Investment, Idiosyncratic Risk, and Ownership

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Abstract

High-powered incentives may induce higher managerial effort, but they also expose managers to idiosyncratic risk. If managers are risk averse, they might underinvest when firm-specific uncertainty increases, leading to suboptimal investment decisions from the perspective of well-diversified shareholders. We empirically document that, when idiosyncratic risk rises, firm investment falls, and more so when managers own a larger fraction of the firm. This negative effect of managerial risk aversion on investment is mitigated if executives are compensated with options rather than with shares or if institutional investors form a large part of the shareholder base.

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Introduction

In frictionless capital markets, only the systematic component of risk is relevant for investment decisions. By contrast, idiosyncratic risk should not affect the valuation of investment projects, as long as firm owners are diversified and managers maximize shareholder value. However, the data indicates that there is a significant negative relation between idiosyncratic risk and investment for publicly traded firms in the United States. In addition, consistent with the predictions of agency theory, executives in publicly traded firms across the world hold a substantial stake in their firms. Combining these two observations suggests that, since investment decisions are undertaken by managers on behalf of shareholders, poorly-diversified managers may cut back on investment when uncertainty about the firm's future prospects increases, even if this uncertainty is specific to the firm.

In this paper, we argue that managerial risk aversion induces a negative relation between idiosyncratic volatility and investment. We find that the negative relation between investment and idiosyncratic risk is stronger when managers own a larger fraction of the firm. This difference in investment-risk sensitivities across firms is economically large. For instance, idiosyncratic uncertainty increased during the 2008-09 financial crisis. During this period, firms with higher fractions of insider ownership reduced investment by 8 percent of their existing capital stock, compared to 2 percent for firms with a more diversified shareholder base.

Our results suggest that forcing managers to bear firm-specific risk induces a wedge between manager and shareholder valuations of investment opportunities and may lead to under-investment from the perspective of well-diversified shareholders. Shareholders can mitigate this effect through effective monitoring or by providing a convex compensation scheme using stock-option grants. We find that the effect of insider ownership on the investment-risk relation is weaker for firms with higher levels of institutional ownership. This is consistent with the notion that institutional investors are more effective monitors than individual shareholders. In addition, we find that, controlling for the level of insider ownership, firms with more convex compensation contracts, which therefore increase in value with uncertainty, have lower investment-risk sensitivity. In fact, proponents of option-based compensation have used this argument to justify providing executives with downside protection as a compromise between supplying incentives and mitigating risk-averse behavior.

We estimate firm-specific risk using stock-return data, where we decompose stock-return volatility into a systematic and a idiosyncratic component. Our first concern is that idiosyncratic volatility is endogenous, and could be correlated with the firm's investment opportunities. If Tobin's Q is an imperfect measure of investment opportunities, this would lead to omitted variable bias. We address this issue by considering alternative measures of growth opportunities as well as estimation methods that directly allow for measurement error in Tobin's Q. In addition, we instrument for idiosyncratic risk with a measure of the firm's customer-base concentration. Our intuition is that firms selling to only a few customers are less able to diversify demand shocks for their product across customers, and will thus be riskier. We find that idiosyncratic volatility remains a statistically significant predictor of investment, even after addressing these endogeneity concerns. We consider this to be evidence supportive of a causal relation from idiosyncratic risk to investment.

Our second main concern is that insider ownership is endogenous, and could be correlated with firm characteristics that might be affecting the investment-uncertainty relation. For instance, insider ownership can be correlated with costs of external finance: If a firm is unable to attract outside investors, then insiders will be forced to hold a substantial stake in the firm. In this case, convex costs of external finance will lead to a negative relation between firm-specific uncertainty and investment, through a precautionary-saving motive. Alternatively, insider ownership may be correlated with the degree of industry competition, since a competitive product market could serve as a substitute for high-powered incentives. Imperfect competition may then affect the investment-uncertainty relation through the convexity of the marginal product of capital. We address these concerns by comparing the investment of firms with different levels of insider ownership but with similar degrees of size, financial constraints, market power, industry competition, and degree of investment irreversibility. Controlling for these firm characteristics, we find that firms with higher insider ownership display higher sensitivity of investment to idiosyncratic risk.

The rest of the paper is organized as follows. Section 1 reviews the related research. Section 2 provides a simple model illustrating how idiosyncratic risk can affect capital investment. Section 3 documents empirically the negative relation between idiosyncratic risk and investment. Section 4 shows how this relation varies with levels of insider ownership, convexity of executive compensation schemes, and institutional ownership. Section 5 addresses concerns about endogeneity of idiosyncratic volatility and of insider ownership. Section 6 explores whether our results hold out of sample, in particular during the financial crisis of 2008-09. Section 7 concludes. Details on data construction are delegated to the appendix.

1 Related Research

In traditional economic theory, there is no role for managerial characteristics in firm decisions. However, several recent papers have provided empirical evidence to the contrary. Bertrand and Schoar (2003) find a role for managerial fixed effects in corporate decisions. Malmendier and Tate (2005) construct a measure of overconfidence, based on the propensity of CEOs to exercise options early, and find greater investment-cashflow sensitivity in firms with overconfident CEOs. Graham, Harvey and Puri (2009), using psychometric tests administered to corporate executives, show that traits such as risk aversion, impatience, and optimism are related to corporate policies.

Various studies have indicated that the identity of a firm's shareholders may be important. Himmelberg, Hubbard and Love (2002) document that, even in publicly traded firms, insiders hold a substantial share of the firm. In a cross-country analysis, they find that countries with higher levels of investor protection are characterized by lower levels of insider ownership. Admati, Pfleiderer and Zechner (1994) illustrate theoretically that large investors exert monitoring effort in equilibrium, even when monitoring is costly. Gillan and Starks (2000) and Hartzell and Starks (2003) provide empirical evidence supporting the view that institutional ownership can lead to more effective corporate governance.

The theoretical research in real options has extensively examined the sign of the relation between investment and total uncertainty. The theoretical conclusions are rather ambiguous, as the the sign depends, among other things, on assumptions about the production function, the market structure, the shape of adjustment costs, the importance of investment lags, and the degree of investment irreversibility. An incomplete list includes Hartman (1972), Abel (1983) and Caballero (1991). More recently, Chen, Miao and Wang (2010) and DeMarzo, Fishman, He and Wang (2010) explore the effect of managerial risk aversion and idiosyncratic risk on investment decisions in dynamic models. The previous papers focus on the firm's partial equilibrium problem, while Angeletos (2007) and Bloom (2009) investigate the general-equilibrium effects of an increase in uncertainty on investment.

Most of these theoretical papers make no distinction between idiosyncratic and systematic uncertainty. By contrast, we differentiate between idiosyncratic and systematic uncertainty, because managers can hedge exposure to systematic but not to idiosyncratic risk. For instance, Knopf, Nam and Thornton (2002) find that managers are more likely to use derivatives to hedge systematic risk when the sensitivity of their stock and stock-option portfolios to stock price is higher and the sensitivity of their option portfolios to stock-return volatility is lower.

Several empirical studies have explored the predictions of real option models. An incomplete list includes Leahy and Whited (1996), Guiso and Parigi (1999), Bond and Cummins (2004), Bulan (2005), and Bloom, Bond and VanReenen (2007). With the exception of Bulan (2005), these papers focus on the relation between investment and total or systematic uncertainty facing the firm. This branch of the research mostly finds a negative relation between uncertainty and investment, though results appear to be somewhat sensitive to the estimation method. We contribute to this research by showing that managerial risk aversion may be an important channel behind the investment-uncertainty relation.

2 Model

Here we propose a simple two-period model that demonstrates how idiosyncratic risk can affect capital investment in the absence of adjustment costs or other investment frictions. We abstract from such frictions because we are interested in a different channel: Investment decisions are taken by risk-averse managers who hold undiversified stakes in their firm. We focus on the idiosyncratic rather than the total uncertainty facing the firm because, as long as managers have access to the same hedging opportunities as shareholders, the presence of systematic risk need not lead to distorted investment decisions from the shareholders' perspective. By contrast, since top executives are not permitted to buy put options or short their own company's stock, they cannot hedge away their exposure to firm-specific risk. Thus, idiosyncratic risk introduces a wedge between managers' and shareholders' optimal decisions.

A firm starts with cash C at $t = 0$ and produces output at $t = 1$ according to:

$$y = X\sqrt{K} + e\,, \tag{1}$$

where e is managerial effort, K is installed capital, and $X \sim N(\mu, \sigma^2)$ is a shock specific to the firm. For simplicity, we assume that there is no aggregate uncertainty.

The manager owns a fraction λ of the firm, while the remaining shares are held by shareholders who are risk averse but hold the market portfolio. We assume that the manager cannot diversify his stake in the firm. The manager derives utility from consumption (c_0, c_1) and disutility from effort (e):

$$U_0 = u(c_0) - v(e) + \beta\, E_0\, u(c_1)\,. \tag{2}$$

Utility over consumption takes the form $u(c) = -e^{-A\,c}$ where A is the coefficient of absolute risk aversion, and the disutility of labor is an increasing convex function, $v' > 0$, $v'' > 0$, $v(0) = v'(0) = 0$.

The manager's contract consists of a choice of ownership, λ, and an initial transfer, T. Given the contract, the manager will then choose how much to invest in capital, K, how much effort to provide, e, and how much to save in the riskless asset, B, to maximize (2), subject to (1) and the two following budget constraints:

$$c_0 = \lambda(C - K) - B + T \tag{3}$$

$$c_1 = \lambda(X\sqrt{K} + e) + R\,B\,. \tag{4}$$

We assume that the principal cannot write contracts on K, e, or B. The assumption that K is not contractible may seem odd at first, since in practice capital expenditures are observable and reported by the firm. Note, however, that even though the level of investment may be observable, the amount of idiosyncratic risk undertaken is not, and what K captures here is the amount of risky investment. We could extend the model to allow for two types of capital, one risky and one riskless. We could then have the principal write contracts on the total investment undertaken by the firm, but not on the capital stock chosen. Nonetheless, doing so would not change our results, given that the manager can also save in the private market.

Proposition 1 *The manager's optimal choice of capital, K^*, bonds, B^*, and effort, e^*, are such that:*

$$K^* = \left(\frac{\mu}{2\,R + \lambda\,A\,\sigma^2}\right)^2 , \tag{5}$$

$$R\,v'(e^*) = \lambda\,u'(c_0)\,, \tag{6}$$

$$u'(c_0^*) = \beta R\,E_0 u'(c_1^*)\,. \tag{7}$$

The elasticity of investment to idiosyncratic risk is:

$$\frac{\partial \log K}{\partial \log \sigma^2} = -\frac{\lambda\,A\,\sigma^2}{R + \frac{1}{2}\,\lambda\,A\,\sigma^2}\,, \tag{8}$$

and is decreasing in λ, A, and σ^2.

The first thing to note is that, as long as $\lambda > 0$, the manager will underinvest from the perspective of the shareholders, who are diversified and thus behave as if risk-neutral with respect to X. Their optimal capital choice equals $K^{fb} = \mu^2 / (2R)^2$. By contrast, the manager holds an undiversified stake in the firm, and therefore his choice of capital stock will depend on the level of the idiosyncratic risk of the firm, σ^2.

If λ were optimally chosen, it would depend, among other things, on the level of idiosyncratic risk, and on the manager's risk aversion and cost of effort.[1] When the principal chooses λ, she faces a trade off: Increasing λ induces higher effort on the part of the manager, but it also leads to underinvestment, since the manager is risk averse. This is similar to the classic incentives versus insurance tradeoff. The difference here lies in the cost of providing incentives. For instance, in Holmstrom (1979) the cost of providing incentives is simply the utility cost to the agent, whereas here there is an additional cost, namely underinvestment in capital.

In the following sections, we will investigate two testable implications of the model:

- **PREDICTION** 1: Firm-level investment will display a negative relation with idiosyncratic risk.
- **PREDICTION** 2: The negative relation between investment and idiosyncratic risk will be stronger for firms with higher levels of insider ownership.

In our empirical results we will take the variation in insider ownership as given. In reality, there are many reasons why shares of insider ownership may vary across firms. The concern would then be that λ varies endogenously with some unobservable firm characteristics, which are actually responsible for the negative investment-risk relation. A first candidate is risk aversion, and we can obtain some intuition from the model regarding the effect of risk aversion on the endogeneity of λ. Given that we do not observe the manager's risk aversion, our results will be biased toward rejecting the second prediction, even if the model is true. For instance, suppose that λ varies exactly inversely proportional to A, so that less risk-averse managers are given higher stakes in the firm, then the investment-risk relation will be flat along levels of insider ownership.

There are, however, some additional candidates that are outside the model. Insider ownership may be correlated with the degree of financial constraints, or it could be endogenously related to the level of competition in the product market. In Sections 5.2-5.3 we will explore these possibilities in more detail.

[1] In our numerical solution, provided in the appendix, we find that the optimal λ is decreasing with the level of idiosyncratic risk and the manager's risk aversion because in that case the costs of underinvestment are lower, and is increasing with the marginal cost of effort. This is consistent with the empirical findings of Graham et al. (2009). Nonetheless, this decrease in λ does not completely undo the effect of managerial risk aversion. In equilibrium, investment is more sensitive to risk in firms where managers are more risk averse.

3 Investment and Idiosyncratic Risk

In this section we examine the first prediction of our model, namely the response of investment to the volatility of idiosyncratic risk, controlling for several factors that might affect this relation.

3.1 Data and Implementation

We construct our baseline measure of idiosyncratic volatility using weekly data on stock returns from CRSP.[2] In order to estimate a firm's idiosyncratic risk, we need to remove systematic risk factors that the manager can insure against. Therefore, for every firm, i, and every year, t, we regress the firm's return on the value-weighted market portfolio, R_{MKT}, and on the corresponding value-weighted industry portfolio, R_{IND}, based on the Fama and French (1997) 30-industry classification.

Our measure of yearly idiosyncratic investment volatility for firm i is the volatility of the residuals across the 52 weekly observations. Thus, we decompose the total weekly return of a firm i into a market-, an industry-, and a firm-specific or idiosyncratic component as follows:

$$R_{i,\tau} = a_{1,i} + a_{2,i} F_{i,\tau} + \varepsilon_{i,\tau} \quad , \tag{9}$$

where τ indexes weeks, and $F_{i,\tau} = [R_{MKT}, R_{IND}]$. Our measure of idiosyncratic risk is the log volatility of the regression residuals:

$$\log(\sigma_{i,t}) = \log \sqrt{\sum_{\tau \in t} \varepsilon_{i\,\tau}^2} \quad . \tag{10}$$

Our measure of idiosyncratic risk is highly persistent, even though it is constructed using a non-overlapping window: The pooled autocorrelation of $\log(\sigma_{i,t})$ is 78 percent in the 1970-2005 sample. We also examined the robustness of our results to alternative definitions of the volatility measure. As a first alternative we used the volatility of the firm's raw returns, σ_t^{total}, which does not isolate any idiosyncratic risk. As a second alternative, we used the volatility, σ_t^{rmkt}, of the residuals from a market-model regression of firm returns on the market

[2]In the absence of any microstructure effects, using higher frequency data yields more precise estimates of volatility. Thus, when estimating volatility, in principle one should use the highest frequency data available (daily or even intra-day). However, since not all stocks trade every day, using daily data would bias down our estimates of covariance with the market and other factors, thus yielding upward-biased estimates of idiosyncratic volatility. In addition, this bias would vary with the liquidity of the firm's traded shares. Given that most stocks trade at least once a week, we view weekly data as a compromise between getting more precise estimates and being free of microstructure effects.

portfolio alone, where $F_{i,\tau} = [R_{MKT}]$. As a third alternative, we used the volatility, σ_t^{rff3}, of the residuals from a regression of firm returns on the Fama and French (1993) three factors, where $F_{i,\tau} = [R_{MKT}, R_{HML}, R_{SMB}]$. All three volatility measures are highly correlated (in excess of 95 percent) and lead to qualitatively and quantitatively similar results.

We estimate the response of investment to idiosyncratic risk using the following reduced-form equation:

$$\frac{I_{i,t}}{K_{i,t-1}} = \gamma_0 + \beta \ \log(\sigma_{i,\,t-1}) + \gamma_1 \ Z_{i,\,t-1} + \eta_i + g_t + v_{\,i,\,t} \quad , \tag{11}$$

where the dependent variable is the firm's investment rate (I_t/K_{t-1}), and $Z_{i,\,t}$ is a vector of controls: i) log Tobin's Q, defined as the ratio of a firm's market value to the replacement cost of capital ($\log(V_t/K_t)$) and measured as in Fazzari, Hubbard and Petersen (1988); ii) the ratio of cashflows to capital (CF_t/K_{t-1}), computed as in Salinger and Summers (1983); iii) log firm size, measured as the firm's capital stock, scaled by the total capital stock to ensure stationarity ($\log \hat{K}_t = \log(K_{i,t}/\frac{1}{N_f}\sum_i^{N_f} K_{i,t})$); iv) the firm's own stock return (R_t); and v) log firm leverage, measured as the ratio of equity to assets ($\log(E_t/A_t)$). We control for variables that could jointly affect volatility and investment, in order to address biases due to omitted variables. In papers focusing on investment, it is standard to control for Tobin's Q and cashflows. We control for firm size because smaller firms tend to be more volatile and to grow faster; we control for stock returns because volatility and stock returns are negatively correlated, and we want to ensure that we are picking up the effect of volatility rather than a mean effect due to news about future profitability; we control for firm leverage because equity volatility increases with leverage, while highly levered firms might invest less due to debt overhang (Myers, 1977). The exact details about the data construction are provided in the appendix. We use a semi-log specification to capture the possibility that the investment-Q (or investment-σ) relation is not linear, as for example in Eberly, Rebelo and Vincent (2008). Our results are robust to a linear specification for either Q or idiosyncratic volatility. Depending on the specification, we include firm dummies (η_i) or time dummies (g_t). Finally, the errors ($v_{i,t}$) are clustered at the firm level.

Our sample includes all publicly traded firms in COMPUSTAT over the period 1970-2005, excluding firms in the financial (SIC code $6000-6999$), utilities (SIC code $4900-4949$), and government-regulated industries (SIC code > 9000). We also drop firm-year observations with missing SIC codes, with missing values for investment, Tobin's Q, cashflows, size, leverage, stock returns, and with negative book values of capital. We also drop firms with fewer than 40 weekly observations in that year. Our sample includes a total of 104,646 firm-year observations. Finally, to eliminate the effect of outliers, we winsorize our data by year at the 0.5% and 99.5% level in all specifications.

3.2 Effect of Idiosyncratic Risk on Investment

Our estimates of Equation (11) are reported in Table 1. The first column shows that, when we include only idiosyncratic volatility and firm-fixed effects, the coefficient on idiosyncratic volatility is -3.5% and statistically significant. The second column presents the results of the benchmark estimation for Equation (11), in which case the coefficient on idiosyncratic volatility is -2% and statistically significant. In the third column we allow the time effects to vary by industry so as to capture any unobservable component varying at the industry level. In this case, identification comes from differences between a firm and its industry peers. To keep the number of fixed effects manageable, we use the 2-digit SIC classification. In this specification, the coefficient on $\log(\sigma_{i,t-1})$ remains mostly unaffected at -2%.

Our estimated coefficient of investment on idiosyncratic risk is economically significant. The standard deviation of log idiosyncratic volatility in our sample is 49 percent, so a one-standard deviation increase in $\log\sigma$ is associated with a $1-1.75\%$ decrease in the investment-capital ratio. This is a substantial drop, as the mean investment-capital ratio in our sample is approximately 10 percent.

One concern is that idiosyncratic volatility may be positively correlated with systematic volatility, and thus the negative coefficient on idiosyncratic volatility may simply capture the effect of time-variation in systematic risk premia on investment. To address this issue, we include lagged systematic volatility as an additional regressor in the fourth column of Table 1.[3] The coefficient on idiosyncratic volatility is still negative and significant (-2.4%), whereas the coefficient on systematic volatility is positive (0.6%) and significant. The coefficient on systematic volatility is economically small. Given that the standard deviation of systematic volatility is 73 percent in the sample, these estimates imply that a one-standard deviation increase in systematic volatility is associated with a 0.45% increase in the investment-capital ratio.

The positive coefficient of investment on systematic volatility might seem puzzling at first. In particular, most non-agency theories for the investment-risk relation typically make no distinction between idiosyncratic and systematic risk. Hence, our finding that idiosyncratic

[3] We compute systematic volatility as total volatility minus idiosyncratic volatility, i.e. $\log\sigma^{syst}_{i,t-1} \equiv \log\sqrt{(\sigma^{total}_{i,t-1})^2 - \sigma^2_{i,t-1}}$. Note that systematic volatility varies in the cross-section due to cross-sectional dispersion in betas with the market and industry portfolios.

and systematic risk have different-sign effects on investment would cast doubt on these theories, if at the same time we believed that the effect of risk on investment is causal. However, this effect need not in fact be causal. For example, most real-option models predict that firms with more growth opportunities have more volatile stock returns. If Tobin's Q or cashflows are noisy measures of growth opportunities, the resulting omitted variable problem would bias our results toward a positive coefficient.

One way to control for such a time-varying unobservable firm effect is to include the lagged investment rate as an additional control. In this case, however, the lagged dependent variable is correlated with the unobservable firm-fixed effects, which creates a bias in the standard OLS estimators. We address this issue by using the two-step GMM estimation procedure proposed by Arellano and Bond (1991). This procedure yields consistent estimates, at the cost of imposing the restriction of no-autocorrelation in the error terms. As seen in the fifth column of Table 1, our baseline volatility coefficient is again negative and statistically significant at -1.22%. When we include systematic volatility in the GMM specification, as in column six of Table 1, the coefficient on idiosyncratic volatility is mostly unaffected at -1.12%, while the coefficient on systematic volatility is close to zero and is not statistically significant. This finding is consistent with our intuition that systematic risk and investment opportunities are correlated. Finally, the LM-test of second-order serial autocorrelation and the Sargan J-test of over-identifying restrictions both fail to reject the null at the 10% level.

4 Managerial Ownership and Risk Aversion

In this section we explore the second prediction of our model, namely that the effect of idiosyncratic risk on investment is stronger for firms where managers hold a larger share in the firm. We also examine two related predictions that are outside the model.

First, over the last twenty years, several firms have switched to option-based compensation. Compensating executives with options, rather than with shares, provides managers with a convex payoff, whose value increases in the volatility of the firm. Thus, all else equal, increasing the convexity of the compensation package will tend to mitigate the effect of risk aversion on investment [Ross (2004)]. We will test this prediction by examining the investment-risk sensitivity for firms with different levels of convexity in their compensation schemes. We expect that the negative effect of idiosyncratic risk on investment will be smaller for firms with more convex compensation schemes.

Second, if the investment-risk relation is due to poor managerial diversification, then managers are possibly destroying shareholder value by turning down high-idiosyncratic-risk but positive-net-present-value projects. In order to mitigate this loss in value, shareholders may start monitoring managerial investment decisions. However, monitoring requires expertise and is costly, and hence, due to free-riding problems, small investors are unlikely to act as effective monitors. By contrast, institutional investors own large blocks of a firm's shares, and they have an incentive to develop specialized expertise in monitoring investment decisions. Therefore, if institutional-investor ownership is correlated with corporate governance, we expect to find a weaker effect of insider ownership on the investment-uncertainty relation in firms with higher institutional ownership.

4.1 Insider Ownership

In this section we examine how the investment-risk sensitivity varies with ownership by insider managers. We expect that investment will be more sensitive to idiosyncratic risk in firms where the managers hold a larger fraction of the firm's shares.

Our source of managerial-ownership data is the Thomson Financial database of filings derived from Forms $3, 4$, and 5, over the period 1986-2005. We take as our measure of insider ownership in year t the reported yearly holdings of a firm's shares held by firm officers at the end of that year or at the latest filing date, as a fraction of the shares outstanding in the firm. After dropping missing and zero ownership values, the sample consists of $41,206$ firm-year observations.

Table 2 presents some summary statistics for firms with different levels of insider ownership. Every year, we sort firms into quintiles based on their lagged level of insider ownership. We report time-series averages of the median firm characteristic within ownership quintiles. The median level of insider ownership across the five groups varies from 0.06% to 17.4%. The firms with high levels of insider ownership tend to be smaller growth firms. They tend to have higher Tobin's Q, be more profitable, and invest more on average. In addition, they seem to be more likely to face high costs of external finance: They have lower financial leverage, lower ratios of physical capital to book assets, and higher levels of the Whited and Wu (2006) index of financial constraints. Finally, firms with high insider ownership tend to have lower market power, as evidenced by their lower level of sales as a fraction of industry total.

We investigate how the investment-uncertainty relation varies with the degree of insider ownership by estimating Equation (11) separately for firms in different insider-ownership quintiles. Table 3 presents the results using our benchmark measure of insider ownership (columns one and two), as well as adjusting our ownership measure for executive option holdings (columns three and four; see Section 4.2 and the appendix for details).

The difference in the sensitivity of investment to idiosyncratic risk between the first and the fifth insider-ownership quintile ranges from -2.6% to -4%, depending on controls, and is statistically significant, with p-values ranging from 0.022 to 0.066. The dispersion in sensitivities is economically significant: For firms with high levels of insider ownership, a one-standard deviation increase in log idiosyncratic volatility is associated with a drop of 1.5% to 2% in investment-capital ratios, compared to the group mean of 12 percent. By contrast, for firms with low insider ownership the effect is small in magnitude and not statistically significant: A one-standard deviation increase in log idiosyncratic volatility is associated with a drop of 0.05% to 0.4% in investment-capital ratios, compared to the group mean of 9 percent.

Our results here indicate that the investment-uncertainty relation varies with the level of insider ownership. This evidence is consistent with the view that the investment-risk relation is at least partly due to poor managerial diversification. However, note that insider ownership is endogenous, and thus may be correlated with various other firm characteristics. We will explore this possibility in detail in Sections 5.2-5.3.

4.2 Option-Based Compensation

The previous section focused on ownership by insiders in the form of shares in the firm, which exposes the manager to both profits and losses. An alternative form of ownership gives the manager call options on the firm's shares, which allow the executive to participate in gains but not in losses. Due to the convex shape of the payoff function, an executive who is mostly compensated with options rather than with shares will be effectively less risk averse, and in fact he may even be risk loving in some regions. Consequently, we expect that investment will be less sensitive to idiosyncratic volatility in firms with more convex executive compensation schemes.

We use data on CEO option grants from Execucomp and the Black-Scholes option-pricing model, adjusted for dividends, to compute the partial derivatives with respect to stock-return volatility (*vega*) and to stock price (*delta*). For a given option scheme, the two variables of interest are $N_o \times vega$ and $N_o \times delta$, where N_o is the number of options granted. The first variable measures the change in the executive compensation scheme per unit increase in idiosyncratic volatility. The second variable measures the change in the executive compensation scheme per unit increase in the underlying stock price.

Ross (2004) shows that simply granting an executive more call options does not necessarily make him less risk averse. The reason is that there is an offsetting effect coming from the option's delta, or its sensitivity to stock-price changes. Thus, to investigate the effect of increased convexity in executive compensation schemes, it is necessary to control for the level of ownership. We adjust the ownership measures constructed in Section 4.1 for executives' exposure through options. Since one single share has $delta = 1$, endowing the manager with N_o options with a $delta = N_\delta$ is equivalent, in terms of stock-price exposure, to endowing him with $N_o \times N_\delta$ units of stock. Thus, we add to the number of shares held by executive j an amount equal to $\sum_s N_{j,i,s,t}\, delta_{j,i,s,t}$.

In order to compute the Black-Scholes sensitivities, we need estimates of the time-to-maturity and of the exercise price for all options. Execucomp provides this information for new option grants, but not for existing options. To address this issue, we use the Core and Guay (2002) procedure for deriving approximate estimates of these sensitivities based only on data from a single proxy statement. We construct firm-level measures of convexity, $\overline{VEGA}_{i,t}$, and level exposure, $\overline{DELTA}_{i,t}$, by aggregating across executives in Execucomp (see the appendix for more details). Our sample contains data from 1992-2005 and $12,708$ observations.

We then investigate the effect of the convexity of the executive compensation scheme on the investment-uncertainty relation, controlling for the level of insider ownership. Every year, we sort all firms into three equal-sized groups based on insider ownership. Within each such group, we then sort firms into three equal-sized groups based on $\overline{VEGA}_{i,t}$. We estimate Equation (11) separately for firms in each of the 3×3 groups, and report results for the four corners in Table 4. Columns one and two show results using our benchmark (not adjusted for options) measure of insider ownership, while columns three and four show results for our options-adjusted measure. Controlling for the level of insider ownership, the negative effect of idiosyncratic risk on investment is present only for firms with low convexity of executive compensation. For firms with high convexity, the effect of idiosyncratic risk on investment is in most cases positive, though statistically insignificant. The difference in the sensitivity of investment to idiosyncratic risk for firms with high- and low- levels of compensation convexity ranges from 2.8% to 4.7%, depending on controls and ownership levels, and is always statistically significant (p-values range from 0.004 to 0.05).

4.3 Corporate Governance

In this section, we explore the effect of insider ownership on the investment-uncertainty relation among groups of firms with different levels of institutional ownership.

Section 4.2 documented that increasing the convexity of an executive compensation scheme can mitigate the effect of managerial risk aversion on the investment-uncertainty relation. An alternative to providing more convex incentives is more effective monitoring by shareholders. Large institutional investors are likely to be more effective monitors, due to increased expertise and incentives to overcome the free-rider problem. Thus, we expect the effect of insider ownership on the investment-uncertainty relation to be smaller for firms with high institutional ownership.

We construct our institutional-ownership measure from the Thomson Financial Institutional Holdings (13F) database, following Nagel (2005). As before, every year, we sort firms in three equal-sized groups based on their level of institutional ownership. Within each group, we then sort firms into three equal-sized groups based on the level of insider-ownership. We estimate Equation (11) separately for firms in each of the 3×3 groups and we report results for the four corners in Table 5. Columns one and two show results using our benchmark (not adjusted for options) measure of insider ownership, while columns three and four show results for our options-adjusted measure.

The effect of insider ownership on the investment-uncertainty relation is concentrated in the sub-sample of firms with low institutional ownership. In that sub-sample, investment is more sensitive to risk in firms with high insider ownership. In particular, the difference in the sensitivity of investment to idiosyncratic risk between high- and low- insider-ownership firms ranges from -4.0% to -6.2% and is statistically significant at the 1% level. By contrast, for firms with high levels of institutional ownership, there is *no* difference in the sensitivity of investment to risk between firms with high- and low- insider ownership.

Our evidence that high institutional ownership alleviates the effect of insider ownership on the investment-uncertainty relation suggests that with regard to firm-specific risk, management and shareholder valuations of investment projects are not perfectly aligned.

5 Addressing Endogeneity Concerns

In this section, we address concerns about endogeneity. In particular, we address the possibility that idiosyncratic risk is correlated with a firm's investment opportunities. This possibility would lead to omitted variable bias. In addition, we recognize that insider ownership is partly an endogenous choice, and could be related to firm characteristics that could influence the investment-idiosyncratic risk relation, such as financial constraints or competition in the product market.

5.1 Omitted Variable Bias and Endogeneity

In Section 3 we document a robust negative relation between idiosyncratic risk and the investment of publicly traded firms. However, interpreting our findings as evidence of a causal relation is not straightforward. Our measure of volatility is based on stock returns, which are endogenous and incorporate information about the firm's growth opportunities and the firm's investment commitments. This endogeneity gives rise to the possibility of omitted variable bias and of reverse causality bias.

Both of these issues can be understood in the context of a model that differentiates between assets in place and growth options as a source of firm value. As stressed by Berk, Green and Naik (1999) and others, the value of a firm can be decomposed as the value of existing assets plus the value of growth opportunities. The volatility of stock returns will then be a weighted average of the volatility of each component. Since options are levered claims on the firm, most real-option models predict that the volatility of the growth options is greater than the volatility of assets in place. This scenario therefore raises two concerns.

First, a firm exhibiting high volatility of stock returns (idiosyncratic or systematic) could simply be a firm with high growth opportunities. Failure to properly account for growth opportunities, for example if Q is mismeasured, would lead to an omitted variable problem. This would likely bias our estimates upward, as long as idiosyncratic volatility and growth opportunities are positively correlated.

Second, investment decisions affect the mix between growth options and assets in place. For instance, consider a situation where the firm has committed today to undertake investment in a particular project in the future. This decision to transform the growth option into a productive asset increases the share of firm value that is due to assets in place, and thus affects the volatility of stock returns today. If the idiosyncratic volatility of growth options is greater than that of assets in place, the decision to exercise the option will lower the volatility of stock returns today. In this case, we face a reverse causality problem which will bias our estimates toward finding a negative relation.

In this section we try to alleviate these concerns. We deal with the omitted variable bias by using alternative measures of growth opportunities and by allowing for measurement error in Q in the estimation. We address the issue of endogeneity by instrumenting for idiosyncratic volatility with a measure of the firm's customer-base concentration.

Alternative Measures of Growth Opportunities

We consider two alternative measures of growth opportunities. Our first alternative measure is based on Bond and Cummins (2004) and Cummins, Hassett and Oliner (2006), who construct a measure of Tobin's Q from data on analysts' earnings forecasts from the Institutional Broker's Estimate System (I/B/E/S). We follow Cummins et al. (2006) in constructing our alternative measure for Q, denoted by Q^{ibes}. This measure essentially replaces the numerator of Q with the discounted present value of cashflows computed using analyst forecasts (see appendix for details). The sample ranges from $1982-2005$ and contains 33,628 firm-year observations. The correlation between the average firm Q and Q^{ibes} is 63 percent with a robust t-statistic of 33.0.

Our second alternative measure of growth opportunities is based on Kogan and Papanikolaou (2010a). This measure is the beta of a regression of a firm's stock return on a proxy for investment-specific shocks, namely a portfolio long the investment-producing sector and short the consumption-producing sector (β^{imc}). Their measure is derived from a structural model, and the intuition is that firms with more growth opportunities are more likely to benefit from a positive investment shock, defined as a reduction in the cost of new capital. Following Kogan and Papanikolaou (2010a), we drop the capital-producing firms from the sample, leaving us with a sample of 77,001 firm-year observations. The correlation between the average firm Q and β^{imc} is 18 percent with a robust t-statistic of 6.4.

We then estimate Equation (11) replacing Tobin's Q with our two alternative measures. The results are presented in Table 6. The first two columns show the results using Q^{ibes}. The first column uses OLS, while the second column uses the Arellano and Bond (1991) GMM estimator and includes the lagged investment rate in the set of regressors. The coefficient of investment on idiosyncratic volatility is -1.8% and -0.9% respectively. The third and fourth columns of Table 6 show the results using our second measure of growth opportunities, β^{imc}, with OLS and GMM estimation respectively. The coefficient of investment on idiosyncratic volatility is negative and a bit higher than our benchmark estimates, ranging from -2.9% to -4.6%. In all four cases, the coefficient on idiosyncratic volatility is statistically significant. In three out of the four cases, the coefficient on the alternative measure of growth opportunities is significant at the 1% level. In columns 2 and 4, the Sargan and LM tests fail to reject the null of valid instruments and the null of second-order serial autocorrelation in the residuals respectively. Including all three measures of growth opportunities (Q^{ibes},

β^{imc}, and log Tobin's Q) in the same specification does not materially affect our results: The OLS (Arellano-Bond) estimate on idiosyncratic volatility equals -0.9% (-1.42%) with a t-statistic of -2.1 (-3.3), though the p-value on the LM AR(2) test is only 0.097.[4]

Measurement Error in Tobin's Q

Here, rather than considering alternative measures of growth opportunities, we deal with possible measurement error in Tobin's Q directly in the estimation. To that end, we follow the approach of Erickson and Whited (2000), who propose a higher-order GMM estimation method to correct for measurement error in Q. Their methodology exploits the non-normality of Tobin's Q, and hence in this section we replace $\log Q$ with Q in the set of controls. The model is identified as long as the true Tobin's Q is non-normally distributed. Our sample passes the identification test in 11 out of the 36 cross-sections, based on individual p-values. Given that the smallest p-value is less than 0.004%, the Bonferroni test rejects the null of no identification in the entire sample with a p-value of $36 \times 0.004\% = 0.14\%$.[5]

We report the results of estimating Equation (11) using the third-order-moment Erickson and Whited (2000) estimator in the eighth column of Table 6. We report the time-series average of the coefficient in each cross-section, and we estimate the standard errors via the Fama and MacBeth (1973) procedure. For comparison purposes, the seventh column presents the corresponding OLS estimates when $\log Q$ is replaced with Q in the set of controls. Using the Erickson and Whited (2000) estimator, the coefficient on idiosyncratic volatility is -3.2%, which is close to the OLS estimate of -3.7%. Both coefficients are statistically significant at the 1% level. Interestingly, the coefficient on Tobin's Q using the Erickson and Whited (2000) estimator is more than twice the magnitude of the OLS estimator, which is consistent with the presence of measurement error in Q. Based on the τ^2 statistic, the empirical proxy for Tobin's Q, i.e. the usual accounting measure of book-to-market, explains 46 percent of the variation in the true measure of investment opportunities, which is comparable to the findings of Erickson and Whited (2000; 2002) and Bakke and Whited (2007).

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[4]Including the firm's systematic volatility ($\log \sigma^{syst}_{i,t-1}$) as an additional regressor does not affect our results: The coefficient on idiosyncratic risk is negative, ranging from -0.8% to -5.7%, and statistically significant. By contrast, in four out of the six cases, the coefficient on systematic volatility is now either negative or statistically insignificant. We interpret this as evidence consistent with the view that the positive coefficient on ($\log \sigma^{syst}_{i,t-1}$) in Section 3.2 arises from failure to properly control for investment opportunities. Given that this paper focuses on idiosyncratic risk, we reserve the full set of results for the online appendix.

[5]The Bonferroni test is a conservative upper bound for the p-value of the joint test. Suppose that we run two tests and reject if either A or B occurs. Each has probability p of rejecting under the null. Then, the overall probability of rejecting is $P(A \bigcup B) = P(A) + P(B) - P(A \bigcap B) \leq 2\,p$. Note that this test makes no assumption that A and B are independent.

Instrumenting for Idiosyncratic Volatility

In this section we consider an alternative approach to address concerns about endogeneity. Rather than trying to control for investment opportunities directly, we instrument for volatility with a measure of a firm's customer-base concentration. We construct a measure of the concentration of a firm's sales using data from the COMPUSTAT segment files, which cover the 1976-2005 period. We construct our measure as a Herfindahl concentration index of a firm's sales across customers, denoted by H (for details, see appendix). Subsequently, we use $H_{i,t}$ as an instrument for idiosyncratic volatility. Our instrument does not vary a lot over time, hence the identification comes mostly from the cross-sectional dimension of the panel. We therefore drop firm-fixed effects from the estimation and we replace them with the firm's lagged investment rate.

The two requirements for customer-base concentration to be a valid instrument for idiosyncratic volatility are i) that customer-base concentration affects idiosyncratic volatility, and ii) that customer-base concentration affects investment only through its effect on idiosyncratic volatility. Our intuition as to why the first restriction would be satisfied, is that a firm selling to only a few customers has less ability to diversify the customers' idiosyncratic demand shocks for its product, and will thus be riskier. This restriction can be tested empirically using tests for weak instruments. The second restriction (the exclusion restriction) is a bit more problematic. In economic terms, the exclusion restriction implies that a firm's investment opportunities do not depend on how concentrated its customer base is.

There are two direct channels through which customer-base concentration could be correlated with investment opportunities. First, there may be a mechanical link between customer-base concentration and the firm's market share, since firms with few customers may tend to be smaller. The firm's customer-base concentration can then be correlated with investment opportunities because firms with low market share might have greater room to grow and thus possibly higher investment opportunities. A second possibility is that the degree of customer-base concentration may vary by industry, and so may investment opportunities. To address these concerns, we control for the lagged level of sales (relative to industry sales) and for industry dummies.[6] Industry effects, along with the lagged value of the investment rate, partially account for the presence of unobservable persistent components at the firm level. A first-stage regression of $\log \sigma_{i,t}$ on $H_{i,t}$, controlling for firm sales,

[6]Including both firm sales and firm size ($\hat{K}$) leads to a failure to reject the null of weak instruments with the Kleibergen and Paap (2006) Wald F-test when estimating Equation (11) within insider-ownership quintiles. To keep results comparable, we drop firm size from the set of additional controls.

industry dummies, and lagged investment has a t-statistic of 17.3 (16.8), suggesting that the instrument is not weak.

We report the results of estimating Equation (11) using instrumental variables in columns nine and ten of Table 6. Depending on whether we only control for lagged investment rate and sales (column nine) or for the full set of controls (column ten), the coefficient on idiosyncratic volatility is negative, statistically significant, and ranges from -11.7% to -14.8%. These numbers imply that a one-standard deviation increase in the fitted value of idiosyncratic volatility from the first-stage regression leads to a fall in investment-capital ratios between 3.1% and 4.2%. The Kleibergen and Paap (2006) test rejects the null of weak instruments.

We view these results as supportive of a causal relation, whereby idiosyncratic risk negatively affects public-firm investment. Note that the coefficient of investment on idiosyncratic risk is higher in absolute value than the estimates in Table 1, which is consistent with the presence of attenuation bias in our OLS estimates. We then explore whether our results on insider ownership in Section 4.1 are driven by variation in the attenuation bias across ownership quintiles. Using instrumental variables, the difference in the sensitivity of investment to idiosyncratic risk between the top and bottom quintiles ranges from 17% to 20% (p-values range from 0.5% to 1.5%), depending on controls. The full set of results is reported in the online appendix. As before, the dispersion in the sensitivities of investment to risk is close to the average sensitivity in the cross-section.

Finally, there are some additional, less direct channels through which customer-base concentration may be correlated with a firm's investment opportunities. First, firms with a small number of large customers may need to make match-specific investments in new distribution channels or in training their sales work force. Even though these do not constitute investment in physical capital, but rather in organization capital, there might be complementarities between physical and organization capital. We address this concern by adding the firm's investment in organization capital (sales and general administrative expenses, or SGA, scaled by stock of organization capital, as in Eisfeldt and Papanikolaou (2010)) as an additional control. Doing so does not affect our results, as the coefficient of investment on idiosyncratic risk ranges from -11.2% to -11.7% and is statistically significant. Second, firms with a small number of large customers may be perceived as riskier by investors, and thus may face a higher cost of external borrowing. A higher cost of external funds would raise the discount rate the firm applies when valuing projects and will therefore lower investment. Note that in this case, customer concentration implies higher *systematic* risk, which translates into higher cost of borrowing. To address this, we include credit-rating fixed effects in the specification, and we find that the coefficient of investment on idiosyncratic volatility ranges from −13.9% to −19.7% and is statistically significant. When replacing the credit-rating dummies with lagged systematic volatility, the coefficient ranges from −12.8% to −15.1%.

5.2 Financial Constraints

As mentioned in Section 4.1, firms with high insider ownership might be firms that for some reason face high costs of external finance and are thus unable to attract outside investors. Froot, Scharfstein and Stein (1993) argue that in the presence of convex costs of external finance, risk-neutral managers have a precautionary-saving motive. In this case, manageres may underinvest in projects with high idiosyncratic risk. As a result, our findings in Section 4.1 could be driven not by differences in insider ownership per se, but rather by differences in the likelihood that a firm is financially constrained. Indeed, Table 2 shows that firms where insider ownership is high are also smaller firms, with higher values of the Whited and Wu (2006) index of financial constraints.

We consider three proxies for the likelihood of a firm facing financial constraints. The first is the financial-constraints index of Whited and Wu (2006). The second is based on the firm's credit rating by Standard and Poor's. All else equal, firms with a better credit rating have more access to the public debt markets, and hence are less likely to be financially constrained. We group firms with a similar credit rating as follows: Group 1 contains firms rated AA- or better, group 2 contains firms rated A, group 3 contains firms rated BBB, group 4 contains firms rated BB+ or worse, and group 5 contains unrated firms. Third, small firms might be more opaque and thus might face difficulty in attracting outside investors. To address this possibility, we consider firm size as an additional, albeit somewhat crude, measure of financial constraints.

We estimate Equation (11) separately for firms with different levels of size, credit rating, and the Whited and Wu (2006) index. Investment is more sensitive to risk for smaller firms, for firms with lower credit rating, and for firms with higher values of the Whited and Wu (2006) index. The difference in sensitivities ranges from −1% to −3.6%, depending on the measure of financial constraints and the specification, and is statistically significant in five out of the six cases (p-values range from 0.001% to 0.152, see online appendix for full set of results). Hence, there is some evidence that the investment-risk sensitivity is stronger for financially constrained firms.

The results above raise raise the possibility that our findings might be driven by financial constraints rather than by insider ownership. We address this concern by reporting Equation (11) for firms with different levels of insider ownership, where the peer group is now firms with similar levels of financial constraints. In particular, we first sort firms on measures of financial constraints into five groups. Within each group of firms with similar level of financial constraints, we then sort firms into five quintiles based on the level of insider ownership. We repeat this process every year, we pool the insider-ownership quintiles across different levels of financial constraints, and we estimate Equation (11) separately for each pooled quintile. Our double-sorting procedure is successful at creating groups of firms with substantial dispersion in insider ownership, but essentially no dispersion in financial constraints (see online appendix for firm characteristics across these portfolios).

We present results in Table 7. Controlling for size or financial constraints has little impact on our findings. The difference in the investment-idiosyncratic risk sensitivities between the high- and low- insider-ownership groups ranges from -2.2% to -3.3%, depending on the specification, and the p-values range from 0.004 to 0.059.

Overall, we conclude that, though there is some evidence that financially constrained firms exhibit higher investment-risk sensitivity, this does not seem to be the main driver behind our results. Within firms with the same size or likelihood of being constrained, firms with higher insider ownership have investment that is more sensitive to risk.

5.3 Product-Market Competition

Firms can exhibit varying sensitivities of investment to risk for operational reasons. These broadly fall into two categories: i) real-option effects, where increased uncertainty can affect both the level and the timing of investment, and ii) imperfect-competition effects, where the marginal product of capital depends on the level of uncertainty due to convexities.[7] In addition, insider ownership could vary endogenously with the degree of investment irreversibility or imperfect competition. For example, Hart (1983), among others, points out that product-market competition can exert a disciplining effect on managers, and might thus act as a substitute for incentive schemes.

Our concern is that the cross-sectional variation in the investment-risk sensitivity we have identified results from operational forces, to which insider ownership is an endogenous

[7]For instance, Caballero (1991) shows that, given the degree of investment irreversibility facing a firm, the relation between investment and uncertainty is more negative for less competitive firms. Abel (1983) and Hartman (1972) point out that imperfect competition affects the investment-uncertainty relation due to the convexity of the marginal product of capital. However, the sign of this effect is ambiguous, depending on whether uncertainty manifests as shocks to price or to demand.

response. Given that the effect of investment irreversibility and of product-market competition on the investment-risk relation has ambiguous sign theoretically, it is difficult to test the predictions of these models directly. Instead, we rank firms on insider ownership relative to their peers with the same degree of investment irreversibility or imperfect competition. In particular, we first sort firms into three equal-sized groups based on measures of investment irreversibility. Within each investment-irreversibility group, we then sort firms into three equal-sized groups based on measures of imperfect competition. Finally, within each of the $3 \times 3 = 9$ groups, we sort firms based on insider ownership. We repeat this process every year, we pool the insider-ownership bins across different groups of irreversibility and imperfect competition, and we estimate Equation (11) separately for each pooled bin.

The degree of investment irreversibility is notoriously hard to measure. Thus, we use five alternative measures of the degree of investment irreversibility in a given firm: i) the age-adjusted price discount between used and new capital, as disinvestment is more costly when the value of used relative to new capital is low (we use the data in Ramey and Shapiro (2001), see the appendix for details); ii) the fraction of new investment at the industry level that comes from purchases of new versus used capital goods (this measure uses Census data, see the appendix for details); iii) the average ratio of sales of property plant and equipment to total capital at the industry level over the first decade of the sample (1970-80), as it is easier to disinvest in industries where the used capital market is active; iv) the depreciation rate of capital at the industry level, since investment is less irreversible when capital depreciates faster; and v) the beta of a firm with its corresponding industry portfolio. The last measure is based on the insight of Shleifer and Vishny (1992), who point out that firms that are highly correlated with their industry have more difficulty disinvesting following a bad shock, since their peers and potential buyers of this capital are also likely to have suffered a negative shock. We use two measures of imperfect competition: i) the Herfindahl sales-concentration index for the firm's industry, and ii) the ratio of firm sales to industry sales, as a measure of market power. Our triple-sorting procedure is successful at creating groups of firms with substantial dispersion in insider ownership, but no dispersion in investment irreversibility, competition or market power (see online appendix for firm characteristics across these portfolios).

We present the results in Table 8. Investment is more sensitive to idiosyncratic risk for firms with higher levels of insider ownership, relative to their peers with the same degree of investment irreversibility and imperfect competition. The difference in sensitivities between the high- and low- insider-ownership groups ranges from -1.7% to -8.7%, and is almost always significant at the 5% level (p-values range from 0.0005 to 0.062). We conclude that we can rule out an alternative where the main driver behind our insider-ownership results are operational forces such as investment irreversibility, product market competition, and market power.

6 Investment During the Financial Crisis of 2008-09

In this section we document the response of investment to the rise in uncertainty associated with the 2008-09 financial crisis for firms with different levels of insider ownership, convexity of executive compensation, and institutional ownership. This exercise illustrates the empirical relevance of our results during a period when uncertainty was unusually high.

We use the levels of insider ownership before the start of the crisis (end of 2006) to group firms into five insider-ownership portfolios. We then track the change in the investment-capital ratio of these portfolios, relative to their pre-crisis levels. We do not readjust the portfolios, even though the level of insider ownership might have shifted in the 2007-09 period, since such shifts could be endogenous to the financial crisis. We compute the portfolio-average level of the investment rate and of lagged idiosyncratic volatility for these five portfolios, weighted by the lagged capital stock (assuming equal weights or reporting portfolio medians leads to very similar results).

Panels A and B of figure 1 plot the change, from the pre-crisis levels, in log idiosyncratic volatility and in portfolio investment rates, respectively, for the high- and low- insider-ownership portfolios. Panel A shows that the level of log idiosyncratic volatility went up by roughly the same amount (50 percent) for both the high- and the low- insider-ownership group. However, as we show in Panel B, the investment rate of the high-ownership group dropped by 8.4% in 2009, compared to a 1.8% drop for the low-ownership group. This drop in investment rates is not driven by variation in financial constraints correlated with insider ownership, as we obtain similar magnitudes when ranking firms by insider ownership within groups of firms with the same size, credit rating, or level of the Whited and Wu (2006) index (see online appendix for results).

In addition, we compute the average investment rates for firms with different levels of compensation convexity, controlling for level of insider ownership, as in Section 4.2. We pool across portfolios with different levels of compensation convexity, and we plot the investment rates of the high- and the low-vega portfolios in Panel C. Investment fell for both groups, but it dropped substantially more for firms with low compensation convexity (5%) than for firms with high compensation convexity (2%). Note that there was no significant differential increase in idiosyncratic risk among firms with different levels of compensation convexity.

Furthermore, we look at whether institutional ownership played a role during the crisis. In particular, we examine the behavior of firms with different levels of institutional and insider ownership, as in Section 4.3. We show the results in Panel D. Investment dropped across the board, but the most substantial decline was among firms with low institutional *and* high insider ownership.

In Panel E (F) we plot the difference between the weighted average (median) investment rate of portfolios of high- and low- insider ownership ($i_t^H - i_t^L$), versus the weighted average (median) lagged level of idiosyncratic volatility across all firms ($\bar{\sigma}_{t-1}$) for the entire 1987-2009 period. These panels essentially summarize the main results of the paper: The investment of high-insider-ownership firms is substantially more sensitive to changes in the level of idiosyncratic risk, compared to the investment of low-insider-ownership firms. The correlation between the difference in average (median) investment rates across portfolios of high- and low- insider ownership and the average level of idiosyncratic risk is -45% (-20%) in levels or -56% (-34%) in first differences.

7 Conclusion

In this paper we demonstrate a robust negative, and likely causal, relation between idiosyncratic risk and investment for publicly traded firms in the United States. We find evidence that the negative effect of idiosyncratic risk on investment is stronger when executives hold a higher fraction of the firm's shares, consistent with the view that this negative effect arises from poor managerial diversification. Nevertheless, the effect of insider ownership on the investment-uncertainty relation disappears for firms primarily held by institutional investors, possibly due to more effective monitoring of managerial decisions. In addition, we find that the negative relation between uncertainty and risk is weaker in firms with more convex compensation schemes.

It has been empirically documented that private entrepreneurs hold poorly diversified portfolios, with most of their wealth invested in the single firm they own, and that therefore the degree of entrepreneurial risk aversion is crucial for entrepreneurial investment decisions (Moskowitz and Vissing-Jørgensen, 2002). Our results indicate that there might be important similarities between privately held and publicly traded businesses regarding the investment decision-making process, since these decisions are made by poorly diversified executives, rather than by well-diversified shareholders.

Our results point to a potential cost of providing steep incentive schemes to risk-averse managers. In other words, there might be some justification for granting options, instead of shares, to executives, in order to preserve incentives while mitigating risk aversion. Even though executives are undiversified, a compensation scheme giving measures of downside protection could serve to better align management and shareholder incentives, at least when it comes to the effect of diversifiable risk on investment decisions. Alternatively, strong shareholders could effectively monitor managerial investment decisions.

Our results also indicate that managerial risk aversion might have played an important role during the 2008-09 financial crisis. During the crisis, uncertainty increased dramatically, while investment collapsed. Even though the increase in firm-specific uncertainty was comparable across the board, investment declined substantially more in firms with higher insider ownership. Our findings therefore point to an additional source of macroeconomic fluctuations: Increases in uncertainty induce risk-averse managers to reduce investment, and thus lead to a reduction in future output. Thus, our results support the view of Bloom (2009), who identifies changes in uncertainty as a real cause of macroeconomic fluctuations.

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Table 1: Idiosyncratic Risk and Investment

I_t/K_{t-1}	No Controls	BENCH	$IND \times T$	Syst	AB: I_{t-1}/K_{t-2}	
$\log(\sigma_{i,t-1})$	-0.0346	-0.0196	-0.0197	-0.0244	-0.0122	-0.0112
	(-13.78)	(-8.44)	(-8.32)	(-9.94)	(-2.69)	(-2.44)
$\log(\sigma_{t-1}^{syst})$				0.0063		0.0004
				(5.51)		(0.30)
$\log(Q_{t-1})$		0.0699	0.0692	0.0690	0.0289	0.0266
		(45.05)	(43.41)	(44.31)	(3.67)	(3.62)
CF_{t-1}/K_{t-2}		0.0222	0.0218	0.0220	0.0144	0.0153
		(9.91)	(9.88)	(9.84)	(4.16)	(4.47)
$\log(\hat{K}_{t-1})$		-0.1179	-0.1243	-0.1188	-0.1068	-0.1136
		(-31.80)	(-31.67)	(-32.09)	(-6.87)	(-7.46)
R_{t-1}		0.0146	0.0131	0.0148	0.0148	0.0155
		(8.66)	(7.47)	(8.75)	(4.32)	(4.75)
$\log(E_{t-1}/A_{t-1})$		0.0352	0.0346	0.0346	0.0524	0.0512
		(14.13)	(13.82)	(13.96)	(13.03)	(13.01)
I_{t-1}/K_{t-2}					0.2397	0.2317
					(7.54)	(7.48)
Observations	104646	104646	104646	104619	72216	72216
R^2	0.399	0.563	0.569	0.563		
AR(2) test (p-value)					0.150	0.188
Sargan J-test (p-value)					0.221	0.655
Fixed Effects	F	F,T	F, $I \times T$	F, T	F, T	F, T
Estimation Method	OLS	OLS	OLS	OLS	GMM	GMM

Table 1 reports estimation results of Equation (11), where the dependent variable is the investment rate (I_t/K_{t-1}). Our baseline measure of risk, $\sigma_{i,t-1}$, is constructed from a regression of weekly firm-level returns on the CRSP VW index and the corresponding industry portfolio. Additional regressors include lagged values of: Tobin's Q (Q_{t-1}) defined as in Fazzari et al. (1988); operating cashflows (CF_{t-1}/K_{t-2}) defined as the ratio of operating income (item 18) to the replacement cost of capital, computed as in Salinger and Summers (1983); the firm's size ($\log(\hat{K}_{t-1})$) defined as the log value of its replacement cost of capital, scaled by average capital across all firms; the firm's stock return (R_{t-1}); leverage (E_{t-1}/A_{t-1}), defined as the ratio of book equity (item 216) to book assets (item 6); systematic volatility($\log(\sigma_{t-1}^{syst})$), defined as the (log of the) square root of the difference between the firm's total variance and its idiosyncratic variance. Item refers to COMPUSTAT items. The sixth column presents results using the Arrellano-Bond estimator, where the lagged investment rate is included in the specification. We report the LM-test of second-order serial correlation and the Sargan J-test of over-identifying restrictions. The sample period is $1970-2005$. F denotes firm fixed effects, T denotes time fixed effects, and $I \times T$ denotes industry-time fixed effects. The standard errors are clustered at the firm-level, and t-statistics are reported in parentheses.

Table 2: Summary Statistics: Five Portfolios Sorted on Insider Ownership

Level of insider ownership	Low	2	3	4	High
Insider Ownership	0.06	0.32	1.01	3.40	17.43
Market capitalization (scaled by mean)	20.84	17.23	11.01	6.61	3.51
Book assets (scaled by mean)	27.38	21.04	13.13	7.44	4.38
Tobin's Q	1.64	1.80	1.93	2.27	2.15
Cashflows to capital	12.27	14.41	15.17	15.98	16.05
Investment to capital	8.76	9.41	10.57	12.18	12.47
Idiosyncratic volatility	35.37	36.65	40.74	44.62	49.11
Physical capital to book assets	63.47	58.13	54.11	47.36	46.61
Whited-Wu index	-29.77	-28.65	-25.99	-23.02	-19.71
Book debt to book assets	21.96	20.92	19.39	17.29	16.88
Cash to book assets	6.58	6.64	7.47	8.71	8.38
Dividends to cashflows	3.69	2.14	0.74	0.00	0.00
Sales / industry sales	1.75	1.32	0.88	0.46	0.31

Table 2 shows time-series averages of characteristics of the 5 portfolios sorted by levels of insider ownership. All characteristics, except for Tobin's Q, are in percent. We scale firm market capitalization and book assets at time t by the average across all firms at time t. Every year, we sort firms into quintiles based on the fraction of shares outstanding owned by company officers. The data on ownership is from Thomson Financial and contains all transaction and holdings information filed on Forms $3, 4$ and 5. We restrict attention to insiders with role codes O, OD, OE, OB, OP, OS, OT, OX, CEO, CFO, CI, CO, CT, H, GM, M, MD, P, EVP, VP, and SVP. We normalize the shares owned by insiders by CRSP shares outstanding (shrout). Accounting data are from COMPUSTAT: book debt is item 9 + item 34; cash is item 1; dividends is item 19 + item 21; cashflows is item 14 + item 18; sales is item 12. Market capitalization is the December market capitalization of equity from CRSP. Remaining variables are defined in the notes to Table 1. We report the time-series average of median portfolio characteristics. The sample period is $1987 - 2005$.

Table 3: Effect of Insider Ownership

I_t/K_{t-1}	(1)	(2)	(3)	(4)
$INSD_L \times \log(\sigma_{i,t-1})$	-0.0089	-0.0049	-0.0012	-0.0046
	(-1.10)	(-0.62)	(-0.12)	(-0.51)
$INSD_2 \times \log(\sigma_{i,t-1})$	-0.0155	-0.0045	-0.0086	-0.0019
	(-2.02)	(-0.62)	(-0.95)	(-0.22)
$INSD_3 \times \log(\sigma_{i,t-1})$	-0.0245	-0.0070	-0.0201	-0.0109
	(-2.90)	(-0.83)	(-1.95)	(-1.06)
$INSD_4 \times \log(\sigma_{i,t-1})$	-0.0400	-0.0161	-0.0312	-0.0190
	(-4.13)	(-1.72)	(-2.61)	(-1.65)
$INSD_H \times \log(\sigma_{i,t-1})$	-0.0413	-0.0305	-0.0408	-0.0331
	(-3.52)	(-2.93)	(-2.81)	(-2.60)
$INSD_H - INSD_L$	-0.0324	-0.0255	-0.0396	-0.0285
p-value	0.022	0.049	0.023	0.066
Observations	41206	41206	32616	32616
Fixed Effects	F	F, T	F	F, T
Controls	N	Y	N	Y
Option-adjusted Ownership	N	N	Y	Y

Table 3 reports estimation results of Equation (11), interacting our idiosyncratic volatility measure ($\sigma_{i,t-1}$) with insider-ownership quintile dummies (see notes to Table 2 for more details). $INSD_L$ and $INSD_H$ indicate the dummies for the first and the fifth insider-ownership quintile respectively. The third and fourth columns adjust insider ownership for option holdings, whenever available, otherwise option holdings are assumed to be zero. Depending on the specification, we include firm (F) and year (T) fixed effects. The set of controls includes Tobin's Q, operating cashflows, firm size, the firm's stock return, and leverage (see notes to Table 1 for details). We interact time and firm fixed effects with quintile dummies. The standard errors are clustered at the firm-level, and t-statistics are reported in parentheses.

Table 4: Effect of Insider's Option Exposure to Volatility

I/K	(1)	(2)	(3)	(4)
$INSD_L \times VEGA_L \times \log(\sigma_{i,t-1})$	-0.0221	-0.0172	-0.0223	-0.0175
	(-2.10)	(-1.87)	(-2.10)	(-1.90)
$INSD_L \times VEGA_H \times \log(\sigma_{i,t-1})$	0.0112	0.0127	0.0112	0.0108
	(1.72)	(1.79)	(1.73)	(1.57)
$VEGA_H - VEGA_L$	0.0333	0.0299	0.0335	0.0283
p-value	0.007	0.009	0.007	0.013
$INSD_H \times VEGA_L \times \log(\sigma_{i,t-1})$	-0.0315	-0.0286	-0.0320	-0.0296
	(-2.79)	(-2.83)	(-2.81)	(-2.91)
$INSD_H \times VEGA_H \times \log(\sigma_{i,t-1})$	0.0152	-0.0001	0.0148	-0.0007
	(1.32)	(-0.01)	(1.28)	(-0.07)
$VEGA_H - VEGA_L$	0.0467	0.0285	0.0468	0.0289
p-value	0.004	0.054	0.004	0.052
Total Observations	12708	12708	12708	12708
Fixed Effects	F	F, T	F	F, T
Controls	N	Y	N	Y
Option-adjusted Ownership	N	N	Y	Y

Table 4 reports estimation results of Equation (11) separately for firms with different levels of insider ownership and convexity of executive compensation. See notes to Table 2 for more details on our insider ownership measure. We measure compensation convexity by the Black-Scholes derivative of the value of their option portfolio with respect to the volatility of the underlying, $(\partial V/\partial\sigma)$, and aggregating within firm. The option data is from Execucomp. We use the methodology of Core and Guay (2002) to infer the strike prices and time to maturity for previously granted options. Every year, we first sort firms into terciles based on ownership by insiders (High, Medium, Low), and then sort into terciles based on the sensitivity of compensation to volatility (High, Medium, Low). We report results for the four corner portfolios. The sample period is 1992 – 2005. Depending on the specification, we include firm (F) and year (T) fixed effects. The set of controls includes Tobin's Q, operating cashflows, firm size, the firm's stock return, and leverage (see notes to Table 1 for details). We interact time and firm fixed effects with quintile dummies. The standard errors are clustered at the firm-level, and t-statistics are reported in parentheses. We report the Chow-test p-value for the null hypothesis that the idiosyncratic volatility, $\sigma_{i,t-1}$, coefficients on the high and low vega-groups are the same.

Table 5: Effect of Insider Ownership by levels of Institutional Ownership

I/K	(1)	(2)	(3)	(4)
$INST_L \times INSD_L \times \log(\sigma_{i,t-1})$	-0.0110	0.0042	-0.0116	0.0050
	(-1.12)	(0.45)	(-1.03)	(0.45)
$INST_L \times INSD_H \times \log(\sigma_{i,t-1})$	-0.0627	-0.0359	-0.0740	-0.0453
	(-5.21)	(-3.40)	(-5.04)	(-3.68)
$INSD_H - INSD_L$	-0.0517	-0.0401	-0.0624	-0.0503
p-value	0.001	0.004	0.001	0.002
$INST_H \times INSD_L \times \log(\sigma_{i,t-1})$	-0.0077	0.0005	0.0005	-0.0009
	(-1.34)	(0.08)	(0.08)	(-0.11)
$INST_H \times INSD_H \times \log(\sigma_{i,t-1})$	-0.0098	0.0041	0.0047	0.0001
	(-0.97)	(0.38)	(0.41)	(0.00)
$INSD_H - INSD_L$	-0.0021	0.0036	0.0042	0.0010
p-value	0.857	0.775	0.752	0.952
Total Observations	40705	40705	32230	32230
Fixed Effects	F	F, T	F	F, T
Controls	N	Y	N	Y
Option-adjusted Ownership	N	N	Y	Y

Table 5 reports estimation results of Equation (11) separately for firms with different levels of institutional ownership and levels of insider ownership. See notes to Table 2 for more details on our insider-ownership measure. Our data on institutional ownership come from the SEC 13f filings. Every year, we first sort firms into three equal-sized groups based on institutional ownership (High, Medium, Low), and then sort into three equal-sized groups based on ownership by insiders (High, Medium, Low). We report results for the four corner portfolios. The sample period is $1992 - 2005$. Depending on the specification, we include firm (F) and year (T) fixed effects. The set of controls includes Tobin's Q, operating cashflows, firm size, the firm's stock return, and leverage (see notes to Table 1 for details). We interact time and firm fixed effects with quintile dummies. The standard errors are clustered at the firm-level, and t-statistics are reported in parentheses. We report the Chow-test p-value for the null hypothesis that the idiosyncratic volatility, $\sigma_{i,t-1}$, coefficients on the high and low insider-ownership groups are the same.

Table 6: Endogeneity and measurement error

I_t/K_{t-1}	Q^{ibes}		β^{imc}		$\beta^{imc}\&Q^{ibes}$		OLS	EW_3	IV	
$\log(\sigma_{i,t-1})$	-0.0175	-0.0090	-0.0464	-0.0286	-0.0090	-0.0142	-0.0366	-0.0323	-0.1167	-0.1483
	(-4.78)	(-2.21)	(-15.60)	(-4.67)	(-2.09)	(-3.32)	(-11.95)	(-6.18)	(-7.00)	(-6.88)
Q^{ibes}_{t-1}	0.0435	0.0338			0.0248	0.0122				
	(16.83)	(1.64)			(6.00)	(0.99)				
β^{imc}_{t-1}			0.0074	0.0362	0.0016	0.0018				
			(7.58)	(2.68)	(0.93)	(0.84)				
Q_{t-1}							0.0032	0.0079		
							(9.48)	(2.20)		
$\log(Q_{t-1})$					0.0512	0.0098				0.0569
					(14.81)	(0.87)				(45.48)
Observations	33628	22678	77001	52801	24904	16839	104646	104646	91157	91157
AR(2) test (p-value)		0.822		0.761		0.097				
Sargan J-test (p-value)		0.147		0.397		0.118				
Bonferroni test (p-value)								0.001		
τ^2 statistic								0.465		
Kleibergen-Paap rk Wald F statistic									299.3	230.7
Fixed Effects	F,T	F,T	F,T	F,T	F,T	F,T	F,T	F,T	I	I,T
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Estimation Method	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM	IV	IV

Table 6 reports estimation results of a modified version of Equation (11), where the dependent variable is the investment rate (I_t/K_{t-1}). Q^{ibes} is constructed from analysts' forecasts as in Cummins et al. (2006). β^{imc} refers to the firm's univariate beta with a portfolio long the capital-producing sector and short the consumption-producing sector (IMC), see Kogan and Papanikolaou (2010b) for more details. Columns 1,3, 5 and 7 present results using OLS. columns 2, 4 and 6 present results using the Arrellano-Bond estimator, where the lagged investment rate is included in the specification. We report the LM/AR(2) test of second-order serial correlation and the Sargan/J test of over-identifying restrictions. In columns 1-6 the set of additional controls includes operating cashflows, firm size, the firm's stock return, and leverage (see notes to Table 1 for details). In columns 7-8 we include the lagged investment rate and we replace firm size with the firm's total sales (scaled by industry sales at the 3-digit SIC level) as controls. Depending on the specification, we include firm (F), industry (I) and/or year (T) fixed effects. Column 8 presents results using the Erickson and Whited (2000) estimator. We report the p-value of a joint test for the null of no identification across all time periods using the Bonferroni method and the τ^2 statistic. Columns 9 and 10 present estimation results using instrumental variables, where we instrument for idiosyncratic risk ($\sigma_{i,t-1}$) with the concentration of a firm's customer base, $H_{i,t}$, constructed using customer data from the COMPUSTAT segment files (see text for details). We report the value of the Kleibergen-Paap rk Wald F-test of the null of weak instruments. The critical value assuming 10% maximal IV size equals 16.38 (Stock and Yogo, 2005). In columns 1-6 and 9-10, standard errors are clustered at the firm level. In columns 7-8, standard errors are computed using the Fama and MacBeth (1973) procedure.

Table 7: Effect of insider ownership, controlling for size/financial constraints

I/K	(1)	(2)	(3)	(4)	(5)	(6)
$INSD_L \times \log(\sigma_{i,t-1})$	-0.0070	0.0050	-0.0046	-0.0009	-0.0055	0.0035
	(-0.77)	(0.57)	(-0.47)	(-0.11)	(-0.61)	(0.40)
$INSD_2 \times \log(\sigma_{i,t-1})$	-0.0179	-0.0091	-0.0199	-0.0111	-0.0242	-0.0140
	(-1.96)	(-1.04)	(-2.25)	(-1.32)	(-2.45)	(-1.57)
$INSD_3 \times \log(\sigma_{i,t-1})$	-0.0237	-0.0146	-0.0185	-0.0073	-0.0286	-0.0170
	(-2.33)	(-1.57)	(-1.81)	(-0.72)	(-2.87)	(-1.87)
$INSD_4 \times \log(\sigma_{i,t-1})$	-0.0372	-0.0028	-0.0353	-0.0148	-0.0412	-0.0123
	(-4.01)	(-0.31)	(-3.81)	(-1.62)	(-4.38)	(-1.29)
$INSD_H \times \log(\sigma_{i,t-1})$	-0.0285	-0.0275	-0.0322	-0.0241	-0.0311	-0.0280
	(-2.46)	(-2.59)	(-2.98)	(-2.44)	(-2.63)	(-2.56)
$INSD_H - INSD_L$	-0.0215	-0.0325	-0.0277	-0.0232	-0.0256	-0.0315
p-value	0.059	0.002	0.014	0.023	0.026	0.004
Observations	40985	40985	40773	40773	41206	41206
Control	WW	WW	RT	RT	A	A
Fixed Effects	F	F, T	F	F, T	F	F, T
Controls	N	Y	N	Y	N	Y

Table 7 reports estimation results of Equation (11) separately for firms with different levels of insider ownership, controlling for firm size and degree of financial constraints. Every year, we sort firms into 5×5 groups: based on firm size or the degree of financial constraints and then based on the level of insider ownership. We use three measures of financial constraints: the Whited and Wu (2006) index (WW), the firm's S&P credit rating (RT) and the book value of assets (A). We group firms with a similar credit rating as follows: group 1 contains firms rated AA- or better, group 2 contains firms rated A, group 3 contains firms rated BBB, group 4 contains firms rated BB+ or worse and group 5 contains unrated firms. The sample period is 1987 – 2005. Depending on the specification, we include firm (F) and year (T) fixed effects. The set of controls includes Tobin's Q, operating cashflows, firm size, the firm's stock return, and leverage (see notes to Table 1 for details). We interact time and firm fixed effects with quintile dummies. The standard errors are clustered at the firm-level, and t-statistics are reported in parentheses. We report the difference in coefficients on idiosyncratic risk across quintiles 1 and 5 and the Chow-test p-value for the null hypothesis that the coefficients are equal.

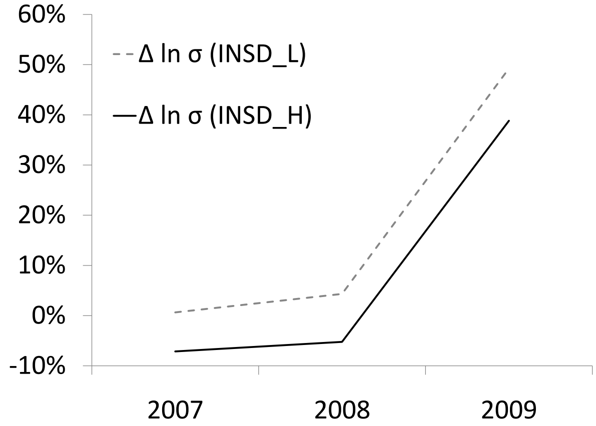
Table 8: Effect of Insider Ownership, controlling for investment irreversibility and competition/market power

I_t/K_{t-1}	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Controlling for degree of investment irreversibility and firm market power									
$INSD_L \times \log(\sigma_{i,t-1})$	0.0024	0.0226	-0.0127	-0.0044	-0.0126	-0.0012	-0.0134	-0.0043	-0.0129	-0.0036
	(0.10)	(0.90)	(-1.91)	(-0.72)	(-2.02)	(-0.20)	(-2.23)	(-0.72)	(-2.06)	(-0.58)
$INSD_2 \times \log(\sigma_{i,t-1})$	-0.0231	-0.0098	-0.0256	-0.0134	-0.0259	-0.0114	-0.0276	-0.0140	-0.0219	-0.0083
	(-0.75)	(-0.27)	(-3.94)	(-2.09)	(-3.92)	(-1.68)	(-4.19)	(-2.07)	(-3.17)	(-1.28)
$INSD_H \times \log(\sigma_{i,t-1})$	-0.0816	-0.0648	-0.0377	-0.0214	-0.0338	-0.0206	-0.0407	-0.0258	-0.0454	-0.0297
	(-2.32)	(-1.94)	(-4.89)	(-3.03)	(-4.41)	(-2.96)	(-5.31)	(-3.72)	(-6.11)	(-4.34)
$INSD_H - INSD_L$	-0.0840	-0.0874	-0.0250	-0.0171	-0.0212	-0.0194	-0.0273	-0.0215	-0.0325	-0.0261
p-value	0.048	0.036	0.013	0.062	0.028	0.033	0.004	0.015	0.001	0.004
Observations	2184	2184	41179	41179	40454	40454	40661	40661	40828	40828
	Controlling for degree of investment irreversibility and industry competition									
$INSD_L \times \log(\sigma_{i,t-1})$	0.0239	0.0291	-0.0093	-0.0018	-0.0074	0.0012	-0.0124	-0.0007	-0.0091	0.0001
	(1.15)	(1.53)	(-1.67)	(-0.34)	(-1.27)	(0.21)	(-2.26)	(-0.14)	(-1.56)	(0.03)
$INSD_2 \times \log(\sigma_{i,t-1})$	-0.0481	-0.0047	-0.0281	-0.0100	-0.0281	-0.0076	-0.0335	-0.0130	-0.0284	-0.0105
	(-1.42)	(-0.13)	(-4.26)	(-1.59)	(-4.45)	(-1.19)	(-5.17)	(-1.93)	(-4.33)	(-1.66)
$INSD_H \times \log(\sigma_{i,t-1})$	-0.0630	-0.0536	-0.0438	-0.0275	-0.0404	-0.0255	-0.0417	-0.0274	-0.0442	-0.0293
	(-1.74)	(-1.45)	(-5.46)	(-3.59)	(-4.97)	(-3.36)	(-5.10)	(-3.64)	(-5.47)	(-3.91)
$INSD_H - INSD_L$	-0.0868	-0.0827	-0.0345	-0.0257	-0.0331	-0.0267	-0.0293	-0.0266	-0.0352	-0.0295
p-value	0.046	0.046	0.000	0.005	0.001	0.005	0.003	0.004	0.000	0.001
Observations	2184	2184	41028	41028	40308	40308	40517	40517	40682	40682
Irreversibility Measure	P	P	δ	δ	β^{ind}	β^{ind}	U	U	S	S
Fixed Effects	F	F, T	F	F, T	F	F, T	F	F, T	F	F, T
Controls	N	Y	N	Y	N	Y	N	Y	N	Y

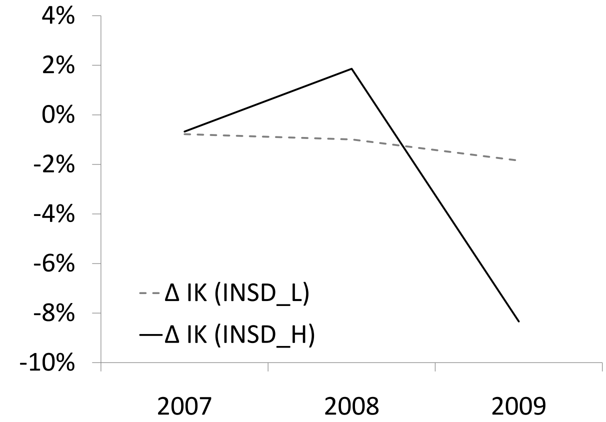
Table 8 reports estimation results of Equation (11) separately for firms with different levels of insider ownership, controlling for the degree of investment irreversibility and industry competition or firm market power. Every year, we sort firms into $3 \times 3 \times 3$ groups: based on the degree of industry irreversibility, then on the degree of firm market power (top panel) or industry competition (bottom panel), and then on the level of insider ownership. We use five measures of investment irreversibility: age-adjusted price discount between new and old capital (P), using data from Ramey and Shapiro (2001); the mean depreciation rate of the industry, (δ); the firm's beta with the corresponding industry portfolio, (β^{ind}); the ratio of new to used investment at the industry level from the Census Bureau, (U); and the average ratio of sales of property plant and equipment to capital for the industry during the 1970-80 period, (S). We use the Herfindahl index as a measure of industry competition and the ratio of firm sales to total industry sales as a measure of firm market power. Industries are defined at the 3-digit SIC code. See notes to Table 2 for more details on our insider-ownership measure. The sample period is $1987-2005$. See notes to Table 1 for details on the set of controls and fixed effects. The standard errors are clustered at the firm-level.

Figure 1: Idiosyncratic Volatility and Investment

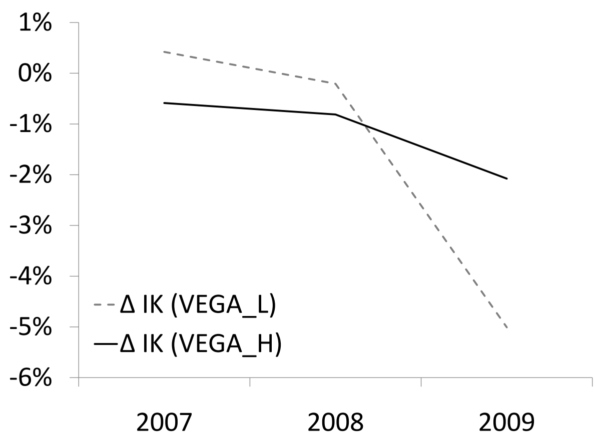
A: Change in idiosyncratic volatility (relative to 2006) for High- and Low- insider-ownership firms



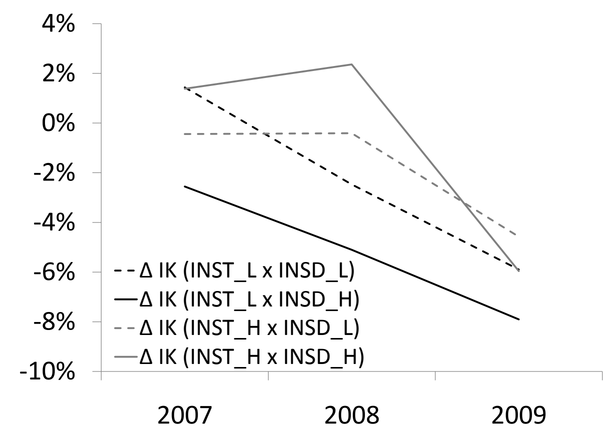
B: Change in portfolio investment rates (relative to 2006) for High- and Low- insider-ownership firms



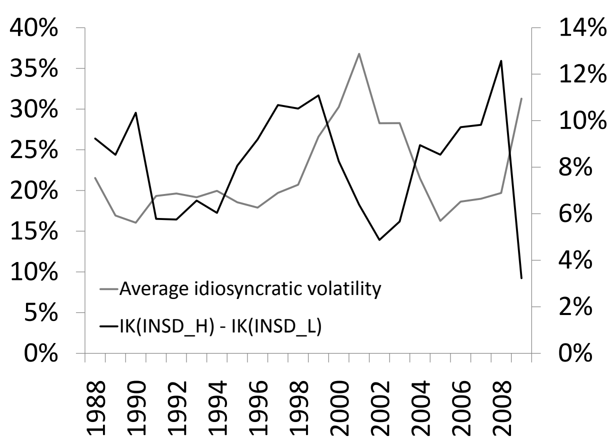
C: Change in portfolio investment rates (relative to 2006) for High- and Low- compensation convexity



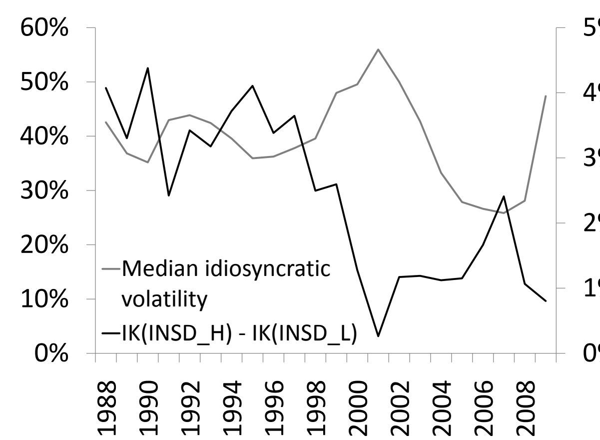
D: Change in portfolio investment rates (relative to 2006) for High- and Low- insider-ownership firms, by levels of institutional ownership



E: Portfolio investment rates of High- minus Low- insider ownership firms versus idiosyncratic volatility, average weighted by capital stock



F: Median portfolio investment rates of High- minus Low- insider -ownership firms versus idiosyncratic volatility, median



Appendix

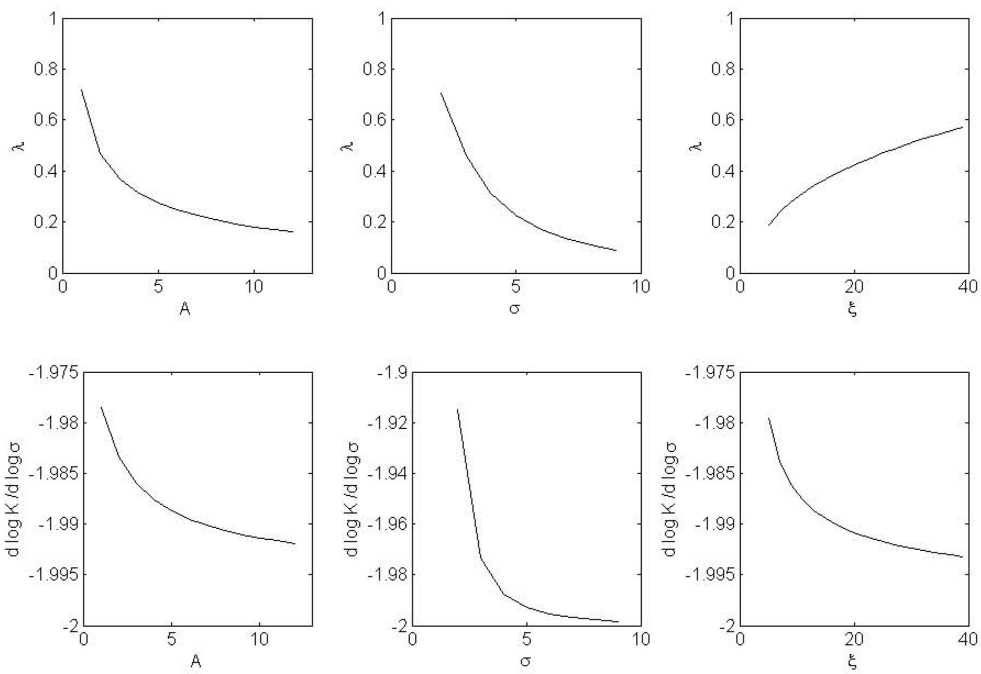
Model: solution for optimal level of ownership

For the model in Section 2, let $v(e) = e^{\xi\, e}$. The optimal choice of insider ownership, λ^*, and transfers, T^*, solves the following maximization program

$$\max_{\lambda, T} \quad \Big\{ -\exp(-A\,((1-\lambda)\,C - T)) - \beta \exp(-A(1-\lambda)(\mu\sqrt{K} + e)) \\ -e^{\xi\, e} - \exp(-A\,(\lambda\, C + T - B)) - \beta\, E_0 \exp(-A\,(\lambda\,(X\sqrt{K} + e) + R\,B)) \Big\}$$

subject to (5)-(7).

Figure 2: Optimal Ownership and Elasticity of Capital to Risk



This figure plots the solution of the model in terms of the optimal share of insider ownership, λ^*, as a function of three parameters: the coefficient of absolute risk aversion, A, the level of idiosyncratic risk of the firm, σ, and the shape of the cost of effort, ξ. The top panel plots λ^*, and the bottom panel plots the elasticity of capital to idiosyncratic risk evaluated at λ^*. We choose $C = 0$, $b = 1$, $R = 1$, $A = 4$, $\sigma = 4$, $\xi = 11$.

Data construction

replacement value of capital

We follow the methodology of Salinger and Summers (1983) and use the perpetual inventory method to compute the replacement value of the capital stock. We initialize the first value of the capital stock as gross PPE (item 7). We then construct the capital stock iteratively as $K_{t+1} = (P_{t+1}/P_t K_t + I_{t+1})(1 - \delta_j)$ where P is the price deflator for fixed non-residential investment, I is capital expenditure (data128) and δ_j is book depreciation rate and the 3-digit SIC level. We compute $\delta_j = 2/L_j$, where L_j is the useful life of capital goods, computed as $L_j = \frac{1}{N_j} \sum_{i \in j} \frac{PPE_{t-1}+I_t}{DEPR_t}$.

Tobin's Q

We construct the numerator of Q as December market value of equity, plus book value of debt (item 9), plus book value of preferred stock (item 56) minus inventories (item 3). The denominator is the replacement value of capital.

insider ownership

Our source of managerial ownership data is the Thomson Financial database of filings derived from Forms $3, 4, 5$, over the period $1986 - 2005$. We take as measure of insider ownership in year t the reported yearly holdings of a firm's shares held by firm officers at the end of that year or at the latest filing date, as a fraction of the shares outstanding in the firm. We include insiders with the following role classifications: O, OD, OE, OB, OP, OS, OT, OX, CEO, CFO, CI, CO, CT, H, GM, M, MD, P, EVP, VP, SVP.

convexity of executive compensation scheme

We use data on CEO option grants from Execucomp and the BlackScholes option-pricing model as adjusted for dividends by Merton (1973) to compute the partial derivatives with respect to stock-return volatility (*vega*) and to stock price (*delta*). We use the Core and Guay (2002) procedure for deriving approximate estimates of the time-to-maturity and of the exercise price for existing option grants. We construct firm-level measures of convexity and level exposure by aggregating across executives in Execucomp:

$$\overline{VEGA}_{i,t} = \sum_j \sum_s \frac{1}{E_{i,t}} N_{j,i,s,t} vega_{j,i,s,t}$$

$$\overline{DELTA}_{i,t} = \sum_j \sum_s N_{j,i,s,t} delta_{j,i,s,t},$$

where $N_{j,i,s,t}$ refers to the options of type s granted to executive j in firm i at time t, $E_{i,t}$ refers to the number of executives in firm i at time t, and $vega_{j,i,s,t}$ and $delta_{j,i,s,t}$ refer to the sensitivities of option s granted to executive j in firm i at time t with respect to volatility and stock price respectively.

option-adjusted insider ownership

Since one single share has $\delta = 1$, endowing the manager with N_o options with a $delta = \delta$ is equivalent, in terms of stock-price exposure, to endowing him with $N_o \times \delta$ units of stock. We thus add $\overline{DELTA}_{i,t}$ to the number of shares held by insiders.

institutional ownership

We obtain data on institutional holdings from the Thomson Financial Institutional Holdings (13F) database. We extract quarterly holdings starting in the first quarter of 1980 and ending in the last quarter of 2005. We calculate the share of institutional ownership by summing the stock holdings of all reporting institutions for each stock at the end of each year. We follow Nagel (2005) in adjusting institutional data for stock splits.

measure of Tobin's Q from I/B/E/S data on analysts' earnings forecasts.

We follow Cummins et al. (2006) in constructing our alternative measure for Q, denoted by Q^{ibes}, for each firm i and each year t:

$$Q^{ibes} = \beta ECF_{it} + \beta^2(1-\delta)ECF_{i,t+1} + \frac{1}{2}(ECF_{i,t} + ECF_{i,t+1}) \sum_{k=3}^{n} [\beta^k (1-\delta)^{k-1}(1+EGR_{it})^{k-2}] \ ,$$

where ECF_{it} and $ECF_{i,t+1}$ are the consensus forecasts for firm i's expected net income in periods t and $t+1$, respectively, scaled by the replacement value of the capital stock at the beginning of period t, EGR_{it} is the firm's expected growth rate of net income in the following periods, β is the discount factor set at 0.91, δ is the depreciation rate set at 0.15, and n is the number of years set at 10.

IMC-beta

We use the firm's stock-return beta with respect to the IMC portfolio returns as a measure of this firm's investment-specific shock sensitivity. For every firm in Compustat with sufficient stock-return data, we estimate a time-series of (β_{ft}^{imc}) from the following regression

$$r_{ftw} = \alpha_{ft} + \beta_{ft}^{imc} r_{tw}^{imc} + \varepsilon_{ftw}, \qquad w = 1 \ldots 52. \tag{12}$$

Here r_{ftw} refers to the (log) return of firm f in week w of year t, and r_{tw}^{imc} refers to the log return of the IMC portfolio in week w of year t. Thus, β_{ft}^{imc} is constructed using information only in year t.

We omit firms with fewer than 40 weekly stock-return observations per year, firms in their first three years following the first appearance in Compustat, firms in the investment sector, financial firms (SIC codes 6000-6799), utilities (SIC codes 4900-4949), and government-regulated industries (SIC code > 9000).

customer concentration

Our measure of customer concentration is based on the Herfindahl index:

$$H_{i,\,t} = \sum_p \left(\frac{sales_{p,\,i,\,t}}{sales_{i,\,t}} \right)^2 \ ,$$

where $sales_{p,\,i,\,t}$ represents the reported sales of firm i to customer p at time t, and $sales_{i,\,t}$ represents the total sales of firm i at time t. Regulation SFAS No. 131 requires firms to report information about operating segments in interim financial reports issued to shareholders. In particular, firms are required to disclose the amount of sales to and the identity of any customer representing more than 10% of the firm's total reported sales. We normalize H by the total sales of the firm, i.e. COMPUSTAT item 12, rather than $\sum_p sales_{p,\,i,\,t}$ because we are interested in the concentration of an entire firm's customer base, rather than within the set of large customers. Our measure effectively replaces the sales of customers who represent less than 10% with zero.

age-adjusted price discount between used and new capital

We use the data from Ramey and Shapiro (2001). The data consists of used sales prices from auctions of equipment from aerospace plants that closed during the 1990s. The data are at the equipment level, and consist of the sale price of the equipment (S), its original acquisition cost (C) and its age (A), along with the SIC code of the buyer. We use this data to construct a measure of the age-adjusted discount (from new to used) at the level of the purchasing industry. Our age-adjusted discount measure is the residual r from the regression:

$$\log(C_i/S_i) = a_0 + a_1 A_i + r_i \ .$$

We average r_i at the purchasing industry level to obtain a measure of the discount. Given that the equipment originally came from aerospace plants, the data are concentrated on a few industries, mostly manufacturing.

We have data for 38 industries, and a sample of 5485 firm-year observations.

purchases of new versus used capital goods

Our data comes from the annual capital expenditures survey (ACES), published by the Census Bureau. We use the 1994 survey, table 2, and compute the ratio of Total expenditures to Total new expenditures at industry level, using SIC codes.

credit rating

Our data on credit ratings comes from Standard& Poor's. We use the firm's long-term credit rating (lrating).

firm industry beta

We estimate the firm's sensitivity to its corresponding industry portfolio from Equation (9).

industry capital depreciation

We measure capital depreciation as the ratio of item 103 (or item 14 - item 65 if missing) to the replacement value of capital. We compute the average at the 3-digit SIC industry level by year.

industry capital sales

We measure capital sales as the ratio of sales of property plant and equipment (item 107) to the replacement cost of capital. We compute the industry-level average of capital sales over the first half of the sample (1970-1987).

investment and volatility during the financial crisis

We compute the average investment rate and the lagged idiosyncratic volatility for each portfolio, weighted by lagged capital stock, as follows:

$$i_t^{vw} = \sum_i CAPX_{i,t} / \sum_i K_{i,t-1},$$

and

$$\sigma_{t-1}^{vw} = \sum_i K_{i,t-1}\, \sigma_{i,t-1} / \sum_i K_{i,t-1},$$