter 3 was done under the assumption of a constant market risk premium, under which all variation in firm returns is derived from changes in $\beta_{i,t}^{CAPM}$. The latter assumption implies a more restrictive CAPM framework than that embodied by Equation (4.1); which, interpreted as a CAPM model, allows the market risk premium to change with market returns relative to a constant risk free rate. Following Bulan (2005), within year volatility in daily stock returns, $\sigma_{i,t}$, is broken down into $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$ according to Equation (4.1). Under the assumption of a constant risk free rate of return, $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ can be loosely interpreted as within year volatility in daily firm returns described by the CAPM represented by Equation (4.1); or alternatively, volatility in market returns that are correlated with the returns of individual firms through $\beta_{i,t}^{CAPM}$. Residual volatility in firm returns that are not explained by correlations with market returns in estimates of Equation (4.1), are described by $\sigma_{i,t}^{FIRM}$. Comparing coefficients estimated on $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$ in the average q and error correction specifications will evaluate the relative importance, to firm level investment behaviour, of volatility(/uncertainty) in market conditions (relevant to the firm) and firm specific, idiosyncratic, volatility(/uncertainty).

Following Bloom, Bond and VanReenen (2007), $\sigma_{i,t}$ is also decomposed into firm specific (time invariant), market wide (time varying, and common to all firms) and idiosyncratic components. This is done by regressing $\sigma_{i,t}$ on full sets of year and firm dummies. Coefficients estimated on the year dummies, σ_t, and firm dummies, σ_i, are recorded along with the residuals $\sigma_{i,t}^{\epsilon}$. Each uncertainty component is interacted with sales growth, $\Delta y_{i,t}$, and included in the two investment specification together with terms in $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$.[2] Comparison of coefficients estimated across $\sigma_t * \Delta y_{i,t}$, $\sigma_i * \Delta y_{i,t}$ and $\sigma_{i,t}^{\epsilon} * \Delta y_{i,t}$ terms will be informative of whether firm specific or market wide volatility(/uncertainty) in returns are most important in firms' decisions to delay investment responses to demand growth.

Comparing the different decompositions of $\sigma_{i,t}$, which follow Bulan (2005) and Bloom, Bond and VanReenen (2007), the market uncertainty component of the latter approach is less specific, defining the same level of market volatility for each firm; where as $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ defines a level of market volatility that is specific (or uniquely relevant) to each firm. Defining market uncertainty in this way may be more appropriate, in so far as volatility(/uncertainty) over some aspects/components of the market may be relevant to some firms but not to others. A market measure of uncertainty σ_t, common to all firms, could over-estimate uncertainty in the market

[2] As in Bloom, Bond and VanReenen (2007) linear terms in the components are not included in estimates of the investment specifications due to complications in finding reliable instruments to identify coefficients on the time invariant σ_i terms in dynamic investment specifications.

that is relevant to firm investment decisions. Thus, comparing the two sets of uncertainty components, the uncertainty measure $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ from Bulan (2005) adds some information from σ_i to the σ_t term from the Bloom Bond and VanReenen (2007) decomposition; and the idiosyncratic Bulan (2005) term, $\sigma_{i,t}^{FIRM}$, combines remaining information from σ_i with $\sigma_{i,t}^{\epsilon}$.

Table 1 below presents correlations across the Bulan (2005) and Bloom, Bond and VanReenen (2007) components of $\sigma_{i,t}$. The correlation coefficients in Column 1 of Table 5 show that all uncertainty components are positively and strongly correlated with $\sigma_{i,t}$ (with the exception of σ_t). In the Bulan (2005) decomposition, the component $\sigma_{i,t}^{FIRM}$ is much more strongly correlated with $\sigma_{i,t}$ than $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$. The terms $\sigma_{i,t}^{FIRM}$ and $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ are positively correlated, but the coefficient is relatively low; suggesting that each measure contains some unique information. The Bloom, Bond and VanReenen (2007) components have roughly similar correlations with $\sigma_{i,t}$; with the correlation between $\sigma_{i,t}$ and $\sigma_{i,t}^{\epsilon}$ being the strongest, and the correlation between $\sigma_{i,t}$ and σ_t being the weakest. The measure $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ has a stronger correlation with the controls for firm specific levels of uncertainty σ_i and $\sigma_{i,t}^{\epsilon}$ than it does with the common time varying measure of market wide uncertainty σ_t; suggesting that $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ likely incorporates a significant amount of information relating market wide uncertainty in σ_t^{FTSE} to individual firms.

[Table 1 Here]

4.3 Results

Tables 2 through 5 below present results from including the Bulan (2005) and Bloom, Bond and VanReenen (2007) components of $\sigma_{i,t}$ in estimates of the error correction and average q specifications. Firm specific components of $\sigma_{i,t}$ had the most significant effect in estimates of both investment specifications, which is consistent with the findings in Bulan (2005) and Bloom, Bond and VanReenen (2007). Whereas in Bulan (2005) market uncertainty was found to have no significant effect when included on its own in estimates of average q specifications, estimates of error correction specifications in this section implied a marginally significant negative effect of terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$ on investment behaviour.[3] Coefficients on the same terms were insignificant in estimates of the average q specification in this section. Coefficients on linear terms in market uncertainty were insignificant in estimates of both investment specifications.

With regards to the Bloom, Bond and VanReenen (2007) components of $\sigma_{i,t}$, coefficients were only significant on terms in $\sigma_i * \Delta y_{i,t}$ in the error correction specification. In Bloom Bond and VanReenen (2007), only coefficients estimated on uncertainty terms in $\sigma_{i,t}^{\epsilon} * \Delta y_{i,t}$ were significant in the error specification. However, results presented here are not inconsistent with the latter findings, in so far as firm specific components (captured either in σ_i or $\sigma_{i,t}^{\epsilon}$) are most important for the decision to delay investment responses to changes in demand. Coefficients estimated on these components of $\sigma_{i,t} * \Delta y_{i,t}$ were insignificant in estimates of the average Q specification; which is not of great surprise given that coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ were only marginally significant in estimates of average q specifications presented in Chapter 1.

Differences in coefficients estimated on the various components of $\sigma_{i,t} * \Delta y_{i,t}$ between estimates of error correction and average q specifications emphasize the importance of comparing effects of uncertainty across estimates of alternative investment specifications. Estimates of average q investment specifications are not very informative of the relative importance of firm specific and market level uncertainty to investment behaviour. Although coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ are significant in estimates of both investment specifications, the significance of coefficients estimated on uncertainty terms in the error correction specification is much less

[3] However these coefficients became insignificant in estimates of the error correction specification, when controls for effects of $\sigma_{i,t}^{FIRM}$ are introduced to the specification

sensitive to the decomposition of $\sigma_{i,t}$.

Table 2 below presents System GMM estimates of the error correction specification including terms in $\sigma_{i,t}$, $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$.[4] The results support $\sigma_{i,t}^{FIRM}$ as the most informative measure in controlling for effects of uncertainty on investment. Column 1 presents estimates of the error correction specification from Chapter 1, which includes linear and sales growth interaction terms in $\sigma_{i,t}$ to control for effects of uncertainty. Column 2 decomposes terms in $\sigma_{i,t}$ into terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$. Coefficients estimated on the 6 uncertainty terms in Column 2 are of low significance (with the exception of the coefficient on $\sigma_{i,t-1}^{FIRM}$). The hypothesis that coefficients on the two uncertainty-sales growth interaction terms are jointly insignificant, can only be marginally accepted at the 10% level based on a p-value of 0.12 from a Wald test of the linear hypothesis. Similarly, a Wald test marginally accepts the hypothesis that coefficients on the two linear uncertainty terms $\Delta\sigma_{i,t}^{FIRM}$ and $\sigma_{i,t-1}^{FIRM}$ are jointly insignificant based on a p-value of 0.12. A Wald test of the hypothesis that coefficients on the terms $\Delta(\beta_{i,t}^{CAPM} * \sigma_t^{FTSE})$ and $\beta_{i,t-1}^{CAPM} * \sigma_{t-1}^{FTSE}$ are jointly insignificant yields a p-value of 0.39. Of the 6 coefficients on uncertainty terms in Column 2, those estimated on $\Delta(\beta_{i,t}^{CAPM} * \sigma_t^{FTSE})$ and $\beta_{i,t-1}^{CAPM} * \sigma_{t-1}^{FTSE}$ appear to be least significant. Column 3 excludes linear terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$. As a result of dropping these terms from the specification in Column 2, the negative coefficient on $\sigma_{i,t}^{FIRM} * \Delta y_{i,t}$ becomes significant in Column 3. The hypothesis that coefficients on $\Delta\sigma_{i,t}^{FIRM}$ and $\sigma_{i,t-1}^{FIRM}$ terms are jointly insignificant in Column 3 is not rejected based on a p-value of 0.17. Whereas the coefficient on $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$ is insignificant in Column 3, estimates of the error correction specification in Column 4 - which only includes linear and interaction terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ - suggest that coefficients estimated on $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$ can capture negative interaction effects between uncertainty and sales growth. However, the results in Column 3 suggest that market volatility, as controlled for by $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$, does not contain any additional information not already controlled for by terms in $\sigma_{i,t}^{FIRM}$. Column 5 presents estimates of the error correction specification which only include terms in $\sigma_{i,t}^{FIRM}$. Comparing coefficients on $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$ in Column 4, and on $\sigma_{i,t}^{FIRM} * \Delta y_{i,t}$ in Column 5, the coefficient on the latter term is more significant and closer to the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 1.

[4]Instruments are based on the preferred System GMM instrument sets from Chapter 1.

[TABLE 2 HERE]

Table 3 below presents System GMM estimation results from including terms in $\sigma_{i,t}$, $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$ in estimates of the average q specification.[5] As in the case of the results presented in Table 2 for the error correction specification, the $\sigma_{i,t}^{FIRM}$ component of $\sigma_{i,t}$ was more informative than $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$. However, unlike in the case of the error correction specification in Column 4 of Table 2, coefficients estimated on terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$ showed no evidence of lower investment responses to demand at higher levels of market uncertainty.

Column 1 of Table 3 presents results from Chapter 1, which included only terms in $\sigma_{i,t}$ in estimates of the average q specification, on which marginally significant, negative coefficients are estimated on $\sigma_{i,t} * \Delta y_{i,t}$. Column 2 decomposes terms in $\sigma_{i,t}$ into $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ and $\sigma_{i,t}^{FIRM}$. Similar to the case of the error correction specification, coefficients on the 6 uncertainty terms are individually insignificant in Column 2. A Wald test does not reject the linear hypothesis that coefficients on the two uncertainty-sales growth interaction terms are jointly insignificant, based on a p-value of 0.31. The two hypotheses that coefficients on $\Delta\sigma_{i,t}^{FIRM}$ and $\sigma_{i,t-1}^{FIRM}$ are jointly insignificant, and that coefficients on $\Delta(\beta_{i,t}^{CAPM} * \sigma_t^{FTSE})$ and $\beta_{i,t-1}^{CAPM} * \sigma_{t-1}^{FTSE}$ are jointly insignificant are not rejected by Wald tests based on p-values of 0.63 and 0.84 respectively. Column 3 of Table 3 drops linear terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ from the specification in Column 2, following Table 2 above. As a result of dropping the latter uncertainty terms the negative coefficient estimated on $\sigma^{FIRM} * \Delta y_{i,t}$ becomes marginally significant, and is of similar magnitude to the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ in Column 1 of Table 3. Column 4 includes only linear and sales growth interaction terms in $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ in estimates of the average q specification; on which all coefficients are individually insignificant. A Wald test does not reject the hypothesis that coefficients on all uncertainty terms in Column 4 are jointly insignificant based on a p-value of 0.58. The hypothesis that coefficients on linear uncertainty terms in Column 4 are jointly insignificant is not rejected by a Wald test either, based on a p-value of

[5] As in Table 2 above, System GMM instrument sets are based on preferred instruments sets from Chapter 1.

0.64. Column 5 presents estimates of the average q specification which only includes terms in $\sigma_{i,t}^{FIRM}$; of which a significant and negative coefficient is only estimated on $\sigma_{i,t}^{FIRM} * \Delta y_{i,t}$. The coefficient on the latter term is similar in magnitude to those in Columns 1 and 3.

[TABLE 3 HERE]

Tables 4 and 5 below present results from decomposing the uncertainty sales growth interaction term, as in Bloom, Bond and VanReenen (2007), in estimates of the error correction and average q specifications. Significant coefficients on sales growth interaction terms between the components of $\sigma_{i,t}$ were only found in estimates of the error correction specification. Whereas significant negative coefficients are estimated on $\sigma_{i,t} * \Delta y_{i,t}$ in the average q specification, when this term is decomposed according to Bloom, Bond and VanReenen (2007), coefficients estimated on the individual components are insignificant. Estimates of error correction specifications suggests that firm specific components of uncertainty are most informative of decisions to delay investment responses to changes in demand. In Bloom, Bond and VanReenen (2007) relevant firm specific uncertainties were captured by the residual term $\sigma_{i,t}^{\epsilon}$; whereas in results presented here firm specific components of uncertainty σ_i were most informative in uncertainty sales growth interaction terms. Differences in coefficients estimated on the components of $\sigma_{i,t} * \Delta y_{i,t}$ between the error correction and average q specification highlight the importance of comparing results across estimates of alternative investment specifications.

Table 4 below presents estimates of the error correction specification, decomposing the uncertainty sales growth interaction term according to Bloom, Bond and VanReenen (2007). Column 1 presents the results from Column 1 of Table 2, in which uncertainty is controlled for using linear and sales growth interaction terms in $\sigma_{i,t}$. Column 2 decomposes the uncertainty sales growth interaction term into $\sigma_{i,t}^{\epsilon} * \Delta y_{i,t}$, $\sigma_t * \Delta y_{i,t}$ and $\sigma_i * \Delta y_{i,t}$. The coefficient estimated on $\sigma_i * \Delta y_{i,t}$ is largest in magnitude and the only coefficient that is significant (of those estimated on uncertainty sales growth interaction terms). A Wald test only marginally accepts the hypothesis that coefficients estimated on all uncertainty-sales growth interaction terms are jointly insignificant based on a p-value of 0.11. Similarly the hypothesis that coefficients on

$\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$ and $\sigma_t * \Delta y_{i,t}$ are jointly insignificant is only marginally accepted by a Wald test based on a p-value of 0.11. Column 3 retains only the sales growth interaction term $\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$ from Column 2; the coefficient on which remains insignificant. Column 4 includes only the sales growth interaction term $\sigma_t * \Delta y_{i,t}$, on which the coefficient remains insignificant from Column 2. Column 5 includes the sales growth interaction term $\sigma_i * \Delta y_{i,t}$, on which the coefficient remains negative and strongly significant from Column 2. Coefficients on respective uncertainty sales growth interaction terms remain almost identical in magnitude across Columns 3, 4 and 5 of Table 4.

[TABLE 4 HERE]

Table 5 below presents a similar set of results to those in Table 4, but for the average q specification. Coefficients estimated on the components of the uncertainty sales growth interaction terms are statistically insignificant across the Columns of Table 5. Column 1 presents the specification in Column 1 of Table 3, in which uncertainty is controlled for by linear and sales growth interaction terms in $\sigma_{i,t}$. Column 2 decomposes the sales growth interaction term into the individual components $\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$, $\sigma_t * \Delta y_{i,t}$ and $\sigma_i * \Delta y_{i,t}$, coefficient on all of which are individually insignificant. A Wald test does not reject the hypothesis that coefficients on uncertainty-sales growth interaction terms are jointly insignificant based on a p-value of 0.39. Similarly a Wald test does not reject the hypothesis that coefficients on $\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$ and $\sigma_t * \Delta y_{i,t}$ are jointly insignificant based on a p-value of 0.28. Columns 3 through 5, individually include each of the components as controls for lower investment responses to changes in demand at higher levels of uncertainty, however estimated coefficients on these terms remain statistically insignificant throughout Columns 3, 4 and 5.

[TABLE 5 HERE]

4.4 Conclusion

Results presented in this section evaluated the effects of different components of $\sigma_{i,t}$ in estimates of error correction and average q investment specifications. The decomposition of $\sigma_{i,t}$ followed two approaches: (i) from Bulan (2005) based on the structure of a CAPM model for daily returns; and (ii) from Bloom, Bond and VanReenen (2007) based on time invariant firms specific, common market wide and idiosyncratic residual components of $\sigma_{i,t}$. Results obtained from estimating error correction and average q specifications, using both sets of components, implied that firm specific, idiosyncratic information contained in $\sigma_{i,t}$ was most informative of investment decisions of firms; which is consistent with previous findings[6].

Volatility in market returns, correlated to firm returns, as described by $\beta_{i,t}^{CAPM} * \sigma_{i,t}^{FTSE}$ (constructed following Bulan (2005)) was marginally informative of investment behaviour, when used as the sole proxy of uncertainty in the error correction specification. This is an interesting result relative to the analysis of Chapter 3, which found no significant effects of $\beta_{i,t}^{CAPM}$ terms in the error correction specification. Although $\beta_{i,t}^{CAPM}$ terms may have been uninformative of variation in user costs of capital across firms (contrary to the predictions of the CAPM) the information contained in the term was informative of firm specific effects of common market wide volatility/uncertainty captured by σ_t^{FTSE}. This could be related to the restrictive assumption of a constant market risk premium in the analysis of Chapter 3, which included only linear terms in $\beta_{i,t}^{CAPM}$ to control for systematic investor risk premiums in the CAPM. If the market risk premium was not constant over time, and was higher in years with larger volatility in market returns, σ_t^{FTSE} could have been controlling for variation across years in the market risk premium, increasing the significance of $\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$ to investment decisions. Furthermore, this measure of market volatility/uncertainty that is relevant for firm volatility/uncertainty was more informative than σ_t - the component of $\sigma_{i,t}$ that represented market wide uncertainty in Bloom, Bond and VanReenen (2007). This may be due to the possibility that adjusting for aspects of market volatility that are relevant for the firm, with $\beta_{i,t}^{CAPM}$, is important in controlling for market wide uncertainty that impacts firm level investment behaviour.

[6]Namely Bulan(2005) and Bloom, Bond and VanReenen (2007)

Contrasts between coefficients estimated on the various uncertainty components in error correction and average q specifications in this Chapter highlight the potential of uncovering additional information by estimating alternative investment specifications. Significant effects of $\beta_{i,t}^{CAPM} * \sigma_{i,t}^{FTSE}$ discussed in the previous paragraph could have been overlooked if the error correction specification was not estimated with this UK data set, and the analysis was based exclusively on estimates of the average q specification.

4.5 Tables of Results

Table 1
Correlations

Correlation Between Uncertainty Measures	$\sigma_{i,t}$	$\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$	$\sigma_{i,t}^{FIRM}$	σ_t	σ_i	$\sigma_{i,t}^{\epsilon}$
$\sigma_{i,t}$	1.000					
Bulan (2005) Measures						
$\beta_{i,t}^{CAPM} * \sigma_t^{FTSE}$	0.418	1.000				
$\sigma_{i,t}^{FIRM}$	0.983	0.254	1.000			
Bloom, Bond and VanReenen (2007) Measures						
σ_t	0.425	0.058	0.436	1.000		
σ_i	0.564	0.319	0.543	-0.081	1.000	
$\sigma_{i,t}^{\epsilon}$	0.664	0.235	0.660	-0.000	-0.015	1.000

Table 2
Error Correction Investment Specification - Bulan (2005) Decomposition

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.116	-.120	-.115	-.109	-.124
	(.131)	(.127)	(.131)	(.106)	(.131)
$\Delta y_{i,t-1}$	.078	.064	.079	.081	.075
	(.051)	(.053)	(.051)	(.050)	(.051)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207				
	(.093)**				
$\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$		-.129	-.160	-.492	
		(.390)	(.396)	(.291)*	
$\sigma_{i,t}^{FIRM} * \Delta y_{i,t}$		-.176	-.184		-.210
		(.120)	(.110)*		(.096)**
$\Delta y_{i,t}$	.715	.709	.717	.518	.720
	(.173)***	(.181)***	(.175)***	(.139)***	(.170)***
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.058	-.052	-.074	-.050
	(.028)*	(.030)*	(.029)*	(.030)**	(.028)*
$\Delta\sigma_{i,t}$	-.030				
	(.018)*				
$\sigma_{i,t-1}$	-.029				
	(.018)				
$\Delta(\beta_{i,t}^{CAPM} * \sigma_t^{FTSE})$		-.0003		-.021	
		(.042)		(.034)	
$\beta_{i,t-1}^{CAPM} * \sigma_{t-1}^{FTSE}$		.054		-.009	
		(.047)		(.035)	
$\Delta\sigma_{i,t}^{FIRM}$		-.025	-.029		-.029
		(.022)	(.020)		(.020)
$\sigma_{i,t-1}^{FIRM}$		-.049	-.031		-.032
		(.024)**	(.019)		(.020)
Sargan/Hansen	.397	.406	.369	.311	.4
DoF	133	130	132	133	133
AR1	-2.985	-3.006	-2.987	-3.491	-2.948
AR2	-1.424	-1.481	-1.464	-1.797	-1.48
AR3	-.121	-.237	-.142	.068	-.162
AR4	.589	.752	.647	.582	.659
Instruments For Equations in First Differences					
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
Instruments For Equations in Levels					
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta(k_{i,t-1} - y_{i,t-1})$					
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 3
Average Q Investment Specification - Bulan (2005) Decomposition

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.015	-.003	-.019	-.037	-.019
	(.103)	(.102)	(.102)	(.096)	(.103)
$\Delta y_{i,t-1}$	.033	.025	.036	.038	.035
	(.043)	(.043)	(.042)	(.044)	(.042)
$\sigma_{i,t} * \Delta y_{i,t}$	-.107				
	(.063)*				
$\beta_{i,t}^{CAPM} * \sigma_t^{FTSE} * \Delta y_{i,t}$		-.005	.024	-.176	
		(.283)	(.281)	(.259)	
$\sigma_{i,t}^{FIRM} * \Delta y_{i,t}$		-.098	-.109		-.107
		(.067)	(.063)*		(.062)*
$\Delta y_{i,t}$	.415	.394	.410	.308	.411
	(.128)***	(.145)***	(.138)***	(.118)***	(.124)***
$Q_{i,t}$	.020	.020	.019	.021	.019
	(.005)***	(.005)***	(.005)***	(.005)***	(.005)***
$\Delta\sigma_{i,t}$	-.012				
	(.015)				
$\sigma_{i,t-1}$	-.017				
	(.013)				
$\Delta(\beta_{i,t}^{CAPM} * \sigma_t^{FTSE})$		-.018		-.013	
		(.031)		(.028)	
$\beta_{i,t-1}^{CAPM} * \sigma_{t-1}^{FTSE}$		-.011		-.024	
		(.028)		(.026)	
$\Delta\sigma_{i,t}^{FIRM}$		-.008	-.013		-.013
		(.014)	(.015)		(.015)
$\sigma_{i,t-1}^{FIRM}$		-.016	-.019		-.019
		(.016)	(.015)		(.015)
Sargan/Hansen	.734	.734	.711	.499	.727
DoF	147	144	146	147	147
AR1	-4.528	-4.598	-4.543	-4.52	-4.512
AR2	-.709	-.604	-.762	-.93	-.755
AR3	-.262	-.266	-.263	-.056	-.266
AR4	.953	.971	.957	.894	.965
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	
Instruments For Equations in Levels					
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 4

Error Correction Investment Specification - BBVR (2007) Decomposition

	(1)	(2)	(3)	(4)	(5)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.116	-.113	-.162	-.199	-.142
	(.131)	(.129)	(.120)	(.117)*	(.116)
$\Delta y_{i,t-1}$	.078	.073	.074	.080	.062
	(.051)	(.050)	(.052)	(.052)	(.051)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207				
	(.093)**				
$\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$		-.143	-.132		
		(.130)	(.131)		
$\sigma_t * \Delta y_{i,t}$		-.230		-.225	
		(.310)		(.280)	
$\sigma_i * \Delta y_{i,t}$		-.344			-.391
		(.184)*			(.193)**
$\Delta y_{i,t}$	.715	1.003	.385	.268	1.263
	(.173)***	(.465)**	(.095)***	(.192)	(.421)***
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.053	-.056	-.060	-.069
	(.028)*	(.029)*	(.030)*	(.030)**	(.028)**
$\Delta\sigma_{i,t}$	-.030	-.028	-.034	-.033	-.026
	(.018)*	(.018)	(.018)*	(.019)*	(.018)
$\sigma_{i,t-1}$	-.029	-.027	-.040	-.045	-.028
	(.018)	(.018)	(.017)**	(.017)***	(.017)*
Sargan/Hansen	.397	.352	.341	.307	.366
DoF	133	131	133	133	133
AR1	-2.985	-2.949	-2.979	-2.823	-3.216
AR2	-1.424	-1.447	-1.738	-2.098	-1.707
AR3	-.121	-.227	.057	-.082	-.252
AR4	.589	.61	.57	.507	.707
Instruments For Equations in First Differences					
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t-1} - y_{i,t-1})$					
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Table 5
Average Q Investment Specification - BBVR (2007) Decomposition

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.015	-.009	-.037	-.038	-.019
	(.103)	(.103)	(.104)	(.105)	(.105)
$\Delta y_{i,t-1}$	.033	.031	.038	.034	.035
	(.043)	(.044)	(.043)	(.045)	(.043)
$\sigma_{i,t} * \Delta y_{i,t}$	-.107				
	(.063)*				
$\sigma^{\epsilon}_{i,t} * \Delta y_{i,t}$		-.060	-.053		
		(.086)	(.085)		
$\sigma_t * \Delta y_{i,t}$		-.183		-.131	
		(.172)		(.178)	
$\sigma_i * \Delta y_{i,t}$		-.179			-.175
		(.131)			(.136)
$\Delta y_{i,t}$	.415	.535	.227	.166	.625
	(.128)***	(.286)*	(.077)***	(.124)	(.298)**
$Q_{i,t}$	.020	.021	.019	.019	.020
	(.005)***	(.005)***	(.005)***	(.005)***	(.005)***
$\Delta\sigma_{i,t}$	-.012	-.011	-.015	-.017	-.011
	(.015)	(.016)	(.014)	(.015)	(.016)
$\sigma_{i,t-1}$	-.017	-.015	-.025	-.028	-.015
	(.013)	(.017)	(.013)**	(.013)**	(.017)
Sargan/Hansen	.734	.802	.622	.662	.732
DoF	147	145	147	147	147
AR1	-4.528	-4.452	-4.363	-4.316	-4.409
AR2	-.709	-.679	-.845	-.839	-.697
AR3	-.262	-.355	-.111	-.219	-.225
AR4	.953	.943	.869	.797	.946
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Chapter 5

Effects of Uncertainty Proxies Based on I/B/E/S Analysts' Forecasts of Earnings per Share in Estimates of Error Correction and Average Q Specifications

5.1 Introduction

In Chapters 1, 3 and 4 investigations into relationships between firm investment and uncertainty relied on a measure for uncertainty based on within year volatility of a firm's daily stock returns. This approach followed previous empirical literature which relied on similar stock return based proxies [1]. This Chapter compares effects implied by coefficients estimated on stock return volatility measures of uncertainty and measures based on volatility of I/B/E/S securities analysts' forecasts of earnings per share in estimates of error correction and average q investment specifications. This comparison is motivated by Bond and Cummins (2004) which found that in estimates of firm level investment specifications with US data, stock return volatility based uncertainty proxies contained information that was most relevant to uncertainty-sales

[1] Leahy and Whited (1996), Bloom Bond and Van Reenen (2007) and Bulan (2005)

growth interaction effects; whereas uncertainty measures based on securities analysts' forecasts were most informative about linear effects of uncertainty. Results presented in this chapter - based on a UK data set - also suggest that stock return volatility is more informative about uncertainty-sales growth interaction effects; while proxies based on I/B/E/S securities analysts' forecast data were better controls for linear effects of uncertainty on investment. Information contained in each proxy appears to be related to investment in different ways, as using the I/B/E/S proxies did not detect any effects of uncertainty on investment responses to demand, and stock return volatility is not very informative about linear effects of uncertainty uncovered with the I/B/E/S proxies. Investment specifications which included the preferred stock return volatility uncertainty-sales growth interaction terms and the preferred linear I/B/E/S terms suggested that the latter are much more important in describing firm investment behaviour. Coefficients estimated on interaction terms between sales growth and stock return volatility based uncertainty measures become insignificant in investment specifications which included the I/B/E/S uncertainty proxies calculated with the UK data set.

Using a panel data set of 946 publicly traded US firms over the period 1982-1999 Bond and Cummins (2004) estimate an investment specification based on average q, comparing effects of stock return volatility based measures of firm level uncertainty to effects captured by indicators of uncertainty based on security analysts' forecasts of earnings per share recorded in the I/B/E/S data base. The stock return volatility measure of firm uncertainty from Bond and Cummins (2004) is calculated in the same way as the measure $\sigma_{i,t}$ in Chapters 1, 3 and 4: within year standard deviation of a firm's daily stock returns. The two I/B/E/S uncertainty proxies in Bond and Cummins (2004) are based on (i) dispersion in analysts forecasts of earnings per share over an accounting period, calculated as the coefficient of variation across different security analysts' forecasts made at the beginning of the accounting period; and (ii) the variance of errors in forecasts of earnings per share, calculated as a weighted sum of squared differences between beginning of period consensus forecasts[2] and realized values of earnings per share at the end of the accounting periods. These proxies are denoted by $DISP_{i,t}$ and $ERR_{i,t}$ respectively in Bond and Cummins (2004). Including these proxies individually in an investment specification based on controls for average q, the authors found that coefficients estimated on each proxy described

[2] Un-weighted mean of security analysts' forecasts

negative linear effects of uncertainty on the investment rate. However, when all the proxies were jointly included in the investment specification, the authors found that the dispersion measure best described linear effects of uncertainty on investment; whereas lower investment responses to demand shocks were best captured by coefficients estimated on interaction terms between sales growth and the proxy based on within year volatility of daily stock returns. The preferred specification presented in Bond and Cummins (2004) included sales growth interaction terms with the stock return volatility measure, and linear terms in $DISP_{i,t}$, coefficients on both of which were significant and negative.[3]

Although a measure similar to $DISP_{i,t}$ was calculated for the data set of UK firms used in Chapters 1, 3 and 4, there were only a limited number of firms for which multiple analysts made consecutive forecasts of earnings per share at the beginning of accounting periods throughout the data set; and for which the dispersion measure could be calculated. Unfortunately there were not sufficient firm year observations in this subset to produce reliable estimates of investment specifications which were consistent with those obtained with the full data set from Chapter 1. There is substantially greater coverage of US firms by securities analysts in the I/B/E/S data set, with which Bond and Cummins (2004) were able to construct their measures $DISP_{i,t}$ and $ERR_{i,t}$ for a larger data set of firms.

Using monthly analysts' forecasts of firms' earnings per share, two new measures of within year firm level uncertainty have been constructed for the full sample of UK firms in the data set from Chapter 1: (i) $REV_{i,t}$ the within year coefficient of variation of monthly average (consensus)[4] forecasts of firm i's end of period earnings per share, made within an accounting period (t); and (ii) $RANGE_{i,t}$ the difference between the highest and lowest monthly consensus forecasts divided by the absolute value of their mean over the accounting period. Unlike the $DISP_{i,t}$ proxy constructed in Bond and Cummins (2004), which is based on discrepancies of forecasts made by different analysts at a single point in time, $REV_{i,t}$ and $RANGE_{i,t}$ are based on within year volatility of monthly consensus (average) forecasts of security analysts. Results

[3]In their results, negative interaction effects with sales growth terms (consistent with the predictions of investment models with real options) were only found using interaction terms with the uncertainty proxy based on within year volatility of daily stock returns.

[4]Where a single firm is covered by multiple analysts, a simple average of analysts' forecasts is used as the consensus forecast for that month.

from estimating investment specifications which include uncertainty proxies such as $REV_{i,t}$ and $RANGE_{i,t}$ have not previously been published.[5]

This chapter presents estimation results of error correction and average q specifications, which include both linear terms and non-linear sales growth interaction terms, in $REV_{i,t}$ and $RANGE_{i,t}$. In Chapter 1, estimates of these two investment specifications contained significant negative coefficients on uncertainty-sales growth interaction terms and only marginally significant coefficients on linear uncertainty terms. In contrast using only the I/B/E/S proxies to control for effects of uncertainty results in strongly significant coefficients on linear uncertainty terms, and insignificant coefficients on uncertainty sales growth interaction terms. Comparing the I/B/E/S and stock return volatility proxies within specifications which include only linear or sales growth interaction uncertainty terms suggests that the two types of proxies contain different information and control for different effects of uncertainty on investment behaviour.

Unlike in the results presented by Bond and Cummins (2004), it is very difficult to capture both linear and sales growth interaction effects of uncertainty using stock return volatility and I/B/E/S proxies within the same investment specification. In estimates of both the error correction and average q specification which included sales growth interaction terms with stock return volatility measures ($\sigma_{i,t} * \Delta y_{i,t}$) and linear I/B/E/S terms, only coefficients on the latter were significant. Although these results contrast those presented for a much larger data set of US firms in Bond and Cummins (2004), the uncertainty measures $DISP_{i,t}$ and $ERR_{i,t}$ are very different from the measures $REV_{i,t}$ and $RANGE_{i,t}$ used in the current Chapter. The results presented here suggest that - compared to the proxy $\sigma_{i,t}$ based on volatility in daily stock returns - the measures $REV_{i,t}$ and $RANGE_{i,t}$ are much more informative of effects of uncertainty on firm level investment behaviour.

[5]The author would like to thank Steve Bond (Nuffield College Oxford), Alexander Klemm (Institute for Fiscal Studies), Rain Newton-Smith (The Bank of England), Muratza Syed (Institute of Fiscal Studies) and Gertjan Vlieghe (Bank of England and London School of Economics) for their work in Bond et al (2004) in which I/B/E/S data on security analysts' forecasts of earnings per share for UK listed companies was merged with a data set of UK firms from DATASTREAM as part of a joint Bank of England and IFS project to investigate the roles of expected profitability, Tobin's Q and cash flow in estimates of firm level investment specifications. The author would also like to thank Steve Bond (Nuffield College Oxford), Richhild Moessner (The Bank of England), Haroon Mumtaz (The Bank of England) and Murtaza Syed (The International Monetary Fund) for their work in the preliminary development of versions of programs used to construct the I/B/E/S uncertainty measures $DISP_{i,t}$, $REV_{i,t}$ and $RANGE_{i,t}$ in the Bond et al. (2004) data set. These programs were extensively checked and reviewed in the course of calculating variables used in estimation results presented in this Chapter.

Whereas coefficients estimated on stock return volatility uncertainty terms differed between error correction and average q specifications in Chapter 1, coefficients on more informative I/B/E/S uncertainty measures are very similar across estimates of the two investment specifications. Coefficients estimated on linear I/B/E/S uncertainty measures were highly significant in estimates of both error correction and average q specifications, and their respective magnitudes were within one standard deviation of each other. By contrasts coefficients estimated on stock return volatility - sales growth interaction terms were marginally insignificant in the average q specification and substantially smaller in magnitude relative to more significant corresponding coefficients in estimates of the error correction specification.

5.2 Alternative Uncertainty Measures

One of the main obstacles in the empirical literature on firm level investment uncertainty relationships is to construct empirical indicators that summarize uncertainty over the expected profitability of investment, and/or act as counterparts to the concepts of uncertainty in theoretical models of firm investment. In the class of theoretical investment models discussed in the literature review in Chapter 1, uncertainty is represented by volatility in stochastic output prices or stochastic components of demand/productivity functions, obeying some type of Brownian motion. Generally, the class of models developed in Dixit and Pyndick (1994) and Abel and Eberly (1996) only allow for a single productivity, demand or price index to vary over time. Investment uncertainty relationships described by the latter class of theoretical models are governed by the functional relationships between marginal revenue products of capital and the specific variable that varies over time. In the models of Hartman (1972) and Abel (1983), whether the marginal revenue product of capital is concave or convex, with respect to the stochastic variable, wholly determines whether the effect of greater volatility in the stochastic variable has a negative or positive effect on the desired level of the capital stock. Concepts of uncertainty represented in such theoretical models (in the form of volatility in demand or productivity) have no empirically observable counterpart. Moreover, the investment decisions of firms in the real world are made facing joint uncertainty over demand, productivity, production and financing costs, as well as tax, regulatory and political environments. Whether investigating general empirical relationships between investment and uncertainty over firm returns, or the specific predictions of theoretical models, it is unlikely for a single empirically observable measure to either (i) summarize all uncertainties over expected operating environments and profits that are relevant to the investment decisions of firms, or (ii) fully represent concepts of uncertainty specified in theoretical models. Thus it is important in empirical research to compare results obtained by using alternative uncertainty measures, each of which may be additionally informative about particular uncertainties relevant to the investment decisions of firms.

Information contained in uncertainty proxies based on within year stock return volatility may differ from the I/B/E/S indicators of uncertainty due to the fact that high frequency daily stock returns could contain information that is not captured with measures based on lower frequency data on monthly observations on analysts' forecasts. Alternatively, there is evidence to suggest that stock returns can exhibit excessive volatility, that cannot be attributed to changes in information about the fundamental profitability of a firm or its future dividend payout: Shiller (1981) describes how *"...measures of stock price volatility over the past century appear to be far too high - five to thirteen times too high - to be attributed to new information about future real dividends..."*. Despite a potential disconnect between volatility in share prices and volatility in the conditions of a firm's *real* operating market, uncertainty in share prices can have very real consequences on a firm's financing costs. Moreover, a lack of market confidence in the prospects of a firm, captured by volatility in stock returns, could have a strong influence on a firm's investment decisions. Such effects may not be easily described with data on securities analysts' forecasts. Comparing effects of uncertainty captured by stock return based proxies and those captured by alternative measures can be informative of how different information contained in each measure is related to investment behaviour.

The Institutional Brokers' Estimate System (I/B/E/S) (now owned by Thomson Reuters) was founded by the New York brokerage firm Lynch, Jones & Ryan. The I/B/E/S database contains securities analysts' forecasted earnings for U.S. companies going back to 1976 and for international companies going back to 1987. The database incorporates raw data reported by securities analysts to calculate several time series of earnings projections of each company, including several short run forecasts as well as long run trends. In cases when several analysts provide data on the same firm, I/B/E/S reports individual as well as average - consensus - forecast measures. The I/B/E/S database covers over 45,000 companies in 70 markets, it is provided to over 50,000 institutional money manager as clients. More than 700 firms contribute data to I/B/E/S, from the largest global houses to regional and local brokers.[6]

Bond and Cummins (2004) found that two measures of uncertainty based on I/B/E/S security analysts' forecasts of earnings per share: $DISP_{i,t}$ and $ERR_{i,t}$, were positively correlated with each other as well as with a proxy based on within year volatility of daily stock returns. However, OLS regressions of one proxy on the others yielded very poor fits. This implies that the different proxies likely contain separate information on uncertainty that may be more or

[6] $http://thomsonreuters.com/products_services/financial/financial_products/products_az/ibes$

less relevant to firm investment decisions - or relevant in different ways. This conjecture was further supported by their findings that short run and long run effects of uncertainty were best described by measures based on volatility in daily stock returns and disagreement in analysts' forecasts, respectively.[7] Uncertainty described in theoretical models - or considered relevant by managers making investment decisions - will not likely be summarized by a single measure. Different indicators may be particularly informative about uncertainties that have different effects on investment behaviour of firms: one proxy may be more informative for valuing real options, whereas another measure may summarize uncertainties relevant to risk premia in required rates of return. In the findings of Bond and Cummins (2004) $DISP_{i,t}$ was most informative about linear effects of uncertainty in their investment specification - impacting long run desired levels of capital; whereas volatility in stock returns best described non-linear effects on short run investment dynamics through uncertainty sales growth interaction terms.

The uncertainty term labeled $DISP_{i,t}$ in Bond and Cummins(2004) is based on disagreement among different securities analysts tracked by I/B/E/S, forecasting end of period profits for the same firm, at the beginning of the accounting period.[8] As this measure requires forecasts from multiple analysts for every firm year observation to identify uncertainty over expected profits, its use can be limiting on the number of firms for which there is sufficient forecasts data. Unfortunately this is a serious limitation in the UK data set. The minimum amount of information required to construct the $DISP_{i,t}$ proxy for uncertainty is only available for a subset of the UK data set, for which at least 2 securities analysts made beginning of period forecasts for end of period earnings per share. This sub-sample has only 58% of the firm year observations available in the full sample. In this small sub-sample it was not possible to obtain satisfactory estimates of baseline investment specifications that were consistent with full sample estimates. An opportunity for future research would be to compare results from using uncertainty terms based on within year volatility of earnings per share forecasts ($REV_{i,t}$ and $RANGE_{i,t}$) with indicators based on disagreement between forecasters at specific points in time ($DISP_{i,t}$).

[7] The proxy based on squared forecast errors, described negative effects of uncertainty (similar to those described by other uncertainty proxies) when individually included in the investment specification; however, this measure was un-informative when included jointly in the investment specification with any of the other proxies.

[8] In their paper this proxy is constructed as the coefficient of variation across analysts in the forecasts of earnings per share made at a single point in time, for the end of the given accounting period

With regards to $DISP_{i,t}$ as a proxy for uncertainty, although it is likely that greater certainty over future profits would lead to more agreement in analysts' forecasts, it is less clear that greater uncertainty would translate into greater disagreement. Differences in forecasts may arise due to availability of information and also the way in which that information is processed into forecasted profits. It is possible to have similar forecasts of earnings per share despite highly uncertain future profits if analysts have access to the same information and use similar methods to construct their forecasts. However, Bond and Cummins (2004) note that the extent to which differences in forecasts reflect differences in the way analysts process the same information could be indicative of uncertainty about the correct process of generating future profits from the perspective of firms.

It is important to note that recent literature has indicated that disagreement or dispersion of investor beliefs in stock returns may be related to investment decisions beyond information that reflects uncertainty over firm profitability. Disagreement between analysts may have real impacts on the pricing of stocks and on firm behaviour that is distinct from effects of uncertainty emphasized in Bond and Cummins (2004); and may or may not be captured in measures such as $DISP_{i,t}$. Gilchrist, Himmelberg and Huberman (2005) develops a model in which increases in the dispersion of investor beliefs under short-selling constraints predict a *bubble* or a rise in a stock's price above its fundamental value. The model predicts that managers respond to bubbles by issuing new equity and increasing capital expenditures. The predictions of this model are evaluated using the variance of analysts' earnings forecasts as a proxy for the dispersion of investor beliefs to identify the *bubble* component in Tobin's Q. Gilchrist, Himmelberg and Huberman (2005) compare firms traded on the New York Stock Exchange and those traded on NASDAQ, finding that the model successfully captures key features of the technology boom of the 1990s. In a panel data set it is found that orthogonalized shocks to dispersion of investor beliefs have positive and statistically significant effects on Tobin's Q, net equity issuance, and real investment.

Sadka and Scherbina (2007) documents a close link between mis-pricing and liquidity by investigating stocks with high analyst disagreement; noting that previous research finds that such stocks tend to be overpriced, but that prices correct downwards as uncertainty about earnings is resolved. Analysis in Sadka and Scherbina (2007) suggests that the latter mis-pricing persists due to the fact that disagreement in analysts forecasts coincides with high trading costs. Finding that in the cross-section, less liquid stocks tend to be more severely overpriced. If disagreement in analysts forecasts leads to an overvaluation in a firm stock, and as suggested in Gilchrist, Himmelberg and Huberman (2005) managers respond by issuing new equity and increasing capital expenditures, such effects could oppose negative effects of uncertainty on investment described by measures such as $DISP_{i,t}$ from Bond and Cummins (2004).

The second alternative uncertainty measure calculated in Bond and Cummins (2004) using the I/B/E/S data, is based on the variance of errors made by securities analysts in forecasting a firm's earnings per share in the recent past ($ERR_{i,t}$). Squared forecast errors are calculated using the difference between the beginning of period consensus forecasts[9] and realized earnings per share at the end of the accounting period reported by I/B/E/S. Bond and Cummins (2004) note that a single value of the squared forecast error in a given period is not informative about the uncertainty faced by a firm over that period, and thus rely on a variance measure of forecast errors over several years. However, using too few observations results in imprecise measures of the variance, and using too many observations produces limited time series variation in the resulting measure; and could impose continued relevance of past levels of uncertainty. To overcome these issues Bond and Cummins (2004) include current and past squared errors as separate variables in their investment specification to allow different weights to be assigned without imposing any specific pattern to those weights. Due to the limited number of time series observations in their panel only 2 lags of the squared forecast errors were included.

Relative to the uncertainty measures based on I/B/E/S analysts' forecasts used in Bond and Cummins (2004), which rely on data from a single point in time to measure uncertainty over a given accounting period, the alternative indicators of uncertainty used in this chapter rely on variation of monthly I/B/E/S forecasts within an accounting period. The first measure $REV_{i,t}$ is calculated as the coefficient of variation across all monthly consensus forecasts of end of pe-

[9]Un-weighted mean of forecasted earnings per share taken across all analysts that made forecasts for a given firm, as reported by I/B/E/S

riod earnings per share for firm i in the accounting period t. The second alternative measure used, $RANGE_{i,t}$, is the difference between the highest and lowest of these monthly consensus forecasts for end of period earnings per share, divided by the absolute value of the mean of monthly consensus forecasts within the accounting period. Unlike the I/B/E/S measures in Bond and Cummins (2004) $REV_{i,t}$ and $RANGE_{i,t}$ do not contain information on disagreement across different individual analysts' forecasts. To measure uncertainty faced by a firm $REV_{i,t}$ and $RANGE_{i,t}$ rely on changes in analysts' consensus forecasts of earnings per share made every month within a year for a firm's end of period earnings. Using $REV_{i,t}$ and $RANGE_{i,t}$ to describe the level of uncertainty faced by firms assumes that earnings per share forecasts for firms facing higher uncertainty are more sensitive to the arrival of new information over time resulting in greater volatility of consensus forecasts over an accounting period.

The proxies $REV_{i,t}$ and $RANGE_{i,t}$ should provide a reliable description of the level of uncertainty over future operating conditions and expected earnings within an accounting period. The degree of certainty in the expected operating environment and profitability of investments should clearly be correlated with more stable forecasts of earnings per share; as in more stable environments the new information revealed to forecasters over the accounting period has little impact on their expectations and updated forecasts. If forecasts made at the beginning of the period factored in a wide range of possible outcomes, I.E. uncertainty over expected profitability, those forecasts would be frequently revised throughout the period with the arrival of new information, and with unexpected changes in firms' operating environments. Stable operating environments, in which there are no (unforeseeable) drastic changes to the profitability of firms (causing forecasts to be substantially revised), would be represented by low values of $REV_{i,t}$ and $RANGE_{i,t}$. These two alternative uncertainty measures constructed with the I/B/E/S data are closely related to the proxy based on volatility in stock returns. If it were the case that stock market values only reflect expectations of future revenues/dividends and incorporated constant discount rates while analysts only made unbiased reports of their best forecasts of expected future dividends and future profitability - both stock return volatility and the uncertainty measures based on analysts' forecasts of earnings per share would follow volatility in firm value functions. In an empirical data set differences between I/B/E/S and stock return volatility proxies would be driven partly by higher frequency and volatility of the daily stock returns as compared to the monthly analyst forecasts. Comparing the effects of these two uncertainty indicators could be revealing of information contained in higher frequency stock returns and how that information relates to firm investment behaviour.

A potential shortfall in the $REV_{i,t}$ and $RANGE_{i,t}$ proxies lies in the possibility that, over time, analysts receive little new information regarding a firm facing highly uncertain operating conditions, which would then not be reflected by $REV_{i,t}$ or $RANGE_{i,t}$ if the forecasts of earnings per share are not revised. However, this is a rather extreme criticism of these measures. It would be highly unlikely for a forecast made 12 months prior to the announcement of *uncertain* earnings per share to be equally accurate as - and go un-revised up to the time of - a forecast made 1 month prior to the announcement. The capacities of analysts would have to be very poor indeed if they could not resolve any uncertainty over a 12 month period leading up to their forecasted event. It is worth noting that this shortcoming is similar to the issue confronting the use of $DISP_{i,t}$ in Bond and Cummins (2004), which may not identify highly uncertain future operating conditions if analysts processed uncertain information about firms in similar ways. Because such issues arises for different reasons in $DISP_{i,t}$, and $RANGE_{i,t}$ and $REV_{i,t}$ it could be useful to compare results obtained from using measures based on both disagreement and within year volatility in analysts' forecasts. For example: analysts may disagree over the expected earnings per share of a firm, but receive no new information over the accounting period that would lead to changes in forecasts, resulting in high values of $DISP_{i,t}$ and low values of $RANGE_{i,t}$ and $REV_{i,t}$. Table 1 presents correlations between the 4 uncertainty measures $\sigma_{i,t}$, $REV_{i,t}$, $RANGE_{i,t}$ and $DISP_{i,t}$ for the sub-sample of firms for which all 4 could be calculated with the UK data. The measure $\sigma_{i,t}$ has a positive correlation with $DISP_{i,t}$ that is only slightly lower than those between $\sigma_{i,t}$ and the other two I/B/E/S measures. Correlations between $DISP_{i,t}$ and the 2 other I/B/E/S measures of uncertainty are much higher than correlations between the three I/B/E/S indicators and $\sigma_{i,t}$. Correlations in Table 1 suggest that although all three variables are positively correlated, $DISP_{i,t}$ likely contains additional information beyond which can be controlled for using $REV_{i,t}$, $RANGE_{i,t}$ or $\sigma_{i,t}$. Unfortunately, due to issues of data availability in the current sample, further comparison of these 4 uncertainty measures will have to be left open to future research.

[TABLE 1 HERE]

Table 2 below presents time series correlations between annual average values of the I/B/E/S measure $REV_{i,t}$ and measures of perceived uncertainty as well as a measure of capacity utilization, which indicates the state of the business cycle, from the CBI Quarterly Industrial Trends survey.[10] The high positive correlation between $REV_{i,t}$ and the CBI survey measure of uncertainty suggests that within year volatility in the consensus forecasts of end of period earnings per share is capturing perceived uncertainty represented in the aggregated CBI survey measure. Furthermore both measures of uncertainty appear counter-cyclical based on strong negative correlations with the survey measure of capacity utilization.

[TABLE 2 HERE]

Tables 3 and 4 below demonstrate the differences in information contained in firm-level measures of uncertainty based on the I/B/E/S data relative to the proxy based on within year volatility of daily stock returns. Table 4 below presents correlations between the 3 measures of uncertainty in the full panel data set of UK firms. The uncertainty measure based on stock return volatility, $\sigma_{i,t}$ exhibits small but positive correlations with the I/B/E/S indicators of uncertainty. As one would expect the I/B/E/S proxies have positive correlations close to one. Table 3 below shows OLS results and R^2 statistics from regressing the uncertainty measures on each other, including full sets of year dummies. Column 1 presents results from regressing $RANGE_{i,t}$ on $REV_{i,t}$. Columns 2 and 3 presents results from regressing $\sigma_{i,t}$ on $RANGE_{i,t}$ and $REV_{i,t}$ respectively. Similarities in the R^2 statistics and the squared correlations from Table 4, demonstrate that the positive correlation coefficients between $\sigma_{i,t}$ and the I/B/E/S measures in

[10] 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 authorizations. The survey measure of capacity utilization from the CBI's Quarterly Industrial Trends survey is defined as the percentage of firms reporting that they operate at full capacity.

Table 2 are not just attributable to common year effects[11]. The lower coefficients of correlation and R^2 statistics resulting from regressions of $\sigma_{i,t}$ on the I/B/E/S proxies for uncertainty are indicative of substantial differences in the information contained in these alternative measures of uncertainty. Results from these tables suggest that - relative to results presented in Chapter 1 - including the I/B/E/S proxies in estimated investment specifications would make use of additional information to describe effects of uncertainty over future operating environments on investment behaviour.

[TABLE 3 HERE]

[TABLE 4 HERE]

[11]The squared values of the correlation coefficients in Table 3 correspond to R^2 statistics from OLS regressions of one variable on the other and a constant.

5.3 Estimation Results

This section presents results from estimating error correction and average q specifications which compare the I/B/E/S uncertainty proxies $RANGE_{i,t}$ and $REV_{i,t}$ with $\sigma_{i,t}$ (the within year stock return volatility based measure of uncertainty from Chapters 1, 3 and 4) as controls for the effects of uncertainty on firm investment. Some aspects of the results presented here are consistent with the findings of Bond and Cummins (2004) in which I/B/E/S uncertainty measures were found to be more informative about linear effects of uncertainty, and $\sigma_{i,t} * \Delta y_{i,t}$ interaction terms were useful in detecting weaker investment responses to demand growth at higher levels of uncertainty. However, when both the preferred linear and non-linear controls for effects of uncertainty are included in the specification estimated with the UK data set, only coefficients estimated on linear I/B/E/S terms are significant. Coefficients on the linear I/B/E/S uncertainty measures were highly significant in estimates of both investment specifications, implying very similar effects of uncertainty.

In the current set of results $\sigma_{i,t} * \Delta y_{i,t}$ terms were found to be more informative than $RANGE_{i,t} * \Delta y_{i,t}$ or $REV_{i,t} * \Delta y_{i,t}$ terms in estimates of average q and error correction specifications which exclude controls for linear effects of uncertainty. Strongly significant negative coefficients were estimated on first difference and lagged level terms in both $RANGE_{i,t}$ and $REV_{i,t}$, which are much more informative of linear effects of uncertainty than terms in $\sigma_{i,t}$. Unlike in the results of Bond and Cummings (2004), estimates of investment specifications that include $\sigma_{i,t} * \Delta y_{i,t}$ terms together with $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$ (or $\Delta REV_{i,t}$ and $REV_{i,t-1}$) yield insignificant-coefficients on uncertainty-sales growth interaction terms. Estimates of the preferred investment specification in Bond and Cummins (2004) included significant negative coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms and on the $DISP_{i,t}$ term, constructed with the I/B/E/S data.

Insignificant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ uncertainty sales growth interaction terms in specifications which include linear I/B/E/S uncertainty terms, bring into question evidence presented in Chapter 1 which supported lower investment responses to higher levels of uncertainty. On one hand it is possible that significant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms in Chapter 1 proxied for effects that are better captured by linear I/B/E/S terms. Arguably, estimates of investment specifications in Chapter 1 (and perhaps other specifications which do not include terms similar to $RANGE_{i,t}$ and $REV_{i,t}$) omit important, informative controls for a linear effect of uncertainty on firm investment behaviour (perhaps through a risk premium component in the required rate of return), and could therefore be subject to omitted variable bias. On the other hand the estimates of the error correction and average q specifications could look different in a much larger sample. Comparing the data sets in Bond and Cummins (2004) with the data set used to produce the results in the current chapter, the former is considerably larger: 946 firms from 1982-1999, compared to 655 firms from 1987-2000. However, Bond and Cummins (2004) did not use any uncertainty measures similar in nature to $RANGE_{i,t}$ or $REV_{i,t}$.

5.3.1 $RANGE_{i,t}$ and $REV_{i,t}$ in the Error Correction and Average Q investment Specifications

Table 5 (below) presents estimation results for the error correction and average q specifications using the three uncertainty measures $\sigma_{i,t}$, $RANGE_{i,t}$ and $REV_{i,t}$. Columns 1 and 4 present the System GMM estimates[12] of the error correction and average q specifications from Chapter 1, including the linear and sales growth interaction uncertainty terms $\Delta\sigma_{i,t}$, $\sigma_{i,t-1}$ and $\sigma_{i,t} * \Delta y_{i,t}$. In both specifications significant negative coefficients are estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms. The coefficient on this term is significant at the 5% level in the error correction specification and roughly double the magnitude of the same coefficient in the average q specification, which is only significant at the 10% level.

Columns 2 and 3 of Table 5 substitute the uncertainty proxy $\sigma_{i,t}$ with $RANGE_{i,t}$ and $REV_{i,t}$ respectively, in the error correction specification from Column 1. In Section 1.3.1 of Chapter 1 a restriction was imposed on the coefficients of a re-arranged ADL[2,2] specification to arrive at the error correction specification in Column 1 of Table 5. This restriction, and its underlying assumptions can be verified based on a t-test of a coefficient estimated on an additional $y_{i,t-1}$ term added to the error correction specification; failure to reject the hypothesis that the coefficient is not statistically different from zero supports the restriction of the ADL[2,2] specification

[12]The preferred instruments sets are taken from Chapter 1, in which they were constructed based on comparisons of Differenced Sargan/Hansen test statistics between several alternative instrument sets in the appendix of Chapter 1.

to the error correction specification. Adding additional terms in $y_{i,t-1}$ to the specifications in Columns 2 and 3 of Table 5 yields insignificant coefficient estimates on these terms; implying that the assumptions underlying the error correction specification appear robust to the inclusion of $REV_{i,t}$ and $RANGE_{i,t}$ terms.[13]

As a result of substituting the uncertainty terms between Columns 1 and 2 of Table 5, the significant negative coefficient on the uncertainty sales growth interaction term becomes insignificant - as a result of a much larger standard error, despite the larger magnitude of the coefficient itself. Coefficients estimated on the linear uncertainty terms in Column 2 are much larger in magnitude and strongly significant, relative to the marginally significant coefficients on linear $\sigma_{i,t}$ terms in Column 1. These significant coefficients point to a negative linear effect of higher uncertainty on investment in the short run and on the capital stock in the long run, which was not found by including linear $\sigma_{i,t}$ terms in estimates of the error correction specification in Chapter 1. Although the coefficient estimated on the error correction term is insignificant in Column 2, this coefficient becomes significant in estimates of the preferred error correction specification presented below in Table 9. Column 3 presents results from re-estimating the specification from Column 2, using the uncertainty term $REV_{i,t}$ in place of $RANGE_{i,t}$. Results are very similar in terms of the significance of estimated coefficients. The larger magnitude of the coefficients estimated on uncertainty terms in Column 3, relative to Column 2, is due to the smaller mean values of $REV_{i,t}$ relative to $RANGE_{i,t}$ in the data set.

[TABLE 5 HERE]

Column 5 of Table 5 (above) presents estimates of the average q specification from Column 4, replacing the uncertainty proxy $\sigma_{i,t}$ with $RANGE_{i,t}$.[14] As a result, the coefficient on the uncertainty-sales growth interaction term $RANGE_{i,t} * \Delta y_{i,t}$ becomes insignificant. As with the case of the error correction specification, the significance of coefficients estimated on the linear terms $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$ increase considerably in Column 5, relative to coefficients

[13]Furthermore, changing the uncertainty terms between columns 1 and 2 does not impact the validity of the preferred instruments used to estimate the error correction specification that were selected in Chapter 1 for the error correction and average q specifications on the basis of Differenced Sargan/Hansen test statistics.

[14]As mentioned in the case of the error correction specification, this substitution does not affect the validity or choice of preferred instruments for the average q specification.

estimated on $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ in Column 4. The highly significant negative coefficient estimated on $\Delta RANGE_{i,t}$ in Column 5 appears to be capturing all short run effects of uncertainty on investment rates in the average q specification; whereas the statistically insignificant coefficient estimated on $RANGE_{i,t} * \Delta y_{i,t}$ shows no evidence of lower investment responses to demand at higher levels of uncertainty. Column 6 of Table 5 presents estimates of the average q specification from Columns 4 and 5, using $REV_{i,t}$ to control for effects of uncertainty. The significance of coefficient estimates is unchanged as a result of substituting $REV_{i,t}$ for $RANGE_{i,t}$ between Columns 5 and 6.

Table 6 below presents results from estimating the specifications from the columns of Table 5 excluding the linear uncertainty terms. Comparing coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms in the error correction and average q specifications between Tables 5 and 6, excluding the linear uncertainty terms in Table 6 has a very limited effect on point estimates and their significance. Comparing Columns 2 and 3 across Tables 5 and 6, excluding linear uncertainty terms decreases the magnitude of coefficients estimated on $RANGE_{i,t} * \Delta y_{i,t}$ and $REV_{i,t} * \Delta y_{i,t}$, which remain insignificant in the error correction specification. In the case of the average q specifications, excluding the linear uncertainty terms between Columns 5 and 6 of Tables 5 and 6 changes the sign of the coefficient estimated on uncertainty sales growth interaction terms; the coefficients themselves remain insignificant. The results of Table 6 imply that it is not the inclusion of linear uncertainty terms in Table 5 that is preventing lower investment responses to demand growth at higher levels of uncertainty from being captured by coefficients estimated on $RANGE_{i,t} * \Delta y_{i,t}$ and $REV_{i,t} * \Delta y_{i,t}$ terms. The interaction terms between sales growth and these measures of uncertainty are simply not very informative about the investment behaviour of the UK firms in our sample.

[TABLE 6 HERE]

In contrast, the I/B/E/S uncertainty measures appear to be very informative about negative linear effects of uncertainty in estimates of the investment specifications in Table 5. These linear effects were found to be only marginally significant when using the measure of uncertainty based on stock return volatility, in estimates of the error correction and average q specifications in Chapter 1. Tables 7 and 8 below present a more direct comparison of $\sigma_{i,t}$ with the I/B/E/S uncertainty terms in specifications which include only linear uncertainty terms (Table 7) or only sales growth interaction terms (Table 8).

5.3.2 Linear Uncertainty Terms

Table 7 below presents a set of results which compares $\sigma_{i,t}$, $RANGE_{i,t}$ and $REV_{i,t}$ as controls for linear effects of uncertainty in the error correction and average q specifications. The results suggest that the I/B/E/S uncertainty proxies are much more informative about linear effects of uncertainty on $\Delta k_{i,t}$ and $\frac{I_{i,t}}{K_{i,t}}$ in respective estimates of error correction and average q specifications. Insignificant coefficients on terms in $\sigma_{i,t}$ in specifications which included linear terms in either $RANGE_{i,t}$ or $REV_{i,t}$ suggest that $\sigma_{i,t}$ does not control for any relevant information not already contained in the I/B/E/S measures of uncertainty. This result is consistent with the findings of Bond and Cummins (2004) in which measures of uncertainty constructed using I/B/E/S analysts' forecasts of earnings per share (although conceptually quite different from $REV_{i,t}$ or $RANGE_{i,t}$) were more informative about linear effects of uncertainty than measures based on stock return volatility in estimates of average q investment specifications with US data.

Columns 1 to 3 of Table 7 present estimates of error correction specifications and Columns 4 to 6 present estimates of average q specifications. Each column of Table 7 excludes uncertainty-sales growth interaction terms and includes two sets of linear uncertainty terms, each set comparing different uncertainty proxies. Column 1 presents estimates of the error correction specification, including linear uncertainty terms in $\sigma_{i,t}$ and $RANGE_{i,t}$. Coefficients estimated on terms in $\sigma_{i,t}$ are jointly insignificant based on a Wald test of the linear hypothesis with a p-value of 0.47; whereas the hypothesis that coefficients estimated on $RANGE_{i,t}$ terms are jointly insignificant cannot be accepted at the 5% level. Column 2 presents estimates of the same specification, in which terms in $RANGE_{i,t}$ have been substituted for terms in $REV_{i,t}$. Coefficients estimated on $\sigma_{i,t}$ in Column 2 are also jointly insignificant (p-value of 0.43 based on a Wald test of the linear hypothesis), whereas the hypothesis that coefficients estimated on $REV_{i,t}$ are jointly insignificant is again rejected at the 5% level. Column 3 presents results from including sets of linear terms in both $RANGE_{i,t}$ and $REV_{i,t}$ in the error correction specification, of which a significant coefficient is only estimated on $\Delta REV_{i,t}$, however the hypothesis that all coefficients on uncertainty terms in Column 3 are jointly insignificant is rejected at the 1% level.

[TABLE 7 HERE]

Columns 4 through 6 of Table 7 above compare linear uncertainty terms in estimates of the average q specification. As in the case of the error correction specification coefficients estimated on terms in $\sigma_{i,t}$ were individually and jointly insignificant when included with linear terms in $RANGE_{i,t}$ and $REV_{i,t}$ in estimates of average q specifications in Columns 4 and 5. The hypothesis that coefficients estimated on $RANGE_{i,t}$ terms in Column 4 are jointly insignificant is rejected at the 2% level; and likewise the hypothesis that coefficients on $REV_{i,t}$ terms in Column 5 are jointly insignificant is rejected at the 1% level. Unlike in estimates of the error correction specifications in Columns 1 and 2, all coefficients on I/B/E/S uncertainty terms are individually significant in Columns 4 and 5. Column 6 includes both sets of linear terms in the I/B/E/S uncertainty measures, and as in the case of the error correction specification the hypothesis that coefficients on these terms are jointly insignificant is rejected; in the case of estimates in Column 6, at the 4% level.

5.3.3 Uncertainty Sales Growth Interaction Terms

Table 8 below compares the uncertainty terms $\sigma_{i,t}$, $RANGE_{i,t}$ and $REV_{i,t}$ as controls for lower investment responses to demand growth at higher levels of uncertainty, in uncertainty-sales growth interaction terms included in estimates of the error correction and average q specifications. In the case of both the error correction and average q specifications, $\sigma_{i,t}$ appears more informative about lower investment responses to demand shocks at higher levels of uncertainty. Coefficients on I/B/E/S uncertainty-sales growth interaction terms across Table 8 suggest that those terms do not contain any information that is relevant to explaining investment responses to changes in demand in estimates of the error correction and average q specifications. This is also consistent with the findings of Bond and Cummins (2004), in which uncertainty proxies based on stock return volatility were preferred over indicators based on I/B/E/S analysts' forecasts of earnings per share, to control for lower investment responses to demand at higher uncertainty in estimates of average q specifications.

Columns 1 and 2 of Table 8 present estimates of the error correction specification, and Columns 3 and 4 present estimates of the average q specification. Each column excludes linear uncertainty terms and includes sales growth interaction terms with $\sigma_{i,t}$ and one of the I/B/E/S uncertainty measures. Column 1 includes $\sigma_{i,t} * \Delta y_{i,t}$ and $RANGE_{i,t} * \Delta y_{i,t}$ terms and Column 2 includes $\sigma_{i,t} * \Delta y_{i,t}$ and $REV_{i,t} * \Delta y_{i,t}$ terms in estimates of error correction specifications. In Column 1 the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ is significant at the 10% level (but not the 5% level), whereas the coefficient on $RANGE_{i,t} * \Delta y_{i,t}$ is insignificant. In Column 2 coefficients on both uncertainty sales growth interaction terms are individually insignificant, and the hypothesis that they are jointly insignificant is just marginally accepted with a p-value of 0.11. Columns 3 and 4 respectively include terms in $\sigma_{i,t} * \Delta y_{i,t}$ and $RANGE_{i,t} * \Delta y_{i,t}$ and terms in $\sigma_{i,t} * \Delta y_{i,t}$ and $REV_{i,t} * \Delta y_{i,t}$ in estimates of the average q specification. Coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms remain significant in both Columns 3 and 4, however that is only at the 10% level.

[TABLE 8 HERE]

5.3.4 Preferred Controls for Uncertainty

Table 9 below presents estimates of the error correction and average q specifications using $\sigma_{i,t} * \Delta y_{i,t}$ to control for lower investment responses to demand at higher levels of uncertainty, and the I/B/E/S measures $RANGE_{i,t}$ and $REV_{i,t}$ to control for linear effects of uncertainty on investment. As a result of combining different uncertainty proxies to control for linear and non-linear effects of uncertainty, coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms become insignificant in both investment specifications.

Although coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms are not significant in estimates of investment specifications in Table 9 below, minor changes to the instrument set used to estimate the error correction specification in Table 10 cause the latter coefficient to become significant. Based on the significant negative coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms in Columns 1 and 2 of Table 10 below, uncertainty - as controlled for by $\sigma_{i,t}$ - may have a significant effect on investment dynamics, in addition to those captured by linear I/B/E/S terms $REV_{i,t}$ and $RANGE_{i,t}$. This effect of uncertainty captured by sales growth interaction terms is more fragile than in results presented in Chapter 1, and does not appear to be very informative of investment behaviour in estimates of specifications which control for separate linear effects of uncertainty with I/B/E/S terms. Based on results presented in this chapter, it cannot be ruled out that more significant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms in specifications from Chapter 1 proxy for effects of uncertainty that may be better explained by linear terms in $REV_{i,t}$ and $RANGE_{i,t}$. The highly significant coefficients on the latter terms suggest that specifications estimated in Chapter 1 omitted relevant effects of uncertainty that were not captured by $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta\sigma_{i,t}$ or $\sigma_{i,t-1}$ terms. Consequently coefficient estimates in those specifications could be affected by omitted variable bias, and may not accurately depict relationships between $\sigma_{i,t}$ and investment responses to demand. Results presented in Tables 3 and 4 of the current Chapter indicate that the stock return volatility and I/B/E/S measures of uncertainty contain very different information. According to coefficients estimated on terms constructed with these various measures, effects of uncertainty captured by the linear I/B/E/S terms were the most relevant to investment behaviour described by the error correction and average q specifications estimated with this data set of UK firms.

Column 1 of Table 9 below presents estimates of the error correction specification excluding linear uncertainty terms and including the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$. Column 2 adds the linear uncertainty terms $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$ to the specification in Column 1, on which coefficients are negative and significant. As a result of adding the I/B/E/S uncertainty terms in Column 2, the magnitude of the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ decreases by roughly half while its standard error remains relatively constant - causing the coefficient to become insignificant. Column 3 replaces the linear terms in $RANGE_{i,t}$ with the same terms in $REV_{i,t}$, resulting in almost no change to the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$. One important feature to note of the estimates presented in Columns 2 and 3 is the significant coefficient on the error correction term, which was insignificant in Tables 5 and 6, which included $RANGE_{i,t} * \Delta y_{i,t}$ and $REV_{i,t} * \Delta y_{i,t}$ terms[15].

[TABLE 9 HERE]

Column 4 of Table 9 above presents estimates of the average q specification including the uncertainty sales growth interaction term $\sigma_{i,t} * \Delta y_{i,t}$ and excluding controls for linear effects of uncertainty. Column 5 adds $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$ terms to the specification in Column 4, coefficients estimated on both of which are significant and negative. As a result of adding the linear I/B/E/S controls for uncertainty the coefficient estimated on $\sigma_{i,t} * \Delta y_{i,t}$ becomes insignificant in Column 5. Column 6 replaces terms in $RANGE_{i,t}$ from the specification in Column 5 with terms in $REV_{i,t}$, resulting in no change to the statistical significance of estimated coefficients.

Coefficients estimated on the linear I/B/E/S uncertainty terms between the error correction and average q specifications in Table 9 imply very similar effects of uncertainty. Coefficients on $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$ in Columns 2 and 5 are all strongly significant, and differences in magnitudes of coefficients between the investment specification are very small relative to their respective standard errors. Similarly, coefficients on $\Delta REV_{i,t}$ and $REV_{i,t-1}$ terms are also very similar across the error correction and average q specification in Columns 3 and 6. Estimated coefficients are all highly significant and differences between columns are small relative to standard errors.

Table 10 below presents estimates of the same specifications from Table 9, excluding $\Delta^2 y_{i,t-2}$ as an instrument for equations in levels. The instrument appendix of this chapter presents results of Differenced Sargan/Hansen tests on these alternative instrument sets, which support

[15] I/B/E/S uncertainty sales growth interaction terms are not included in the preferred investment specifications, as results presented in Table 8 indicate that the I/B/E/S proxies contain little (if any) information relevant to investment behaviour as described by estimates of either investment specification.

the exclusion of $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels of the error correction specification. Comparing Columns 2 and 3 between Tables 9 and 10, the slight change in the instrument set causes the magnitude of the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ to increase by roughly 60%. Although the single asterisk reported next to coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ indicates significance at the 10% level, the t-statistics and p-values of these coefficients were -1.94 and 0.052 in Column 1 and -1.91 and 0.056 in Column 2 - making them only just insignificant at the 5% level. Although the latter coefficient is not highly significant in these columns, the fact that its insignificance does not appear entirely robust to small changes in the instrument set suggests that these coefficients may be capturing additional effects of uncertainty not explained by the I/B/E/S terms, at least in the error correction specification. Effects of uncertainty described by coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms do not appear to be as important as the linear effects of uncertainty described by the I/B/E/S terms in this data set of UK firms. Given results of previous literature[16] and the findings of Chapter 1, it is possible that specifications presented in Tables 9 and 10 may look different when estimated with a larger data set. However, no previous study has included uncertainty measures similar to $REV_{i,t}$ or $RANGE_{i,t}$ in estimates of firm level investment specifications.

[TABLE 10 HERE]

5.3.5 Hybrid Investment Specifications

Tables 11 and 12 below present results from estimating hybrid investment specifications from Chapter 1, which include both average q and error correction terms as explanatory variables. The alternative uncertainty proxies $RANGE_{i,t}$ and $REV_{i,t}$ are used to control for linear effects of uncertainty in the hybrid investment specifications in Tables 11 and 12. Controlling for linear effects of uncertainty with the latter uncertainty proxies results in comparable estimates of hybrid investment specifications to those presented in Chapter 1; which controlled for linear effects of uncertainty with terms in $\sigma_{i,t}$. As in the results presented in Chapter 1, coefficients on average q terms are significant, whereas coefficients on error correction terms are insignificant in estimates of hybrid investment specifications which control for linear effects of uncertainty with

[16]Significant negative coefficients were found on uncertainty sales growth interaction terms in firm level investment specifications estimated with UK data by Bloom, Bond and Van Reenen (2007), with Italian data by Bond and Lombardi (2008), and with US data by Bond and Cummins (2004).

the I/B/E/S uncertainty measures. Including terms in both $RANGE_{i,t}$ and $REV_{i,t}$ in estimates of hybrid investment specifications suggests that terms in $REV_{i,t}$ may be more significant. This is consistent with results presented in Table 7 for the less general average q and error correction specifications.

An interesting result of including the linear I/B/E/S terms in the hybrid investment specifications is a significant and negative coefficient on the uncertainty sales growth interaction term. Including I/B/E/S controls for linear effects of uncertainty in either the error correction or average q investment specifications resulted in insignificant coefficients on uncertainty sales growth interaction terms in Table 9. However, the coefficient on the uncertainty sales growth interaction term was only significant in hybrid investment specifications presented in Table 11, in which investment is measured by $\Delta k_{i,t}$ as opposed to $\frac{I_{i,t}}{K_{i,t}}$.

Table 11 below presents estimates of hybrid investment specifications in which investment is measured as $\Delta k_{i,t}$. Column 1 presents the specification from Chapter 1, which includes $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ as controls for uncertainty. As mentioned above, and discussed in Chapter 1, the coefficient on the error correction term is insignificant, whereas the coefficient on the average q term is significant and positive. This implies that the error correction term does not include any information that cannot be controlled for with $Q_{i,t}$. Column 2 drops terms in $\Delta\sigma_{i,t}$ and $\sigma_{i,t-1}$ and includes terms in $\Delta RANGE_{i,t}$ and $RANGE_{i,t-1}$. Coefficients on the I/B/E/S uncertainty terms are significant and negative. However, they are smaller in magnitude than coefficients on the same terms in the estimates of the error correction specification in Column 2 of Table 9, but very close to coefficients in the average q specification presented in Column 5 of Table 9. This is consistent with $Q_{i,t}$ being more informative than $(k_{i,t-1} - y_{i,t-1})$, and possibly controlling for some linear effects of uncertainty in the investment specifications. Unlike results presented in Table 9, the negative coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ is significant in Column 2 of Table 11; the coefficient is smaller in magnitude and less significant than the same coefficient in Column 1, as a result of replacing the linear terms in $\sigma_{i,t}$ with terms in $RANGE_{i,t}$. Column 3 of Table 11 replaces linear terms in $RANGE_{i,t}$ with terms in $REV_{i,t}$. The coefficient on $\Delta REV_{i,t}$ is slightly more significant than the corresponding coefficient on $\Delta RANGE_{i,t}$ in the previous column.

[TABLE 11 HERE]

Column 4 of Table 11 drops the uncertainty interaction term $\sigma_{i,t} * \Delta y_{i,t}$, and includes linear terms in both $REV_{i,t}$ and $RANGE_{i,t}$. P-values of Wald tests of the linear hypotheses that terms in $REV_{i,t}$ or $RANGE_{i,t}$ are jointly insignificant are reported in the Table 11. The Wald test only marginally accepts this hypothesis for terms in $REV_{i,t}$ at the 10% level, whereas the p-value is much larger for the same hypothesis regarding coefficients on terms in $RANGE_{i,t}$.

Table 12 below presents System GMM estimates of the same specifications from Table 11 with investment measured as $\frac{I_{i,t}}{K_{i,t}}$ as opposed to $\Delta k_{i,t}$ in the specifications and instrument sets. Coefficients on the corresponding linear uncertainty terms between Tables 11 and 12 are very similar. The chief difference that results from changing the measurement of investment in Table 12, is the much smaller magnitude of coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ in Columns 2 and 3. Coefficients on uncertainty sales growth interaction terms in Columns 2 and 3 in Table 12 are insignificant and almost half the magnitude of corresponding coefficients in Table 11. This is consistent with estimates of hybrid specification in Chapter 1[17], in which coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms were slightly larger in magnitude when investment is measured as $\Delta k_{i,t}$.

[TABLE 12 HERE]

[17] As represented by hybrid specifications in Columns 1 of Table 11 and 12

5.4 Conclusion

This chapter has built upon the work of Bond and Cummins (2004) using new proxies for firm level uncertainty based on I/B/E/S data on securities analysts' forecasts of earnings per share; the latter proxies offer alternatives to measures based on stock return volatility used in Leahy and Whited (1996), Bloom, Bond and Van Reenen (2007) and Bulan (2005). In contrast to controls for uncertainty based on disagreement in security analysts forecasts and variance of forecast errors constructed in Bond and Cummins (2004), the uncertainty proxies $REV_{i,t}$ and $RANGE_{i,t}$ used in this chapter are based on within year volatility in monthly consensus forecasts of earnings per share, made by securities analysts and recorded in the I/B/E/S data base. Comparison between proxies based on stock return volatility with the I/B/E/S uncertainty proxies in this chapter suggests that the two measures contain different information. Effects of uncertainty described by coefficients on linear terms in the new I/B/E/S measures - $REV_{i,t}$ and $RANGE_{i,t}$ - were the most relevant to firm investment behaviour explained by estimates of error correction and average q specifications.

When describing either linear or non-linear sales growth interaction effects of uncertainty, the findings presented in this chapter are consistent with Bond and Cummins (2004): The measure based on stock return volatility, $\sigma_{i,t}$, is most informative of lower investment responses to demand at higher levels of uncertainty; whereas I/B/E/S measures (although different from $DISP_{i,t}$ and $ERR_{i,t}$ used in Bond and Cummins (2004)) were highly informative of linear effects of uncertainty on investment behaviour. The I/B/E/S measures $REV_{i,t}$ and $RANGE_{i,t}$ control for relevant effects of uncertainty that were likely omitted by specifications which included linear terms in $\sigma_{i,t}$. Different information contained by the two types of uncertainty proxies may at least in part be due to higher frequency of the daily stock returns data used to calculate $\sigma_{i,t}$, relative to the monthly securities analysts' forecasts of earnings per share that go into the I/B/E/S measures. When the non-linear uncertainty sales growth interaction terms $\sigma_{i,t} * \Delta y_{i,t}$ are included together with linear $REV_{i,t}$ or $RANGE_{i,t}$ terms in estimates of the error correction and average q specifications, only coefficients on the I/B/E/S measures are consistently significant.

In contrast to results presented here, Bond and Cummins (2004) estimated significant negative coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms in average q investment specifications which include linear $DISP_{i,t}$ terms, constructed with forecasts of earnings per share from the I/B/E/S data on US firms; coefficients on which were also significant and negative. In the UK data set analyzed in this chapter, insignificant coefficients estimated on uncertainty-sales growth interaction terms ($\sigma_{i,t} * \Delta y_{i,t}$) in investment specifications which included linear terms in $REV_{i,t}$ and $RANGE_{i,t}$ suggest that the former terms do not contain any information relevant to investment behaviour which is not already controlled for by the I/B/E/S terms. One could speculate that coefficients on these uncertainty terms may appear different in average q and error correction specifications estimated with a larger firm level panel data set - similar in size to that used in Bond and Cummins (2004). However, that study, nor any other that has reported significant negative coefficients on uncertainty-sales growth interaction terms included terms similar to $REV_{i,t}$ or $RANGE_{i,t}$ in estimates of firm level investment specifications. Based on results presented with the UK data in this chapter, one cannot rule out the hypothesis that significant coefficients estimated on $\sigma_{i,t} * \Delta y_{i,t}$ terms proxy for effects that are best captured with linear terms in $REV_{i,t}$ and $RANGE_{i,t}$. These findings motivate future research comparing uncertainty measures similar to $DISP_{i,t}$, $REV_{i,t}$, $RANGE_{i,t}$ and $\sigma_{i,t}$ in estimates of firm level investment specifications, preferably using larger data sets, similar in size to that used in Bond and Cummins (2004). Research into the effects of uncertainty on firm level investment which rely solely on stock return based volatility measures similar to $\sigma_{i,t}$ - as many studies have to date - may overlook relevant effects of uncertainty on investment behaviour.

In contrast to results presented in Chapter 1, coefficients on I/B/E/S uncertainty terms were highly significant in estimates of both error correction and average q specifications. Comparing estimates of error correction and average q specifications in Chapter 1, coefficients estimated on interaction terms between stock return volatility and sales growth were more significant in estimates of the error correction specification. Focusing on either estimates of the error correction or average q specifications from Chapter 1 may have lead to slightly different conclusions with regards to the significance of uncertainty - as measured by within year volatility in daily stock returns - to firm investment behaviour. Although coefficients on uncertainty sales growth interaction terms are not consistently significant in estimates of investment specifications which included linear terms in the I/B/E/S uncertainty measures $REV_{i,t}$ and $RANGE_{i,t}$, coefficients on the latter terms were very similar across estimates of both specifications. In addition to being more informative than linear or sales growth interaction terms in stock return volatility, the I/B/E/S uncertainty measures imply very similar investment uncertainty relationships whether they are included in average q or error correction specifications.

5.5 Instrument Appendix

This brief appendix presents results comparing alternative instrument sets used to estimate the error correction and average q specifications in Tables 9 and 10. Results presented in Table 9 used $\Delta^2 y_{i,t-2}$ as instruments for equations in levels to estimate both the error correction and average q specifications; whereas estimates in Table 10 exclude this instrument. Comparisons based on Differenced Sargan/Hansen tests reported in Table A1 below suggest that the additional moment conditions for equations in levels used in Table 9 may be invalid in the case of the error correction specification.

Column 1 of Table A1 presents estimates of the error correction specification from Column 1 of Table 10, which excludes $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels. Column 2 of Table A1 adds $\Delta^2 y_{i,t-2}$ as an instrument for equations in levels to the instrument set in Column 1, yielding the results from Column 2 of Table 9. A Differenced Sargan/Hansen test is used to evaluate the null hypothesis that the additional moment condition in Column 2 of Table A1 is valid against the alternative that only the moment conditions from Column 1 of Table A1 are valid. Given that the null is valid the Differenced Sargan/Hansen test statistic should follow a χ^2 distribution with degrees of freedom equal to the difference in the number of moment conditions from the two sets of estimates. The value of one less the p-value of the Differenced Sargan/Hansen test statistic is reported in the bottom of Column 2, which rejects the validity of the null hypothesis at the 6% level.

[TABLE A1 HERE]

Column 3 of Table A1 presents estimates of the average q specification from Column 3 of Table 10, which excludes $\Delta^2 y_{i,t-2}$ from the instrument set for equations in levels. Column 4 adds the latter instrument to the instrument set from Column 1, yielding the results from Column 5 of Table 9. Unlike the case of the error correction specification a Differenced Sargan/Hansen test does not reject the null hypothesis that the moment conditions in Column 4 are valid, relative to the alternative that only the subset of moment conditions from Column 3 are valid.

5.6 Chapter 5 Annex and Alternative Results

The Annex to this Chapter is organized into two subsections closely following the Annex to Chapter 1. In the first section results are presented in which alternative coefficient values are imposed on error correction and average q terms in their respective specifications. This analysis was motivated in Chapter 1 due to the fact that System GMM estimates of coefficients on the error correction term were close to OLS estimates - implying the possibility of a significant bias in the System GMM estimates of that coefficient. Imposing alternative values of the coefficient on the error correction term (and $Q_{i,t}$ terms in the average q specification) can help to assess potential impacts of this bias on coefficients estimated on the remaining terms - particularly coefficients on uncertainty terms.[18] The second subsection reproduces System GMM results from key Tables throughout Chapter 5 using a restricted instrument set for equations in levels. Results discussed in the Annex of Chapter 1 suggested that the more restricted instrument set may be more appropriate given potential for less bias in coefficients estimated on the error correction term. As in Chapter 1 key results discussed through Chapter 5 are robust to using the more restricted instrument set.

5.6.1 Chapter 5 Annex

This sub-section of the Annex to Chapter 5 repeats the analysis from the Annex in Chapter 1: issues of bias in coefficients on error correction and average q terms are explored by imposing alternative coefficient values on those terms in the error correction and average q specification respectively. For each specification estimates are presented based on the full instrument set used to generate results in Chapter 5, and then using a restricted instrument set with $\Delta^2 k_{i,t-2}$ or $\Delta\frac{I_{i,t-2}}{K_{i,t-2}}$ as the only instruments for equations in levels - just as in the Annex to Chapter 1. In both the error correction and average q specifications the value and significance of coefficients on the I/B/E/S uncertainty terms are robust to changes in values imposed on error correction and average q terms. As in the Annex to Chapter 1 the GMM criterion function for the error correction specification appears to be quite flat with respect to coefficients on the error

[18]For more details refer to the Annex at the end of Chapter 1

correction term. Again, as in the Annex to Chapter 1, this was not the case for the average q specification, as imposing alternative values on the average q term had a more significant impact on the p-value of the Sargan/Hansen test statistic and thus the minimized value of the GMM criterion function.

Table A2 below presents System GMM estimates of the error correction specification in which effects of uncertainty are controlled for by terms in $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta REV_{i,t}$ and $REV_{i,t-1}$. The instrument set is the same as that used to produce results presented in the body of Chapter 5. No restrictions are imposed on coefficients in estimates of the error correction specification presented in Column 1. Columns 2, 3, 4 and 5 restrict the coefficient on the error correction term to be -0.1, -0.15, -0.2 and -0.3 respectively. Coefficients on all other terms are fairly robust to the alternative values imposed on $(k_{i,t-1} - y_{i,t-1})$. Coefficients on the linear I/B/E/S uncertainty terms are particularly stable across the columns of Table A2. Although the coefficient on $\sigma_{i,t} * \Delta y_{i,t}$ is insignificant across all columns of Table A2, its magnitude is decreasing as the magnitude of the coefficient imposed on the error correction term is increased. The p-values of Sargan/Hansen test statistics are decreasing across the columns of Table A2, implying that the minimized value of the GMM criterion function is increasing as coefficients are changed on the error correction term. However, none of the Sargan/Hansen test reject the validity of the instrument set in results presented in Table A2.

[TABLE A2 HERE]

Table A3 below reproduces the results presented in Table A2 above, using a restricted instrument set for equations in levels. As in results presented in the Annex of Chapter 1 the coefficient estimated on the error correction term in the unrestricted specification is larger in magnitude when estimated with the restricted instrument set. Unlike results presented in Table A2 above, coefficients on uncertainty interaction terms are significant and negative in Table A3 - except column 4. Comparing estimates presented in Column 1 of Tables A2 and A3, using the restricted instrument set causes the coefficient on the uncertainty interaction term to become marginally significant. The following subsection in this annex presents results from re-estimating specifications from the Tables of Chapter 5 using the restricted instrument sets for the error correction and average q specifications. Sargan/Hansen p-values across the columns of Table A3 are fairly insensitive to changes in the imposed values of coefficients on the $(k_{i,t-1} - y_{i,t-1})$ term in the error correction specification. Differences between the Sargan/Hansen p-values and corresponding values of the GMM criterion function across the columns of Table A3 are much smaller relative to those in Table A2.

[TABLE A3 HERE]

Table A4 below presents estimates of the average q specification which includes terms in $\sigma_{i,t} * \Delta y_{i,t}$, $\Delta REV_{i,t}$ and $REV_{i,t-1}$ to control for effects of uncertainty. Specifications in Table A4 are obtained using the same instrument set used to produce results presented in the body of Chapter 5. Following Table A8 in the Annex to Chapter 1, coefficients on the average q term are fixed to alternative values across estimates of the average q specifications in Table A4 below.[19] Results presented in Column 1 are obtained without imposing any restriction on the coefficient on the average q term. Columns 2, 3, 4 and 5 restrict the coefficient on the average q term to values of $\frac{0.1}{E[Q_{i,t}]}$, $\frac{0.15}{E[Q_{i,t}]}$, $\frac{0.2}{E[Q_{i,t}]}$ and $\frac{0.3}{E[Q_{i,t}]}$ respectively. It is difficult to draw conclusions regarding the robustness of remaining coefficient values to alternative values imposed on $Q_{i,t}$, as the Sargan/Hansen test statistics do not support the null hypothesis that the instrument set is valid in Columns 2 through 5. In Column 2, the null hypothesis that the instrument set is valid is only marginally accepted at the 5% significance level, based on a p-value of 0.066 - the largest next to Column 1. In Column 2 coefficients on linear uncertainty terms are significant and negative - though smaller in magnitude relative to corresponding coefficients in Column 1. Sargan/Hansen test statistics reject the hypothesis that the instrument set is valid in Columns 3, 4 and 5.

[TABLE A4 HERE]

[19]For more details on the derivation of the imposed coefficient values and a comparison of coefficients on error correction and average q terms in their respective specifications refer to the Annex in Chapter 1.

Table A5 below presents results from re-estimating the average q specifications from Table A4, using a restricted instrument for equations in levels. Comparing Column 1 in Tables A4 and A5, coefficients on $\frac{I_{i,t-1}}{K_{i,t-1}}$, $Q_{i,t}$, $\Delta REV_{i,t}$ and $REV_{i,t-1}$ terms are slightly larger in magnitude as a result of using the restricted instrument set. Unlike in the set of results presented in Table A4, Sargan/Hansen tests do not reject (or only just marginally accept) the validity of instrument sets in Columns 2 and 3 of Table A5. Coefficients on I/B/E/S uncertainty terms in Column 2 are significant and negative, and very similar to corresponding coefficients in Column 1. Although in Column 3, the magnitudes of coefficients on the linear uncertainty terms are similar to corresponding coefficients in Columns 1 and 2, the coefficients are not statistically significant. However, it is worthwhile to note that the p-values of Sargan/Hansen tests are decreasing substantially from Column 1 to 2 and from Column 2 to 3. Sargan/Hansen test statistics reject the null hypothesis that the instrument set is valid in Columns 4 and 5.

5.6.2 Chapter 5 Alternative Results

Tables 5* through 9* below reproduce results presented in corresponding tables in Chapter 5. Instrument sets for equations in levels have been restricted relative to results from the body of Chapter 5, to include only $\Delta^2 k_{i,t-2}$ and $\Delta\frac{I_{i,t-2}}{K_{i,t-2}}$. Relative to results presented in the body of Chapter 5 coefficients on uncertainty terms in $\sigma_{i,t}$, $RANGE_{i,t}$ and $REV_{i,t}$ are very similar in the results presented below. Coefficients on error correction terms are larger in magnitude and more significant in results presented below for the more restricted instrument set.

[TABLE 5* HERE]

[TABLE 6* HERE]

Table 7* below presents results from including only linear uncertainty terms in the error correction and average q investment specifications estimated with the restricted instrument set. Similar to the case of results presented in Table 7 in Chapter 5 coefficients on linear terms in $REV_{i,t}$ appear to be more significant than those in $RANGE_{i,t}$ in the error correction specification - comparing Columns 1 and 2. In Column 3 the p-value of the linear hypothesis that coefficients on terms in $RANGE_{i,t}$ are jointly insignificant is 0.36. A similar test of coefficients on terms in $REV_{i,t}$ results in a p-value of 0.25. The hypothesis that all coefficients on uncertainty terms are jointly insignificant in the results of Column 3 results in a p-value of 0.08. Tests of the same hypothesis of coefficients on uncertainty terms in the average q specification presented in Column 6 are 0.89, 0.56 and 0.11 respectively.

[TABLE 7* HERE]

[TABLE 8* HERE]

Table 9* below presents results from including $\sigma_{i,t} * \Delta y_{i,t}$ terms to control for uncertainty-sales growth interaction effects and I/B/E/S terms to control for linear effects of uncertainty in the investment specifications. As a result of using the more restricted instrument set in estimating the specifications below, coefficients on $\sigma_{i,t} * \Delta y_{i,t}$ terms are marginally significant in Columns 2 and 3. Coefficients on these terms are insignificant in estimates presented in Table 9 in Chapter 5. However, linear effects of uncertainty captured by coefficients on I/B/E/S terms remain the most significant in estimates of error correction and average q specifications obtained with the restricted instrument sets.

[TABLE 9* HERE]

5.7 Tables of Results

Table 1
Correlations

Uncertainty Covariance Matrix				
	$\sigma_{i,t}$	$REV_{i,t}$	$RANGE_{i,t}$	$DISP_{i,t}$
$\sigma_{i,t}$	1.000			
$REV_{i,t}$	0.331	1.000		
$RANGE_{i,t}$	0.335	0.988	1.000	
$DISP_{i,t}$	0.249	0.395	0.423	1.000

Table 2
Correlations

Uncertainty Covariance Matrix			
	REV_t	$CBI\ UNCER_t$	$CBI\ CAPU_t$
REV_t	1.00		
$CBI\ UNCER_t$	0.84	1.00	
$CBI\ CAPU_t$	-0.85	-0.93	1.00

Table 3
OLS Regressions of Uncertainty Terms

	(1)	(2)	(3)
	$RANGE_{i,t}$	$\sigma_{i,t}$	$\sigma_{i,t}$
rev	2.506 (.028)***		2.307 (.131)***
range		.917 (.052)***	
R^2	.975	.318	.315

Table 4
Correlations

Uncertainty Covariance Matrix			
	$\sigma_{i,t}$	$REV_{i,t}$	$RANGE_{i,t}$
$\sigma_{i,t}$	1.000		
$REV_{i,t}$	0.333	1.000	
$RANGE_{i,t}$	0.336	0.987	1.000

Table 5
Effects of Stock Return Volatility and I/B/E/S Uncertainty Measures

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t}$	-.116	-.300	-.315			
	(.131)	(.050)***	(.058)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.015	-.239	-.247
				(.103)	(.079)***	(.071)***
$\Delta y_{i,t-1}$	.078	.023	.010	.033	.034	.034
	(.051)	(.054)	(.059)	(.043)	(.048)	(.050)
$\sigma_{i,t} * \Delta y_{i,t}$	-.207			-.107		
	(.093)**			(.063)*		
$RANGE_{i,t} * \Delta y_{i,t}$		-.356			-.044	
		(.270)			(.255)	
$REV_{i,t} * \Delta y_{i,t}$			-.892			-.068
			(.687)			(.603)
$\Delta y_{i,t}$	.715	.442	.468	.415	.290	.294
	(.173)***	(.098)***	(.098)***	(.128)***	(.086)***	(.084)***
$(k_{i,t-1} - y_{i,t-1})$	-.049	-.038	-.035			
	(.028)*	(.024)	(.024)			
$Q_{i,t}$				.020	.017	.016
				(.005)***	(.004)***	(.004)***
$\Delta\sigma_{i,t}$	-.030			-.012		
	(.018)*			(.015)		
$\sigma_{i,t-1}$	-.029			-.017		
	(.018)			(.013)		
$\Delta RANGE_{i,t}$		-.158			-.115	
		(.053)***			(.044)***	
$RANGE_{i,t-1}$		-.283			-.195	
		(.062)***			(.052)***	
$\Delta REV_{i,t}$			-.422			-.310
			(.116)***			(.099)***
$REV_{i,t-1}$			-.728			-.520
			(.155)***			(.131)***
Sargan/Hansen	.397	.756	.796	.734	.303	.347
DoF	133	133	133	147	147	147
AR1	-2.985	-4.208	-3.675	-4.528	-3.651	-3.893
AR2	-1.424	-3.918	-3.572	-.709	-2.752	-2.882
AR3	-.121	.067	.041	-.262	.063	.111
AR4	.589	.154	.116	.953	.132	.036
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2			t-2:t-2		
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2			t-2:t-2		
$\Delta RANGE_{i,t}$		t-2:t-2			t-2:t-2	
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$		t-2:t-2			t-2:t-2	
$\Delta REV_{i,t}$			t-2:t-2			t-2:t-2
$\Delta(REV_{i,t} * \Delta y_{i,t})$			t-2:t-2			t-2:t-2

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in

Table 6
Uncertainty Sales Growth Interaction Effects of Stock Return Volatility and I/B/E/S Measures

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.080	-.301	-.325			
	(.112)	(.082)***	(.081)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.022	-.199	-.215
				(.098)	(.080)**	(.076)***
$\Delta y_{i,t-1}$	.076	.084	.090	.048	.051	.056
	(.051)	(.051)	(.054)*	(.042)	(.053)	(.050)
$\sigma_{i,t} * \Delta y_{i,t}$	-.237			-.118		
	(.089)***			(.062)*		
$RANGE_{i,t} * \Delta y_{i,t}$		-.189			.110	
		(.325)			(.253)	
$REV_{i,t} * \Delta y_{i,t}$			-.406			.411
			(.857)			(.558)
$\Delta y_{i,t}$	.774	.526	.522	.446	.340	.328
	(.171)***	(.122)***	(.127)***	(.123)***	(.089)***	(.083)***
$(k_{i,t-1} - y_{i,t-1})$	-.054	-.043	-.043			
	(.029)*	(.028)	(.028)			
$Q_{i,t}$				.020	.020	.020
				(.005)***	(.005)***	(.005)***
Sargan/Hansen	.351	.242	.245	.606	.155	.149
DoF	135	135	135	149	149	149
AR1	-3.541	-3.686	-3.518	-4.606	-4.713	-4.727
AR2	-1.472	-3.408	-3.62	-.924	-2.267	-2.499
AR3	-.123	.025	.018	-.194	-.135	-.126
AR4	.708	.658	.651	.985	.739	.701
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2			t-2:t-2		
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2			t-2:t-2		
$\Delta RANGE_{i,t}$		t-2:t-2			t-2:t-2	
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$		t-2:t-2			t-2:t-2	
$\Delta REV_{i,t}$			t-2:t-2			t-2:t-2
$\Delta(REV_{i,t} * \Delta y_{i,t})$			t-2:t-2			t-2:t-2

Note:
Standard errors for the GMM estimates are based on a two step covariance matrix adjusted using the Windmeijer (2005) finite sample correction. Instruments for equations in first differences and for equations in levels are presented in the table above. Instrument validity is tested using a Sargan/Hansen test (or Hansen-J-test) of the over-identifying restrictions, corresponding p-values and degrees of freedom (DoF) are reported in each Column. The null hypothesis of no serial correlation in the differences residuals is evaluated using Arellano Bond test for autocorrelation (Arellano and Bond (1991)), for which test statistics are reported in each column.

Table 7
Comparing Linear Controls for Effects of Uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.308	-.327	-.374			
	(.096)***	(.094)***	(.094)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.179	-.189	-.266
				(.088)**	(.087)**	(.106)**
$\Delta y_{i,t-1}$	.035	.046	.086	.061	.062	.082
	(.057)	(.059)	(.062)	(.048)	(.048)	(.048)*
$\Delta y_{i,t}$	.457	.462	.417	.246	.249	.270
	(.083)***	(.082)***	(.104)***	(.065)***	(.066)***	(.066)***
$(k_{i,t-1} - y_{i,t-1})$	-.045	-.044	-.044			
	(.023)**	(.023)*	(.030)			
$Q_{i,t}$				.016	.016	.018
				(.004)***	(.004)***	(.005)***
$\Delta\sigma_{i,t}$	-.014	-.016		-.002	-.007	
	(.019)	(.017)		(.014)	(.013)	
$\sigma_{i,t-1}$	-.026	-.027		-.014	-.015	
	(.022)	(.021)		(.017)	(.016)	
$\Delta RANGE_{i,t}$	-.092		.340	-.090		.202
	(.059)		(.210)	(.041)**		(.158)
$RANGE_{i,t-1}$	-.179		.189	-.132		.231
	(.072)**		(.375)	(.047)***		(.291)
$\Delta REV_{i,t}$		-.247	-1.129		-.232	-.766
		(.127)*	(.541)**		(.089)***	(.426)*
$REV_{i,t-1}$		-.437	-.941		-.347	-.943
		(.167)***	(.941)		(.108)***	(.736)
Sargan/Hansen	.564	.519	.637	.833	.829	.511
DoF	135	135	135	149	149	149
AR1	-3.109	-2.996	-2.505	-3.986	-4.04	-2.879
AR2	-2.936	-3.083	-3.398	-2.179	-2.244	-2.464
AR3	-.123	-.026	.189	.204	.181	.277
AR4	.345	.249	.227	.311	.258	.149
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2			t-2:t-2		
$\Delta RANGE_{i,t}$		t-2:t-2			t-2:t-2	
$\Delta REV_{i,t}$			t-2:t-2			t-2:t-2

Table 8
Comparing Controls For Sales Growth Interaction Effects of Uncertainty

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.250 (.074)***	-.269 (.072)***		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.199 (.081)**	-.218 (.082)***
$\Delta y_{i,t-1}$	.120 (.056)**	.117 (.057)**	.061 (.049)	.068 (.051)
$\sigma_{i,t} * \Delta y_{i,t}$	-.174 (.098)*	-.145 (.101)	-.124 (.069)*	-.113 (.068)*
$RANGE_{i,t} * \Delta y_{i,t}$	-.082 (.270)		.138 (.204)	
$REV_{i,t} * \Delta y_{i,t}$		-.318 (.669)		.368 (.511)
$\Delta y_{i,t}$	.756 (.160)***	.729 (.167)***	.517 (.131)***	.498 (.131)***
$(k_{i,t-1} - y_{i,t-1})$	-.049 (.024)**	-.052 (.024)**		
$Q_{i,t}$			.020 (.004)***	.020 (.004)***
Sargan/Hansen	.278	.259	.528	.556
DoF	195	195	209	209
AR1	-3.989	-3.937	-4.197	-4
AR2	-3.51	-3.669	-2.331	-2.458
AR3	.009	.013	-.259	-.226
AR4	.721	.729	.875	.846
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$	t-3:t-4		t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$	t-3:t-4		t-3:t-4	
$REV_{i,t}$		t-3:t-4		t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$		t-3:t-4		t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$			t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta RANGE_{i,t}$	t-2:t-2		t-2:t-2	
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$	t-2:t-2		t-2:t-2	
$\Delta REV_{i,t}$		t-2:t-2		t-2:t-2
$\Delta(REV_{i,t} * \Delta y_{i,t})$		t-2:t-2		t-2:t-2

Table 9
Combining Stock Return Volatility and I/B/E/S Controls For Uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t}$	-.080	-.202	-.231			
	(.112)	(.098)**	(.097)**			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.022	-.121	-.137
				(.098)	(.100)	(.100)
$\Delta y_{i,t-1}$	.076	.015	.018	.048	.037	.038
	(.051)	(.057)	(.057)	(.042)	(.043)	(.045)
$\sigma_{i,t} * \Delta y_{i,t}$	-.237	-.115	-.116	-.118	-.052	-.053
	(.089)***	(.091)	(.091)	(.062)*	(.067)	(.067)
$(k_{i,t-1} - y_{i,t-1})$	-.054	-.059	-.058			
	(.029)*	(.024)**	(.024)**			
$Q_{i,t}$				.020	.018	.018
				(.005)***	(.004)***	(.004)***
$\Delta RANGE_{i,t}$		-.120			-.094	
		(.049)**			(.042)**	
$RANGE_{i,t-1}$		-.226			-.158	
		(.071)***			(.054)***	
$\Delta REV_{i,t}$			-.317			-.252
			(.120)***			(.100)**
$REV_{i,t-1}$			-.581			-.410
			(.172)***			(.138)***
Sargan/Hansen	.351	.564	.542	.606	.77	.778
DoF	135	165	165	149	179	179
AR1	-3.541	-3.258	-3.135	-4.606	-3.784	-3.72
AR2	-1.472	-2.286	-2.449	-.924	-1.6	-1.684
AR3	-.123	-.137	-.109	-.194	-.038	-.007
AR4	.708	.297	.241	.985	.389	.329
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$		t-3:t-4			t-3:t-4	
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta RANGE_{i,t}$		t-2:t-2			t-2:t-2	
$\Delta REV_{i,t}$			t-2:t-2			t-2:t-2

Table 10
Combining Stock Return Volatility and I/B/E/S Controls For Uncertainty - Alternative Instruments

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.231	-.255		
	(.097)**	(.094)***		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.172	-.185
			(.091)*	(.089)**
$\Delta y_{i,t-1}$	.031	.033	.049	.050
	(.059)	(.059)	(.045)	(.046)
$\sigma_{i,t} * \Delta y_{i,t}$	-.182	-.182	-.085	-.091
	(.094)*	(.095)*	(.067)	(.067)
$(k_{i,t-1} - y_{i,t-1})$	-.062	-.062		
	(.022)***	(.023)***		
Q			.017	.017
			(.004)***	(.004)***
$\Delta RANGE_{i,t}$	-.131		-.095	
	(.049)***		(.042)**	
$RANGE_{i,t-1}$	-.223		-.159	
	(.066)***		(.051)***	
$\Delta REV_{i,t}$		-.342		-.251
		(.121)***		(.099)**
$REV_{i,t-1}$		-.577		-.411
		(.165)***		(.133)***
Sargan/Hansen	.737	.697	.856	.873
DoF	155	155	169	169
AR1	-3.127	-3.074	-3.779	-3.746
AR2	-2.581	-2.74	-2.144	-2.21
AR3	-.091	-.073	-.014	.003
AR4	.199	.161	.374	.325
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$	t-3:t-4		t-3:t-4	
$REV_{i,t}$		t-3:t-4		t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$			t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta RANGE_{i,t}$	t-2:t-2		t-2:t-2	
$\Delta REV_{i,t}$		t-2:t-2		t-2:t-2

Table 11

$\Delta k_{i,t}$ Hybrid Investment Specifications

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.148	-.226	-.243	-.382
	(.107)	(.080)***	(.073)***	(.090)***
$\Delta y_{i,t-1}$	.047	.021	.020	.057
	(.049)	(.052)	(.053)	(.056)
$\sigma_{i,t} * \Delta y_{i,t}$	-.180	-.113	-.117	
	(.077)**	(.065)*	(.063)*	
$\Delta y_{i,t}$	.580	.480	.501	.360
	(.142)***	(.133)***	(.132)***	(.085)***
$(k_{i,t-1} - y_{i,t-1})$	-.010	-.021	-.019	-.014
	(.020)	(.019)	(.019)	(.018)
$Q_{i,t}$	.028	.025	.025	.025
	(.006)***	(.006)***	(.006)***	(.006)***
$\Delta\sigma_{i,t}$	-.021			
	(.015)			
$\sigma_{i,t-1}$	-.017			
	(.016)			
$\Delta RANGE_{i,t}$		-.074		.242
		(.039)*		(.157)
$RANGE_{i,t-1}$		-.144		.122
		(.053)***		(.304)
$\Delta REV_{i,t}$			-.198	-.795
			(.092)**	(.399)**
$REV_{i,t-1}$			-.366	-.658
			(.127)***	(.756)
H_0: $\Delta REV_{i,t}$ $= REV_{i,t-1} = 0$				0.12
H_0: $\Delta RANGE_{i,t}$ $= RANGE_{i,t-1} = 0$				0.24
Sargan/Hansen	.664	.645	.582	.785
DoF	164	196	196	166
AR1	-3.543	-3.942	-4.145	-2.72
AR2	-1.63	-2.687	-2.938	-3.551
AR3	-.191	-.152	-.145	.06
AR4	.744	.576	.542	.492
Goodness of Fit	.432	.407	.407	.378
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Table 12

$\frac{I_{i,t}}{K_{i,t}}$ Hybrid Investment Specifications

	(1)	(2)	(3)	(4)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.049	-.174	-.190	-.289
	(.093)	(.095)*	(.095)**	(.096)***
$\Delta y_{i,t-1}$	.040	.035	.041	.079
	(.040)	(.041)	(.043)	(.045)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.124	-.065	-.066	
	(.057)**	(.054)	(.054)	
$\Delta y_{i,t}$	.446	.334	.346	.283
	(.119)***	(.108)***	(.107)***	(.066)***
$(k_{i,t-1} - y_{i,t-1})$	-.0009	-.012	-.012	-.019
	(.014)	(.014)	(.014)	(.015)
$Q_{i,t}$	.021	.018	.018	.015
	(.005)***	(.005)***	(.005)***	(.005)***
$\Delta\sigma_{i,t}$	-.022			
	(.011)*			
$\sigma_{i,t-1}$	-.018			
	(.013)			
$\Delta RANGE_{i,t}$		-.088		.217
		(.039)**		(.158)
$RANGE_{i,t-1}$		-.152		.216
		(.049)***		(.288)
$\Delta REV_{i,t}$			-.228	-.791
			(.094)**	(.426)*
$REV_{i,t-1}$			-.386	-.916
			(.124)***	(.720)
H_0: $\Delta REV_{i,t}$ $= REV_{i,t-1} = 0$				0.17
H_0: $\Delta RANGE_{i,t}$ $= RANGE_{i,t-1} = 0$				0.36
Sargan/Hansen	.767	.697	.679	.593
DoF	167	199	199	169
AR1	-4.489	-3.471	-3.416	-2.937
AR2	-.948	-2.087	-2.198	-2.867
AR3	-.324	-.082	-.037	.215
AR4	.927	.407	.357	.166
Goodness of Fit	.448	.401	.403	.384
Instruments For Equations in First Differences				
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t-1} - y_{i,t-1})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Table A1

$\Delta^2 y_{i,t-2}$ as an Instrument for Equations in Levels

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.231	-.202		
	(.097)**	(.098)**		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.172	-.121
			(.091)*	(.100)
$\Delta y_{i,t-1}$	.031	.015	.049	.037
	(.059)	(.057)	(.045)	(.043)
$\sigma_{i,t} * \Delta y_{i,t}$	-.182	-.115	-.085	-.052
	(.094)*	(.091)	(.067)	(.067)
$(k_{i,t-1} - y_{i,t-1})$	-.062	-.059		
	(.022)***	(.024)**		
$Q_{i,t}$			.017	.018
			(.004)***	(.004)***
$\Delta RANGE_{i,t}$	-.131	-.120	-.095	-.094
	(.049)***	(.049)**	(.042)**	(.042)**
$RANGE_{i,t-1}$	-.223	-.226	-.159	-.158
	(.066)***	(.071)***	(.051)***	(.054)***
Sargan/Hansen	.737	.564	.856	.77
DoF	155	165	179	169
AR1	-3.127	-3.258	-3.779	-3.784
AR2	-2.581	-2.286	-2.144	-1.6
AR3	-.091	-.137	-.014	-.038
AR4	.199	.297	.374	.389
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta^2 y_{i,t}$		t-2:t-2		t-2:t-2
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$			t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$			t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta RANGE_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
Difference Sargan Test				
(1-p-value)		0.944		0.872

Table A2
Error Correction Investment Specification -
Grid of Coefficients on $(k_{i,t-1} - y_{i,t-1})$ Terms

	(1)	(2)	(3)	(4)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.231	-.246	-.258	-.254	-.224
	(.097)**	(.092)***	(.092)***	(.093)***	(.097)**
$\Delta y_{i,t-1}$	.018	.010	-.0006	-.014	-.046
	(.057)	(.056)	(.056)	(.056)	(.058)
$\sigma_{i,t} * \Delta y_{i,t}$	-.116	-.078	-.041	-.014	.020
	(.091)	(.085)	(.088)	(.091)	(.093)
$\Delta y_{i,t}$	.577	.535	.490	.454	.407
	(.172)***	(.167)***	(.174)***	(.179)**	(.185)**
$(k_{i,t-1} - y_{i,t-1})$	-.058	-.1	-.15	-.2	-.3
	(.024)**	(fit)	(fit)	(fit)	(fit)
$\Delta REV_{i,t}$	-.317	-.311	-.317	-.321	-.323
	(.120)***	(.119)***	(.115)***	(.115)***	(.121)***
$REV_{i,t-1}$	-.581	-.594	-.611	-.607	-.572
	(.172)***	(.171)***	(.163)***	(.161)***	(.173)***
Sargan/Hansen	.542	.477	.4	.349	.296
DoF	165	166	166	166	166
AR1	-3.135	-3.204	-3.079	-2.996	-2.814
AR2	-2.449	-2.688	-2.864	-2.871	-2.564
AR3	-.109	-.158	-.2	-.248	-.396
AR4	.241	.224	.15	.077	-.034
Goodness of Fit	.373	.322	.266	.223	.168
Instruments For Equations in First Differences					
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$REV_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta(k_{i,t} - y_{i,t})$					
$\Delta\sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta\sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta REV_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Table A3
Error Correction Investment Specification with Alternative Instruments - Grid of Coefficients on $(k_{i,t-1} - y_{i,t-1})$ Terms

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$
$\Delta k_{i,t-1}$	-.308	-.308	-.305	-.301
	(.090)***	(.089)***	(.092)***	(.096)***
$\Delta y_{i,t-1}$	.066	.063	.053	.033
	(.060)	(.061)	(.061)	(.062)
$\Delta y_{i,t}$	.695	.690	.677	.680
	(.213)***	(.208)***	(.205)***	(.196)***
$\sigma_{i,t} * \Delta y_{i,t}$	-.196	-.186	-.167	-.144
	(.110)*	(.104)*	(.101)*	(.098)
$(k_{i,t-1} - y_{i,t-1})$	-.127	-.15	-.2	-.3
	(.046)***	(fit)	(fit)	(fit)
$\Delta REV_{i,t}$	-.355	-.342	-.331	-.302
	(.139)**	(.134)**	(.130)**	(.125)**
$REV_{i,t-1}$	-.570	-.555	-.536	-.485
	(.225)**	(.219)**	(.222)**	(.229)**
Sargan/Hansen	.384	.394	.373	.312
DoF	123	124	124	124
AR1	-2.7	-2.662	-2.405	-1.925
AR2	-3.454	-3.468	-3.379	-3.254
AR3	-.002	-.039	-.124	-.333
AR4	.067	.087	.088	.113
Goodness of Fit	.264	.246	.210	.212
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$REV_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta(k_{i,t} - y_{i,t})$				
$\Delta\sigma_{i,t}$				
$\Delta\sigma_{i,t} * \Delta y_{i,t}$				
$\Delta REV_{i,t}$				

Table A4
Average Q Investment Specification -
Grid of Coefficients on $Q_{i,t}$ Terms

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.137	-.271	-.345	-.419	-.559
	(.100)	(.109)**	(.118)***	(.125)***	(.154)***
$\Delta y_{i,t-1}$	.038	-.004	-.052	-.100	-.197
	(.045)	(.053)	(.062)	(.069)	(.092)**
$\sigma_{i,t} * \Delta y_{i,t}$	-.053	-.073	-.061	-.046	.005
	(.067)	(.089)	(.091)	(.097)	(.133)
$\Delta y_{i,t}$	.295	.258	.225	.185	.076
	(.120)**	(.166)	(.176)	(.197)	(.279)
$Q_{i,t}$	.018	.1/Qav	.15/Qav	.2/Qav	.3/Qav
	(.004)***	(fit)	(fit)	(fit)	(fit)
$\Delta REV_{i,t}$	-.252	-.156	-.097	-.028	.125
	(.100)**	(.092)*	(.100)	(.113)	(.157)
$REV_{i,t-1}$	-.410	-.221	-.083	.071	.390
	(.138)***	(.108)**	(.126)	(.154)	(.223)*
Sargan/Hansen	.778	.066	.012	.006	.002
DoF	179	180	180	180	180
AR1	-3.72	-2.763	-2.197	-1.713	-.869
AR2	-1.684	-2.187	-2.26	-2.374	-2.288
AR3	-.007	-.853	-1.386	-1.73	-1.954
AR4	.329	.66	.532	.251	-.315
Goodness of Fit	.411	.285	.248	.226	.202
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$REV_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta \frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta Q_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta \sigma_{i,t} * \Delta y_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta REV_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2

Table A5
Average Q Investment Specification with Alternative Instruments - Grid of Coefficients on $Q_{i,t}$ Terms

	(1)	(2)	(3)	(4)	(5)
	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\frac{I_{i,t-1}}{K_{i,t-1}}$	-.265	-.263	-.256	-.270	-.331
	(.105)**	(.107)**	(.114)**	(.123)**	(.149)**
$\Delta y_{i,t-1}$	.061	-.002	-.054	-.090	-.149
	(.057)	(.056)	(.060)	(.065)	(.081)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.076	-.012	.034	.086	.236
	(.074)	(.094)	(.105)	(.123)	(.168)
$\Delta y_{i,t}$	.354	.206	.126	.058	-.132
	(.130)***	(.172)	(.196)	(.235)	(.338)
$Q_{i,t}$	.025	.1/Qav	.15/Qav	.2/Qav	.3/Qav
	(.008)***	(fit)	(fit)	(fit)	(fit)
$\Delta REV_{i,t}$	-.311	-.253	-.202	-.155	-.082
	(.115)***	(.125)**	(.124)	(.128)	(.180)
$REV_{i,t-1}$	-.493	-.415	-.336	-.252	-.103
	(.178)***	(.199)**	(.204)	(.216)	(.293)
Sargan/Hansen	.831	.429	.143	.032	.002
DoF	126	127	127	127	127
AR1	-2.833	-2.936	-2.872	-2.694	-2.068
AR2	-2.51	-2.16	-1.671	-1.315	-.763
AR3	.031	-.692	-1.226	-1.519	-1.69
AR4	.152	.343	.261	.026	-.559
Goodness of Fit	.373	.315	.290	.277	.265
Instruments For Equations in First Differences					
$\frac{I_{i,t}}{K_{i,t}}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$Q_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$REV_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
Instruments For Equations in Levels					
$\Delta\frac{I_{i,t}}{K_{i,t}}$	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$					
$\Delta Q_{i,t}$					
$\Delta\sigma_{i,t}$					
$\Delta\sigma_{i,t} * \Delta y_{i,t}$					
$\Delta REV_{i,t}$					

5.8 Alternative Results for Chapter 5

[h]

Table 5*: Alternative Instruments
Effects of Stock Return Volatility and I/B/E/S Uncertainty Measures

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.145	-.369	-.381			
	(.091)	(.083)***	(.080)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.081	-.272	-.284
				(.126)	(.063)***	(.065)***
$\Delta y_{i,t-1}$	.105	.042	.035	.057	.051	.057
	(.049)**	(.069)	(.071)	(.050)	(.054)	(.060)
$\sigma_{i,t} * \Delta y_{i,t}$	-.313			-.164		
	(.105)***			(.097)*		
$RANGE_{i,t} * \Delta y_{i,t}$		-.481			.062	
		(.281)*			(.273)	
$REV_{i,t} * \Delta y_{i,t}$			-1.203			.177
			(.766)			(.658)
$\Delta y_{i,t}$	.723	.477	.493	.476	.300	.306
	(.182)***	(.124)***	(.132)***	(.181)***	(.110)***	(.111)***
$(k_{i,t-1} - y_{i,t-1})$	-.119	-.114	-.120			
	(.044)***	(.047)**	(.047)**			
$Q_{i,t}$				.027	.025	.027
				(.009)***	(.008)***	(.009)***
$\Delta\sigma_{i,t}$	-.053			-.030		
	(.022)**			(.018)*		
$\sigma_{i,t-1}$	-.063			-.036		
	(.037)*			(.029)		
$\Delta RANGE_{i,t}$		-.147			-.152	
		(.055)***			(.057)***	
$RANGE_{i,t-1}$		-.254			-.248	
		(.084)***			(.079)***	
$\Delta REV_{i,t}$			-.389			-.392
			(.132)***			(.130)***
$REV_{i,t-1}$			-.647			-.642
			(.207)***			(.192)***
Sargan/Hansen	.772	.757	.751	.803	.582	.588
DoF	102	102	102	105	105	105
AR1	-3.669	-2.178	-2.173	-3.454	-3.285	-3.258
AR2	-2.496	-3.391	-3.539	-1.04	-3.067	-3.076
AR3	-.168	.103	.099	-.386	.086	.151
AR4	.53	.147	.136	1.008	-.123	-.202
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta\sigma_{i,t}$						
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						
$\Delta RANGE_{i,t}$						
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$						
$\Delta REV_{i,t}$						
$\Delta(REV_{i,t} * \Delta y_{i,t})$						

Table 6*: Alternative Instruments
Uncertainty Sales Growth Interaction Effects of Stock Return Volatility and I/B/E/S Measures

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.158	-.400	-.405			
	(.093)*	(.078)***	(.078)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.085	-.274	-.294
				(.116)	(.051)***	(.061)***
$\Delta y_{i,t-1}$	.096	.072	.067	.064	.058	.065
	(.050)*	(.055)	(.054)	(.050)	(.045)	(.047)
$\sigma_{i,t} * \Delta y_{i,t}$	-.346			-.164		
	(.095)***			(.086)*		
$RANGE_{i,t} * \Delta y_{i,t}$		-.463			.137	
		(.313)			(.151)	
$REV_{i,t} * \Delta y_{i,t}$			-1.165			.367
			(.848)			(.382)
$\Delta y_{i,t}$	.824	.544	.541	.496	.337	.327
	(.181)***	(.132)***	(.130)***	(.164)***	(.095)***	(.101)***
$(k_{i,t-1} - y_{i,t-1})$	-.137	-.150	-.160			
	(.047)***	(.049)***	(.051)***			
$Q_{i,t}$				.031	.030	.032
				(.009)***	(.008)***	(.008)***
Sargan/Hansen	.633	.349	.331	.643	.225	.245
DoF	104	104	104	107	107	107
AR1	-3.394	-2.161	-2.081	-3.654	-4.718	-4.072
AR2	-2.829	-3.952	-4.018	-1.282	-3.175	-3.186
AR3	-.103	-.0005	-.042	-.268	-.167	-.143
AR4	.653	.707	.731	1.101	.737	.721
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta \sigma_{i,t}$						
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						
$\Delta RANGE_{i,t}$						
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$						
$\Delta REV_{i,t}$						
$\Delta(REV_{i,t} * \Delta y_{i,t})$						

Table 7*: Alternative Instruments
Comparing Linear Controls for Effects of Uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.427	-.442	-.479			
	(.096)***	(.093)***	(.109)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.288	-.298	-.342
				(.111)***	(.111)***	(.122)***
$\Delta y_{i,t-1}$	.076	.082	.124	.067	.074	.105
	(.061)	(.062)	(.067)*	(.060)	(.061)	(.059)*
$\Delta y_{i,t}$	.414	.424	.400	.299	.297	.269
	(.104)***	(.099)***	(.108)***	(.079)***	(.081)***	(.082)***
$(k_{i,t-1} - y_{i,t-1})$	-.103	-.103	-.143			
	(.045)**	(.045)**	(.057)**			
$Q_{i,t}$				.020	.020	.027
				(.009)**	(.009)**	(.009)***
$\Delta\sigma_{i,t}$	-.023	-.030		.003	-.006	
	(.022)	(.021)		(.019)	(.018)	
$\sigma_{i,t-1}$	-.049	-.057		-.018	-.021	
	(.032)	(.030)*		(.027)	(.026)	
$\Delta RANGE_{i,t}$	-.120		.188	-.142		.049
	(.060)**		(.242)	(.054)***		(.194)
$RANGE_{i,t-1}$	-.205		-.136	-.192		.083
	(.079)***		(.449)	(.080)**		(.375)
$\Delta REV_{i,t}$		-.303	-.739		-.325	-.519
		(.129)**	(.613)		(.116)***	(.485)
$REV_{i,t-1}$		-.486	-.121		-.471	-.725
		(.186)***	(1.104)		(.184)**	(.906)
Sargan/Hansen	.643	.641	.501	.776	.728	.471
DoF	103	103	103	106	106	106
AR1	-1.905	-1.873	-1.257	-2.726	-2.674	-2.085
AR2	-4.06	-4.124	-4.012	-2.492	-2.538	-2.554
AR3	.096	.151	.209	.331	.282	.43
AR4	.085	.02	.215	-.06	-.023	-.244
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4			t-3:t-4		
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$			t-3:t-4			t-3:t-4
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta\frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta\sigma_{i,t}$						
$\Delta RANGE_{i,t}$						
$\Delta REV_{i,t}$						

Table 8*: Alternative Instruments
Comparing Controls For Sales Growth Interaction Effects of Uncertainty

	(1)	(2)	(3)	(4)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t-1}$	-.339 (.063)***	-.350 (.064)***		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			-.296 (.063)***	-.317 (.062)***
$\Delta y_{i,t-1}$	.101 (.058)*	.096 (.060)	.090 (.051)*	.095 (.051)*
$\sigma_{i,t} * \Delta y_{i,t}$	-.218 (.109)**	-.204 (.107)*	-.130 (.077)*	-.125 (.086)
$RANGE_{i,t} * \Delta y_{i,t}$	-.045 (.272)		.169 (.147)	
$REV_{i,t} * \Delta y_{i,t}$		-.138 (.683)		.376 (.275)
$\Delta y_{i,t}$	.835 (.185)***	.830 (.183)***	.464 (.172)***	.464 (.185)**
$(k_{i,t-1} - y_{i,t-1})$	-.155 (.052)***	-.160 (.053)***		
$Q_{i,t}$			.028 (.008)***	.028 (.007)***
Sargan/Hansen	.248	.247	.46	.52
DoF	143	143	146	146
AR1	-3.356	-2.996	-3.748	-3.548
AR2	-4.557	-4.43	-3.362	-3.546
AR3	-.199	-.235	-.186	-.157
AR4	.727	.727	.903	.882
Instruments For Equations in First Differences				
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4		
$\frac{I_{i,t-1}}{K_{i,t-1}}$			t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4		
$Q_{i,t}$			t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$	t-3:t-4		t-3:t-4	
$RANGE_{i,t} * \Delta y_{i,t}$	t-3:t-4		t-3:t-4	
$REV_{i,t}$		t-3:t-4		t-3:t-4
$REV_{i,t} * \Delta y_{i,t}$		t-3:t-4		t-3:t-4
Instruments For Equations in Levels				
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2		
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$			t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$				
$\Delta Q_{i,t}$				
$\Delta \sigma_{i,t}$				
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$				
$\Delta RANGE_{i,t}$				
$\Delta(RANGE_{i,t} * \Delta y_{i,t})$				
$\Delta REV_{i,t}$				
$\Delta(REV_{i,t} * \Delta y_{i,t})$				

Table 9*: Alternative Instruments
Combining Stock Return Volatility and I/B/E/S Controls For Uncertainty

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\Delta k_{i,t}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$	$\frac{I_{i,t}}{K_{i,t}}$
$\Delta k_{i,t}$	-.158	-.289	-.308			
	(.093)*	(.088)***	(.090)***			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				-.085	-.242	-.265
				(.116)	(.111)**	(.105)**
$\Delta y_{i,t-1}$	.096	.060	.066	.064	.056	.061
	(.050)*	(.059)	(.060)	(.050)	(.057)	(.057)
$\sigma_{i,t} * \Delta y_{i,t}$	-.346	-.190	-.196	-.164	-.059	-.076
	(.095)***	(.112)*	(.110)*	(.086)*	(.072)	(.074)
$(k_{i,t-1} - y_{i,t-1})$	-.137	-.122	-.127			
	(.047)***	(.046)***	(.046)***			
$Q_{i,t}$				.031	.026	.025
				(.009)***	(.008)***	(.008)***
$\Delta RANGE_{i,t}$		-.139			-.127	
		(.055)**			(.051)**	
$RANGE_{i,t-1}$		-.231			-.201	
		(.089)***			(.076)***	
$\Delta REV_{i,t}$			-.355			-.311
			(.139)**			(.115)***
$REV_{i,t-1}$			-.570			-.493
			(.225)**			(.178)***
Sargan/Hansen	.633	.432	.384	.643	.808	.831
DoF	104	123	123	107	126	126
AR1	-3.394	-3.021	-2.7	-3.654	-2.833	-2.833
AR2	-2.829	-3.548	-3.454	-1.282	-2.304	-2.51
AR3	-.103	-.026	-.002	-.268	.019	.031
AR4	.653	.091	.067	1.101	.158	.152
Instruments For Equations in First Differences						
$\Delta k_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4			
$\frac{I_{i,t-1}}{K_{i,t-1}}$				t-3:t-4	t-3:t-4	t-3:t-4
$\Delta y_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$(k_{i,t} - y_{i,t})$	t-3:t-4	t-3:t-4	t-3:t-4			
$Q_{i,t}$				t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t}$	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4	t-3:t-4
$\sigma_{i,t} * \Delta y_{i,t}$	t-3:t-4	t-3:t-4		t-3:t-4	t-3:t-4	t-3:t-4
$RANGE_{i,t}$		t-3:t-4			t-3:t-4	
$REV_{i,t}$		t-3:t-4			t-3:t-4	
Instruments For Equations in Levels						
$\Delta^2 k_{i,t}$	t-2:t-2	t-2:t-2	t-2:t-2			
$\Delta \frac{I_{i,t-1}}{K_{i,t-1}}$				t-2:t-2	t-2:t-2	t-2:t-2
$\Delta^2 y_{i,t}$						
$\Delta Q_{i,t}$						
$\Delta \sigma_{i,t}$						
$\Delta(\sigma_{i,t} * \Delta y_{i,t})$						
$\Delta RANGE_{i,t}$						
$\Delta REV_{i,t}$						

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