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FIRM VALUE, RISK, AND GROWTH OPPORTUNITIES

Hyun-Han Shin
René M. Stulz

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ABSTRACT

We show that Tobin's q, as proxied by the ratio of the firm's market value to its book value, increases with the firm's systematic equity risk and falls with the firm's unsystematic equity risk. Further, an increase in the firm's total equity risk is associated with a fall in q. The negative relation between the change in total risk and the change in q is robust through time for the whole sample, but it does not hold for the largest firms.

Hyun-Han Shin
University of Buffalo
SUNY Buffalo
School of Management
Buffalo, New York 14260

René M. Stulz
Max M. Fisher College of Business
The Ohio State University
806A Fisher Hall
2100 Neil Avenue
Columbus, OH 43210
and NBER
stulz@cob.ohio-state.edu

1. Introduction.

This paper explores the relation between expected risk and Tobin's q, proxied by the ratio of the firm's market value to the book value of its assets. We find that an increase in systematic equity risk increases q and that an increase in unsystematic equity risk and in total equity risk decreases q, except for the largest firms.

If expected cash flows are unrelated to equity risk, q should be negatively related to systematic risk because cash flows are discounted at a higher rate for firms with greater systematic risk and we would expect unsystematic risk to have no relation with firm value. Our evidence is therefore inconsistent with the view that expected cash flows are unrelated to risk and shows instead that expected cash flows must increase with systematic risk if the capital market discounts cash flows using the capital asset pricing model. Further, our evidence shows that expected cash flows increase with systematic risk to an extent greater than would be required to offset the impact of the increase in systematic risk on the discount rate to keep the present value of cash flows constant as systematic risk increases.

Modern finance theory offers several reasons why expected cash flows might be related to the risk of cash flows. Firm value is often decomposed into the value of assets in place and the value of growth opportunities. There is a considerable literature that emphasizes the option properties of growth opportunities.[1] If growth opportunities are real options on cash flows from assets in place, firms with greater volatility would have more valuable growth opportunities everything else kept constant. The real options view of growth opportunities therefore suggests that a firm's q should increase with the firm's total risk.

Both the static-tradeoff capital structure literature and the risk management literature make the volatility of equity endogenous. With the static-tradeoff capital structure literature, the firm trades off tax benefits from debt with costs of financial distress. For a given level of debt, the

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[1] See Dixit and Pindyck (1993).

greater the volatility of equity the more likely it is that the firm will incur costs of financial distress. The firm can reduce the volatility of equity by reducing its debt. Everything else equal, it is optimal for firms with high costs of financial distress to have less debt and hence a lower equity volatility. If the positive correlation between debt and equity volatility is strong enough, firms with lower equity volatility will have a smaller tax shield of debt and a lower q.[2] In this case, therefore, firm q is negatively related to equity volatility over some range.

The risk management literature argues that firms can benefit from managing risk because excess risk increases the present value of the costs of financial distress and can lead to suboptimal investment if external financing and renegotiations are costly.[3] While Minton and Schrand (1999) provide evidence of a negative contemporaneous relation between cash flow volatility and investment and of a positive contemporaneous relation between the cost of debt and cash flow volatility that is supportive of the arguments of the risk management literature, there is no investigation that focuses on the relation between firm value and expected risk. On theoretical grounds, the risk management literature implies that the equilibrium relation between equity risk and firm q can be positive or negative. To understand this, it is best to think of a firm choosing the optimal amount of hedging by setting the marginal cost of bearing unhedged risk equal to the marginal cost of hedging risk. It is reasonable to assume that the marginal cost of bearing

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[2] Note that as equity volatility falls for a constant face value of debt, the probability of financial distress falls if the firm is not currently financially distressed (see Stulz (2000), chapter 18). As a result, for constant debt, one would expect that a decrease in equity volatility is associated with an increase in the value of the tax shields of debt. Hence, for the assumed result to hold, it must be that debt falls fast enough as equity volatility increases to offset the positive impact of a decrease in equity volatility on the present value of tax shields of debt.

[3] For models where risk leads to suboptimal investment, see Stulz (1990) and Froot, Scharfstein, and Stein (1993). Smith and Stulz (1985) focus on tax and financial distress costs as determinants of risk management policies. A number of recent papers show that the theoretical risk management literature is useful to understand the risk management policies of firms (see, for instance, Geczy, Minton, and Schrand (1997), Tufano (1996), and Haushalter (2000)). Under some conditions, an optimal risk management policy can increase risk. As pointed out by Froot, Scharfstein, and Stein (1993), a policy designed to enable the firm to take advantage of its investment opportunities can lead the firm to take positions in derivatives that increase the variability of its cash flow if investment opportunities are positively correlated with cash flows.

unhedged risk increases with the amount of unhedged risk and that the marginal cost of hedging risk increases with the amount of risk hedged. If the marginal cost function of bearing unhedged risk varies across firms but the marginal cost function of hedging risk does not, firms with a high cost of bearing unhedged risk will have less unhedged risk and there is a positive relation between risk and q. If the marginal cost function of bearing unhedged risk is the same across firms but the marginal cost function of hedging risk varies across firms, the opposite is true. Yet, in both of these cases, an exogenous increase in unhedged risk is associated with a decrease in firm q, so that there is a negative relation between changes in risk and changes in q.

The literature on the diversification discount offers a different reason for why q should increase with firm risk. That literature shows that diversified firms are valued less on average than comparable portfolios of specialized firms.[4] Everything else equal, a diversified firm will generally have lower volatility than a specialized firm. Consequently, the existence of a diversification discount implies that higher volatility firms have higher value. Our evidence is consistent with the existence of a diversification discount for large firms, in that an increase in volatility for these firms has a positive effect on their q.

Finally, the option pricing literature predicts a negative relation between changes in equity value and equity volatility for a levered firm when the rate of return for the firm as a whole has a constant volatility. This negative relation has been studied extensively in papers that analyze the time-series behavior of volatility. Following Black (1976) and Christie (1982), these papers investigate whether the negative relation between equity value and volatility depends on leverage. Some of these papers look at firms (for instance, Cheung and Ng (1992), Duffee (1995), and Bekaert and Wu (2000)) while other papers look at the market as a whole (for instance, Schwert (1989)). The evidence from these papers suggests that in time-series models the negative relation between equity and volatility cannot be explained by leverage alone. This literature therefore

[4] See Lang and Stulz (1994) and Berger and Ofek (1995).

raises the question of how the negative relation between equity value and volatility can be explained.

The paper is organized as follows. In Section 2, we make clearer the predictions of the various literatures summarized in the introduction and discuss the difficulties associated with evaluating the relation between risk and firm value. In Section 3, we describe how our sample and our risk measures are constructed. In Section 4, we show the relation of q to systematic risk, unsystematic risk, and total risk. In Section 5, we attempt to explain our results on the relation between unsystematic risk and firm q. We conclude in Section 6.

2. Risk, growth opportunities, and firm value: Some theoretical issues.

In this section, we discuss the predictions about the relation between risk and firm value in more detail. q is the market value of equity (E) plus debt (D) divided by assets (A), or (E + D)/A. In our empirical work, D is measured using book values since market values of debt are not available for samples like ours. Our empirical work uses various measures of risk, but unless specified otherwise, risk is understood to be total risk, meaning the sum of systematic and unsystematic risk. We divide the analysis into three parts. First, we discuss the impact of growth options on the relation between firm q and risk. Second, we derive the predictions of static capital structure theories and of risk management theories for the relation between q and risk. Third, we investigate the implications of the fact that equity is an option whose value depends on its volatility for our empirical analysis. Fourth, we summarize the testable hypotheses.

2.1. Growth opportunities and the relation between firm q and risk.

To understand the impact of growth opportunities on the relation between firm q and risk, we consider an all-equity firm. We assume further that the firm has an asset in place plus a growth opportunity. The value of the asset in place, A, is given and does not depend on the volatility of its return. If the growth opportunity is an opportunity to expand the firm by acquiring ω more of the asset in place at a cost of K, the value of the firm is A + C, where C is the value of a call option on ωA with exercise price equal to the required investment K. With our assumptions, an increase in the variance of the rate of change of A has no impact on A but increases C. With this notation, q is (A+C)/A. Consequently, for a given value of A, q is an increasing function of the variance of A. An increase in A necessarily increases q since it increases the value of the firm's growth opportunity.

Real options theory does not make an unambiguous prediction for the relation between the variance of equity and q. For instance, nothing precludes the possibility that high volatility firms have high K's. If the positive relation between equity volatility and K were large enough, then there would be a negative relation between q and equity volatility. Growth options would have trivial value for high volatility firms because the exercise price of the options would be large for these firms. Yet, for a given firm, an increase in volatility keeping K, ω, and A constant necessarily increases q.

2.2. Capital structure and risk management theories.

To simplify the analysis, consider a model where large negative shocks to cash flows – and hence firm value -- have deadweight costs. In particular, such shocks increase the costs of financial distress and decrease the tax benefits of debt. If firms could costlessly hedge, they would do so and would have higher value. Further, at the lower level of risk, they could support more debt, so that they would have a larger tax benefit from debt. We can model this situation as one where a firm has a cost of bearing unhedged risk. Assume that the cost of bearing unhedged risk is an increasing convex function of the firm's unhedged risk, where unhedged risk is the risk of cash flows after hedging. The firm also has a cost of hedging risk. Assume that this cost is increasing and convex. The firm can use plain vanilla financial derivatives to hedge some risks.

Plain vanilla financial derivatives generally have very low transaction costs. Some risks are much harder and much more costly to hedge, so that decreasing risk further becomes more expensive. The total cost of bearing a given amount of unhedged risk for the firm is the sum of the cost of bearing that amount of unhedged risk plus the cost of having hedged risk to attain that level of unhedged risk. The firm has an optimal amount of total unhedged risk where the net cost of unhedged risk is minimized.

The optimal amount of unhedged risk is obtained by setting the marginal cost of bearing unhedged risk equal to the marginal cost of hedging risk. With our assumptions, the marginal cost of bearing unhedged risk is increasing in unhedged risk and the marginal cost of hedging risk is decreasing in the unhedged risk the firm bears or, equivalently, is increasing in the extent to which the firm has hedged its risk. Figure 1 shows the marginal cost function of bearing unhedged risk and the marginal cost function of hedging risk. Suppose now that firms differ in their marginal cost of bearing unhedged risk functions but not in their marginal cost of hedging risk functions. In this case, firms will plot on the marginal cost of hedging risk curve. Firms with a higher marginal cost of bearing unhedged risk function will have less unhedged risk as shown in Figure 2. Firms with less unhedged risk will have lower q, however, because their combined total cost of bearing unhedged risk plus hedging risk will be higher. Consequently, it is perfectly possible for firms with more unhedged risk to have higher value when risk management is more valuable for some firms than others.

Consider now the impact of an exogenous increase in risk before hedging. This shifts the cost of hedging risk curve to the right and leaves the cost of bearing unhedged risk curve unchanged as shown in Figure 3. Following the increase in risk before hedging, the firm incurs a larger cost of bearing unhedged risk and pays more to hedge risk. As a result, the firm's q falls and its equilibrium level of bearing unhedged risk increases. Hence, there is a negative relation between changes in unhedged risk and changes in q.

2.3. Equity as an option and the relation between firm q and risk.

The fact that equity has option characteristics has important implications for our analysis. Many papers, using the insights of the option pricing literature, emphasize the relation between equity volatility and firm leverage. These papers have shown a negative relation between equity value and volatility that has been attributed partly to leverage. In particular, Christie (1982) provides evidence that is supportive of the role of leverage in the relation between equity and volatility. A number of recent papers find that leverage can only explain part of the negative relation between stock returns and leverage. For instance, Schwert (1989) finds some support for the leverage hypothesis at the market level. Cheung and Ng (1992) and Duffie (1995) find that the negative relation between the level of stock prices and volatility is stronger for smaller firms. Duffie (1995) argues that the negative relation between changes in volatility and returns is due to a strong positive relation between returns and contemporaneous volatility rather than by the negative relation between future volatility and returns predicted by the leverage argument. Bekaert and Wu (2000) reject the Christie (1982) model for Japan, but find support for a feedback model where changes in conditional volatility lead to changes in expected returns. These and other papers in this literature focus on daily, weekly or monthly returns and investigate the behavior of the time-series of volatility estimates for firms or portfolios. Instead, we focus on finding whether changes in risk can help explain firm value changes, controlling for other determinants of firm value changes.

To understand the implications of the option characteristics of equity for this paper, it is useful to use Merton's (1974) model of equity and debt valuation. With this model, firm value, V, is lognormally distributed and trading is continuous. Financial markets are assumed to be perfect. Interest rates are assumed to be constant. The firm has issued discount debt that matures at a future date and has face value of F. Equity is an option on firm value that pays Max(V – F, 0) at maturity of the discount debt. With these assumptions, the Black-Scholes formula gives the value of equity. Firm value minus the value of equity is the value of the debt. The Modigliani-Miller proposition of leverage irrelevance holds.

With Merton's model, the volatility of the firm is constant and the face value of the debt is constant. Yet, because the firm is levered, the volatility of equity depends on firm value. As firm value increases, the firm becomes less levered and as a result the volatility of equity falls. The relation between firm volatility and equity volatility can be stated precisely as:

$$\text{Equity volatility} = (E_V V/E)^*\text{Firm volatility}$$

where E_V is the derivative of equity value with respect to firm value, which is simply the call option's delta. Figure 4 plots equity volatility as a function of firm value and face value of debt in Merton's model. There is a negative relation between equity volatility and firm value, but this relation depends nonlinearly on the level of firm value. As firm value becomes large relative to the face value of debt, a change in firm value has almost no impact on equity volatility. In contrast, for highly levered firms, a small change in firm value can have a large negative impact on equity volatility. In Merton's model, the face value of debt is given and does not change. The result that we emphasize holds as long as the firm does not increase its debt as firm value increases up to the point where the volatility of equity is kept constant.

Merton's model implies a negative relation between changes in firm value and changes in equity volatility even though in that model there is no relation between firm value and firm risk. Consequently, finding a negative relation between a change in firm value and a change in equity volatility by itself has no implication for whether total risk has an adverse impact on firm value. One might think that focusing on firm total risk instead of equity total risk could eliminate this difficulty. Unfortunately, this is not so with book debt. Without debt values, we cannot estimate the debt beta. If we take the debt beta to be zero, firm volatility is E/(D+E) times equity volatility. Since D + E is our measure of firm value, our estimate of firm volatility is then E/V times equity volatility. Since q is V/A, or (E + D)/A, this approach creates a mechanical positive relation between q and firm volatility for constant equity volatility. To see this, suppose E increases for constant equity volatility, book value of debt, and book value of assets. As a result, firm volatility increases since E/V increases. At the same time, though, q increases because V increases for constant assets, so that there is a positive relation between an increase in V and an increase in firm volatility. With market value measures of debt, we would be able to measure the risk and value of debt. An increase in E for constant equity volatility would correspond to an increase in firm volatility which would decrease D. If firm value is unrelated to firm volatility, D would fall sufficiently to keep V unchanged, so that there would be no relation between firm volatility computed using market values and q computed using market values. To avoid the mechanical relation between q and firm volatility resulting from the use of book values, we focus instead on equity volatility.

Since Merton's model implies a negative relation between firm value and volatility that is due to changes in firm value rather than changes in firm volatility, we should be able to eliminate the effect predicted by Merton's model if we control for changes in firm value that are not caused by changes in firm volatility. Suppose that firm volatility is constant. In this case, firm value changes because of changes in expected cash flows. Hence, by controlling for earnings changes, we should capture some of the value change that is not caused by volatility changes but causes changes in equity volatility. Therefore, when we consider the impact of volatility changes on q taking into account earnings changes, we should be measuring the impact of volatility changes that is not due to the leverage effect. Unfortunately, by doing so we might be understating the impact of volatility changes not due to the leverage effect because an increase in volatility could have an immediate negative impact on earnings. Another way to evaluate the impact of volatility changes that is free of the leverage effect is to look at firms with trivial leverage. We employ both approaches.

Merton's model assumes a constant volatility of firm value. However, if we increase the volatility of firm value keeping the value of assets in place constant, q increases. Hence, if we can use the comparative statics of Merton's model to approximate the comparative statics in a world where firm volatility changes randomly, it follows that positive shocks to firm volatility are associated with increases in q in that model when book value of debt is used. In other words, if we were able to explain changes in value that are not due to changes in volatility, then we should find a positive relation between volatility and q. This is the traditional asset substitution effect emphasized by Jensen and Meckling (1976).

2.4.Testable hypotheses.

None of the theories discussed in this section offer unambiguous predictions about the relation between q and risk, but all theories have clear predictions for the relation between changes in risk and changes in q. These predictions are as follows:

1. **Growth options.** An increase in volatility increases the value of growth options. Since growth options are part of V – A, an increase in the value of growth options increases q. Therefore, there is a positive relation between changes in q and changes in firm risk.
2. **Cost of risk.** Existing static tradeoff capital structure theories and risk management theories generally show that there is a negative relation between unexpected changes in risk and changes in q.
3. **Option characteristics of equity.** Keeping the book value of assets constant, an increase in risk increases the value of equity. However, for constant risk of firm value and constant debt, an increase in firm value decreases the volatility of equity. Hence, keeping volatility of firm value constant, there is a negative relation between the changes in equity risk and the changes in q. This negative relation should be more

pronounced for firms with more debt. Further, the option pricing model implies that the relation between risk and firm value is asymmetric – an increase in firm value has a smaller absolute value impact on volatility than a decrease in firm value.

3. The sample and the risk measures.

Following Fama and French (1998), we start with all firms recorded in COMPUSTAT for the period from 1965 to 1992. Since we use stock returns to measure risk, we restrict our sample to firms whose stock returns are available on the CRSP database. We drop 1% of the observations in each tail of each independent variable used in the regressions we report and require that sample firms have at least one million dollars of assets.

We focus on three different measures of risk. The first measure is systematic risk, measured as beta squared times the variance of the market return. The second measure is unsystematic risk, computed as the variance of the residual of a market model regression. The third measure is the firm's total risk, measured as the variance of the firm's stock return.

The corporate finance literature we referred to in the introduction argues that expected risk measures are relevant in firm valuation. This requires us to form measures of expected risk. One approach would be to use a time-series model. This approach would increase our data requirements since we would need enough past stock returns. A second approach would be to use implied volatilities. However, we want our study to use a broad cross-section of firms rather than only firms that have traded options. We therefore proceed as follows for most tests reported in this paper. When we consider q in fiscal year t, this is the q corresponding to the data available at the end of year t. The focus of our analysis is whether q in year t is related to expected risk for year t+1. We proxy for expected risk in year t+1 by the realized risk in year t+1. The risk measures do not follow random walks. Consequently, we cannot use the risk measure in year t as the expectation of the risk measure in year t+1. If we were to use data before year t+1 to forecast risk in year t+1, we would therefore need a time-series model. Using such a model would force us to discard a large number of firms from our sample if we wanted to forecast yearly volatility. The survivorship bias that the resulting sample would severely limit the interest of our results.[5] With rational expectations, risk in year t+1 is equal to the market's expectation plus a random error. We do not observe the market's expectation of the firm's risk for year t+1. Our proxy for the market's expectation is the market's expectation plus a random error. This error biases the slope of the regression coefficient towards zero when the only independent variable is the risk measure. As a result, we might fail to find a significant relation between changes in risk and changes in firm value because of the errors-in-variables problem.

We estimate the yearly standard deviation of a stock's return using daily returns following Schwert (1989) for the fiscal year period (not for the calendar period). The estimator of the variance of the yearly return is the sum of the squared daily log returns after subtracting the average daily log return in the fiscal year:

$$\hat{\boldsymbol{s}}_{tj}^{2} = \sum_{i=1}^{N_t} (r_{itj} - \bar{r}_{tj})^2$$

where there are N_t daily log returns, r_{jt}, in fiscal year t firm j. To obtain estimates of systematic and unsystematic risk, we use the market model:

$$r_{ij} = \boldsymbol{a}_j + \boldsymbol{b}_j r_{mi} + \boldsymbol{e}_{ij}$$

where r_{ij} is the log return of firm j for day i and r_{mi} is the log return of the CRSP value-weighted index for day i. We report results using ordinary-least-squares estimates of the market model. We also estimated Scholes-Williams $\boldsymbol{b}$'s, which led to similar results. Systematic risk is the product of

[5] Duffee (1995) points out that the relation between volatility and returns is stronger for firms that do not survive in his sample than for firms that do.

b_j^2 and the variance of the value weighted index return. Unsystematic risk is the variance of e_{ij}. Total risk is the sum of systematic risk and unsystematic risk.

Table 1 provides summary statistics for q and for our risk measures. Not surprisingly, unsystematic risk is much larger than systematic risk. The mean of q is positive. Unsystematic risk, total risk, and q have distributions that are skewed to the right. The average first difference of unsystematic risk is positive. This is consistent with evidence of a positive drift of unsystematic risk over our sample period observed by Campbell and Lettau (1999) and Malkiel and Xu (1999).

4. The relation between risk and q.

Table 2 shows the relation between risk and q using several different specifications for our whole sample. In all regressions reported in that table, we use the same control variables. We choose the control variables to be exogenous, but useful in predicting q. We therefore use industry dummy variables determined by the firm's two-digit SIC code, the log of the firm's age, and the log of the firm's assets. The firm’s age is the number of years for which the firm is recorded in COMPUSTAT files up to a given year. The firm’s assets are measured in 1992 dollars using the Consumers Price Index as a deflator. These control variables allow for industry, age, and size effects. In all regressions in Table 2, we use levels of these control variables. We do not reproduce the estimates of coefficients for the control variables.

In the first part of the table, we examine the relation between the level of risk and the level of q. Remember that the predictions from Section 2 are ambiguous for the relation between the level of risk and q while they are unambiguous for the relation between the change in risk and the change in q. Nevertheless, it is instructive to examine the relation between levels. The first four rows of Table 2 show the relation between risk and q using averages across firms over sub-periods of length corresponding to half the sample period. These are regressions of average q on average risk, average of log of inflation-adjusted total assets, average log of firm age, and industry dummies. Regressions (1) and (2) are for the first half sub-period while regressions (3) and (4) are for the second half sub-period. The regressions use the firms with no missing values for variables used in the regressions for the whole sub-period. We also estimated the regressions using averages across the whole sample period, but do not report these regressions here. The results of these regressions are consistent with the results of the regressions we report but the sample is smaller. The concern with these regressions is that they introduce a heavy survivorship bias by requiring firms to be in the sample for so long. In regressions (1) and (3), we use as risk variables the systematic risk and the unsystematic risk of equity. We find results that will hold throughout the paper: there is a positive and highly significant relation between systematic risk and q and a negative and significant relation between unsystematic risk and firm value. The result for systematic risk is consistent with the finding of Fama and French (1993) that growth firms have higher betas. We know that systematic risk is much smaller than unsystematic risk at the firm level. The coefficient of systematic risk is much larger than the coefficient of unsystematic risk, but because unsystematic risk is large compared to systematic risk, the coefficient on total risk is negative and significant in regressions (2) and (4). Regressions (5) and (6) in the table provide average coefficient estimates of the relation between risk and q obtained with yearly cross-sectional regressions. With these regressions, each year we use firms that are in the sample that year and have the information we require to estimate the regression. The survivorship bias in these regressions is therefore minimal. In Table 2 as well as in subsequent tables that report results of cross-sectional regressions, we use standard errors for the t-statistics as in Fama and MacBeth (1973). Regression (5) yields similar results to regressions (1) and (3).

We now turn to regressions that adjust for firm fixed effects, so that our estimates consider the impact of changes in risk on changes in q. Regressions (7) and (8) provide traditional fixed effects estimates using all firms and all years in our sample. We keep industry dummies without taking the difference from the firm mean in the regressions to allow for industry effects in changes in q. We do not require firms to be in the sample every year, but we require that firms be in the sample for at least two years. We find a strong positive relation between q and systematic risk and a strong negative relation between q and unsystematic risk. Again, the coefficient on systematic risk is large in absolute value relative to the coefficient on unsystematic risk, but not so large as to preclude a significant negative relation between unsystematic risk and q. We estimated these regressions using random effects and found similar results.

A natural concern with regressions that use the whole sample is that clustering in the data may lead us to overstate the significance of the estimates. An alternative approach that does not have this difficulty but makes less efficient use of the data absent the clustering problem is to estimate cross-sectional regressions using changes in the variables. Regressions (9) and (10) present averages of yearly cross-sectional estimates. The results are qualitatively the same in these regressions, but the significance is lower as one would expect. Nevertheless, all the coefficients of interest are significant. The reported t-statistics would be overstated if the slope estimates were correlated across years. We find that correlation of the slope estimates is not a problem for the slopes for non-systematic risk and for total risk. There is a significant and large correlation for the slopes for systematic risk. However, the coefficient for systematic risk exceeds five, so that it would remain significant after making the ad hoc adjustments suggested by Frama and French (1998). It is clear from the regressions of Table 2 that changes in systematic risk are related to changes in q differently from changes in unsystematic risk. This is a puzzle, in that the analysis of Section 2 had nothing to say about the distinction between systematic and unsystematic risk.

We saw in Section 2 that none of the theories discussed there made unambiguous predictions about the relation between the level of risk and the level of q even though they made unambiguous predictions about the relation between changes in risk and changes in q. The reason for this is that risk can be related to other variables that predict q. The regressions that use fixed effects or changes allow the firm to be its own control. The regressions with levels use control variables to attempt to capture the cross-sectional variation in q that is not due to cross-sectional variation in risk. We estimate the regressions of Table 2 using three additional sets of control variables. First, we use no control variables. Second, we use the Fama and French (1998) control variables, namely dividends paid, interest expense, R&D expenditures, earnings before interest, and the change in firm value over the following year. Third, we add earnings to the control variables used in Table 2. The bottom line from these experiments is that the coefficients on unsystematic risk and total risk depend on the control variables used. With the Fama and French (1998) control variables, unsystematic risk has a positive relation with q. The difficulty with this result is that many of the control variables used by Fama and French (1998) depend on volatility, so that there is a considerable endogeneity problem that makes the regression coefficients impossible to interpret. For instance, interest paid is a control variable in Fama and French (1998). Our analysis of Section 2 argues that leverage depends on risk, thereby making ordinary least squares inappropriate to estimate the relation of risk and q in the presence of leverage. With higher leverage, firms pay more interest.

As argued in Section 2, theory makes strong predictions about the relation between changes in risk and changes in q. This makes it important for us to understand the robustness of our results when we look at change regressions or fixed effects regressions. We have investigated the robustness of the results in a number of different ways. Table 3 reports the results of some of these investigations. Table 3 shows estimates for the change regressions (we omit the coefficients on the control variables) for the whole sample period and two sub-periods for the four sets of control variables. It is immediately clear from Table 3 that the choice of control variables is not important in the change regressions. We get essentially the same results without control variables and with the full set of changes in the variables that Fama and French (1998) use to try to explain q. In all four sets of results, we find that using the whole sample, the coefficient on systematic risk is significantly positive while the coefficients on unsystematic risk and total risk are significantly negative. We estimated additional regressions not reported here that gave added weight to our conclusion that the control variables are not important in the change regressions. In particular, we estimate the change regressions of Table 2 including the change in total assets and obtained similar results. Another clear result from Table 3 is that the results hold across sub-periods. Table 3 provides two additional robustness tests. First, we re-estimate the change regressions of Table 2, but instead of eliminating the highest and lowest 1% of the variables, we now eliminate the highest and lowest 5% of the variables. This does not affect our results. Second, we re-estimate the change regressions of Table 2 on a sample that eliminates financial firms and utilities. Financial firms are firms with an SIC between 6000 and 6999. Utilities are firms with an SIC between 4900 and 4999. Again, our results are not affected.

Table 3 shows that the negative relation between changes in risk and changes in q cannot be explained by Merton's model. The regressions in Panels 2 and 4 include control variables that should capture the change in q that is not due to the change in risk. Yet, even after including these control variables, we still find a negative relation between changes in risk and changes in q.

We examine the stability of our results over time by inspecting the coefficients of the yearly regressions. Using the cross-sectional specification in Table 2, we find but do not report in a table that the coefficient for systematic risk is positive in all but three years. For unsystematic risk, the coefficient is never positive. Finally, for total risk, the coefficient is positive for four years. It follows from this that the negative relation between changes in risk and changes in q holds through time and that there is no evidence that it holds more strongly earlier or later in our sample period.

5. The determinants of the relation between risk and q.

The empirical evidence shown in Tables 2 and 3 shows that there is a robust relation between changes in unsystematic risk and changes in q. This relation is generally strong enough to lead to a negative relation between changes in total risk and changes in q. At the same time, however, there is a strong positive relation between changes in systematic risk and changes in q. In this section, we investigate whether these results can be explained by the theoretical arguments discussed in Section 2.

We know from Section 2 that Merton's model implies a negative relation between changes in total risk and changes in q when one uses book values of assets and debt to compute q. The regressions in Table 3 were interpreted as evidence that Merton's model is not sufficient to explain the negative relation between changes in total risk and changes in q. With Merton's model, one would expect a stronger negative relation between changes in total risk and changes in q for more highly levered firms. Panel A in Table 4 shows that this is not the case. In that Panel, we split the sample into three groups of firms according to their leverage. We find that the q of less highly levered firms increases more as systematic risk increases and falls more as unsystematic risk increases, but the impact of changes in total risk is unrelated to leverage. The option pricing approach would predict that a change in total risk matters more for more levered firms. We find instead that the absolute value of the coefficient on total risk is larger for less levered firms but not significantly so.

The growth options argument discussed in Section 2 would imply that an increase in risk should have a less adverse impact on firms with more growth opportunities. Panel B in Table 4 uses R&D investment as a proxy for growth opportunities. There is no evidence that firms with more R&D investment are hurt less by an increase in total risk. Another way to proxy for growth opportunities might be to split the sample according to the exchange on which firms are listed, under the presumption that firms with better growth opportunities might belong to NASDAQ. We find in Panel C of Table 4 that both NASDAQ and NYSE firms have a significant negative relation between changes in unsystematic risk and changes in q. There is no evidence that the coefficient on changes in unsystematic risk or changes in total risk are higher for NASDAQ firms than for NYSE firms. This result is not supportive of the real options story discussed in Section 2. With that story, one would expect the negative relation between risk and q to be at least attenuated for NASDAQ firms relative to NYSE firms since one would expect growth opportunities to be generally more valuable with NASDAQ firms than with NYSE firms. This result does suggest, however, that the negative relation between q and risk might be less important for large firms since on average NYSE firms are larger than NASDAQ firms. We explore this conjecture in the next paragraph. A final way to split firms according to investment opportunities is to split the sample according to the firms' q. Presumably, high q firms have higher growth opportunities. Panel D of Table 4 shows that the negative relation between changes in q and changes in total risk is stronger for firms with higher q. However, an increase in unsystematic risk or in total risk has a significant negative impact on q for low q firms also.

One would generally think that risk would be less costly and would be cheaper to manage for large firms. Presumably, large firms have easier access to capital markets and can benefit from the economies of scale associated with risk management. Panel E of Table 4 splits the sample according to firm size. We find that the negative relation between changes in risk and changes in q does not hold for the largest firms. The coefficient on changes in total risk for large firms is 0.162 with a t-statistic of 1.26.

In Table 5, we examine the extent to which the results differ for large and small firms in greater detail. We split the sample so that the small firms are the NYSE and NASDAQ firms whose assets are in the bottom 30^{th} percentile of NYSE firms to make sure that the smallest firms are not just NASDAQ firms. The large firms are the NYSE and NASDAQ firms whose assets are in the top 30^{th} percentile of NYSE firms. We consider the relation between changes in q and changes in total risk for small and large firms for sub-periods and for different control variables. For small firms, there is a significant negative relation between total risk and q regardless of the control variables we use and regardless of the sub-period. For large firms, there is no significant relation between total risk and q for the first half of the sample period irrespective of the control variables we use. For the second half of the sample period, there is a significant positive relation between total risk and q when we use the change in earnings as a control variable but not otherwise.

Another perspective on the impact of firm size on the relation between risk and q comes from pooled fixed effect regressions using large firms only. In regressions for large firms not reported here, we find a significant positive coefficient on total risk when we control for earnings. For instance, when we use the Fama and French (1998) control variables, the coefficient on total risk is 0.177 with a t-statistic of 8.46. Without control variables, the coefficient is –0.045 with a t-statistic of –2.20. Remember that as discussed in Section 2 changes in firm value for a levered firm can lead to a negative relation between changes in risk and changes in q. It is therefore possible that the negative relation between changes in risk and changes in q without controlling for earnings changes is due to that effect so that the impact of changes in risk on q for large firms is measured correctly when we control for earnings but not otherwise. With small firms, the control variables are irrelevant in the sense that the coefficient on total risk is negative and has a t-statistic that is in excess of 13 in absolute value irrespective of the specification in fixed effect regressions.

The standard deviation of the change in total risk is about four times larger for small firms than for large firms. The largest increases and decreases in total risk are similar for the small firms and for the large firms, but there are fewer of them for the large firms than for small firms. Absent our evidence of a positive significant relation between changes in total risk and changes in q for some specifications, one might argue that the smaller dispersion of changes in total risk for large firms might make it harder for us to estimate the relation between changes in total risk and changes in q for these firms. However, the coefficient estimate on total risk is generally positive and significant for the large firms. Further, though this approach leads to biased coefficients, we estimated our regressions after eliminating the 5% largest and smallest values for both the dependent and the independent variables. When we do that, our conclusions are not affected.

The option pricing model predicts an asymmetric relation in the impact of a change in equity on the volatility of equity for a levered firm. The extent to which an increase in the value of equity lowers the volatility of equity is less than the extent to which a decrease in the value of equity increases it. To evaluate the existence of asymmetries in the relation between changes in risk and changes in firm value, we re-estimated our cross-sectional equations allowing for a different effect of increases in risk and decreases in risk. We report the results in Table 6. We cannot reject the hypothesis that the relation between changes in q and either changes in unsystematic risk or changes in total risk is symmetric for the whole sample. However, the absolute value of the impact of an increase in systematic risk is higher than the absolute value of the impact of a decrease in systematic risk. When we look at subsamples based on leverage, we find little evidence of asymmetries except for the firms with the lowest leverage. For these firms, the absolute value of the impact of an increase in unsystematic risk is higher than the absolute value of the impact of a decrease in unsystematic risk. This is consistent with the option pricing model. When we look at subsamples based on size, we find evidence of asymmetries for medium and large firms, but not for small firms. For large firms, an increase in unsystematic risk has a significant negative effect on q, but a decrease in unsystematic risk is associated with an insignificant decrease in firm value. Perhaps more surprisingly, a decrease in total risk for large firms is associated with a significant decrease in firm value. These results indicate that not only is the magnitude of the relation between risk and firm value different for large firms, but so is the shape of that relation.

Interestingly, the impact of leverage on the relation between risk and q is also quite different for small firms and large firms. Though we do not report these results in a table, the effect of an increase in total risk on q for small firms is not significantly different for firms with high leverage and firms with low leverage. In contrast, there is a significant difference in the coefficient on total risk between large firms with low leverage and large firms with high leverage. In particular, for the whole sample period, an increase in total risk significantly increases the q of large firms with low leverage, but not the q of large firms with high leverage.

6. Conclusion.

In this paper, we document a positive relation between changes in systematic risk and changes in q and a negative relation between changes in unsystematic risk and changes in q. These relations hold over time and for a variety of specifications. They lead to a negative relation between changes in total risk and changes in q. We do not find support for the hypothesis that the real option properties of growth opportunities mitigate the adverse impact of increases in risk on q. The negative relation between changes in risk and changes in q cannot be explained by the option properties of equity because it holds at least as strongly for firms with low leverage as for firms with high leverage. Strikingly, the negative relation between q and total risk does not hold for large firms. In the second half of our sample period, the relation between q and total risk is positive for large firms, but the significance depends on the regression specification. One possible explanation for this evidence is that it is consistent with the view that total risk matters less for large firms because of easier access to capital markets and of the economies of scale of risk management. It is interesting to note in this perspective recent evidence showing that derivatives usage reduces firms' exposure to risks and increases firm value.[6] None of the existing theories discussed in this paper help to understand the positive relation between expected cash flows and systematic risk, so that a better understanding of this relation is left for further work.

[6] See Simkins and Laux (1997) and Tufano (1998) for the first result, and Allayannis and Weston (2000) for the second one.

References

Allayannis, G., and J. Weston, 2000, The use of foreign currency derivatives and firm market value, Review of Financial Studies, forthcoming.

Bekaert, G., and G. Wu, 2000, Asymmetric volatility and risk in equity markets, Review of Financial Studies 13, 1-42.

Berger, P. G., and E. Ofek, 1995, Diversification's effect on firm value, Journal of Financial Economics 37, 39-65.

Black, F., 1976, Studies of stock price volatility changes, Proceedings of the 1976 meetings of the American Statistical Association, Business and Economics Statistics Section (American Statistical Association, DC), 177-181.

Campbell, J. Y., and M. Lettau, 1999, Dispersion and volatility in stock returns: An empirical investigation, NBER working paper 7144, National Bureau of Economic Research, Cambridge, MA.

Cheung, Y.-W., and L. K. Ng, 1992, Stock price dynamics and firm size: An empirical investigation, Journal of Finance 47, 1985-1997.

Christie, A. A., 1982, The stochastic behavior of common stock variances: Value, leverage, and interest rate effects, Journal of Financial Economics 10, 407-432.

Dixit, A. K., and R. S. Pindyck, 1993, Investment under uncertainty, Princeton University Press, Princeton, New Jersey.

Duffee, G. R., 1995, Stock returns and volatility: A firm-level analysis, Journal of Financial Economics 37, 399-420.

Jensen, M. C., and W. H. Meckling, 1976, Theory of the firm: Managerial behavior, agency costs and ownership structure, Journal of Financial Economics 3, 305-360.

Fama, E, F., and K. R. French, 1993, Common risk factors in the returns on stocks and bonds, Journal of Financial Economics 33, 3-56.

Fama, E. F., and K. R. French, 1998, Taxes, financing decisions, and firm value, Journal of

Finance 53, 819-843.

Fama, E. F., and J. D. MacBeth, 1973, Risk, return, and equilibrium: Empirical tests, Journal of Political Economy 81, 607-636.

Froot, K. A., D. S. Scharfstein, and J. C. Stein, 1993, Risk management: Coordinating corporate investment and financing policies, Journal of Finance 48, 1629-1658.

Haushalter, G. D., 1999, Financing policy, basis risk, and corporate hedging: Evidence from oil and gas producers, Journal of Finance 55, 107-152.

Geczy, C., B. A. Minton, and C. Schrand, 1997, Why firms use currency derivatives, Journal of Finance 52, 1323-1354.

Lang, L. H. P., and R. M. Stulz, 1994, Tobin's q, corporate diversification, and firm performance, Journal of Political Economy 102, 1248-1280.

Malkiel, B. G., and Y. Xu, 1999, The structure of stock market volatility, unpublished paper, Princeton University, Princeton, NJ.

Merton, R. C., 1974, On the pricing of corporate debt: The risk structure of interest rates, Journal of Finance 29, 449-470.

Minton, B. A., and C. Schrand, 1999, The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing, Journal of Financial Economics 54, 423-460.

Schwert, G. W., 1989, Why does stock market volatility change over time?, Journal of Finance, 1115-1154.

Simkins, B. J., and P. Laux, 1997, Derivatives use and the exchange rate risk of large US corporations, unpublished working paper, Oklahoma State University.

Smith, C. W., and R. M. Stulz, 1985, The determinants of firms' hedging policies, Journal of Financial and Quantitative Analysis 20, 391-406.

Stulz, R. M., 1990, Managerial discretion and optimal financing policies, Journal of Financial Economics 26, 3-28.

Stulz, R. M., 2000, Derivatives, risk management, and financial engineering, Southwestern Publishing, forthcoming.

Tufano, P., 1996, Who manages risk? An empirical examination of risk management practices in the gold mining industry, Journal of Finance 51, 1097-1137.

Tufano, P., 1998, The determinants of stock price exposure: Financial engineering and the gold mining industry, Journal of Finance 53, 1015-1052.

Table 1. Summary statistics for q and risk

The sample period is from 1965 to 1992. The sample consists of all firms in COMPUSTAT with the required data whose stock returns are available from CRSP and whose total assets are greater than 1 million dollars. Following Fama and French (1998), one percent of the observations in each tail of each independent variable is dropped. q is defined as the market value of the firm over its book value. The risk variables are computed using the market model with the value-weighted CRSP index as a proxy for the market portfolio. Systematic risk is the product of the market model beta squared and the variance of the value weighted index return. Unsystematic risk is the variance of market model residuals. Total risk is the sum of systematic risk and unsystematic risk.

	q	Systematic Risk	Non-Systematic Risk	Total Risk
A. Level				
Mean	1.5975	0.0147	0.3021	0.3178
Median	1.1062	0.0063	0.1617	0.1793
Std Dev.	2.1563	0.0233	0.4400	0.4428
Observations	126030	99333	99333	99333
B. Change				
Mean	0.0300	-0.0006	0.0243	0.0237
Median	0.0036	-0.0001	0.0004	0.0001
Std Dev.	1.3536	0.0264	0.2842	0.2904
Observation	113685	90853	90853	90853

Table 2. Pooled regressions of q on risks

The sample period is from 1965 to 1992. For all regressions, control variables are industry dummy variables determined by the firm's two-digit SIC code, the log of the firm's age, and the log of the firm's assets. Regressions (1) through (4) are regressions of firm average q on firm average risks for firms with data for each year in the sub-period. Regressions (1) and (2) are for the first half sub-period. Regressions (3) and (4) are for the second half sub-period. Regressions (5) and (6) are average coefficients of the yearly level cross-section regressions. Regressions (7) and (8) are fixed effects estimates using all firms and all years with year and industry dummies. Regressions (9) and (10) are averages of estimates of yearly cross-section regressions using changes in q and changes the risk measures. For regressions (5), (6), (9) and (10), the t-statistic is for the average coefficient.

Regression		Systematic Risk	Unsystematic Risk	Total Risk	Adj. R^2	No. Obs.
(1)	Coefficient	19.040	-2.113		0.1576	699
	t-stat	5.51	-5.06			
(2)	Coefficient			-0.829	0.1148	699
	t-stat			-2.29		
(3)	Coefficient	25.343	-1.335		0.0782	1196
	t-stat	5.24	-4.59			
(4)	Coefficient			-0.801	0.0552	1196
	t-stat			-2.89		
(5)	Coefficient	18.679	-0.801			
	t-stat	7.22	-5.42			
(6)	Coefficient			-0.254		
	t-stat			-2.27		
(7)	Coefficient	5.590	-0.329		0.0746	86909
	t-stat	26.48	-25.69			
(8)	Coefficient			-0.272	0.0664	88465
	t-stat			-21.57		
(9)	Coefficient	3.425	-0.510			
	t-stat	5.13	-5.28			
(10)	Coefficient			-0.393		
	t-stat			-3.90		

Table 3. Change regressions of q on risks for the whole sample

The sample period is from 1965 to 1992. Each regression reports two sets of estimates: One model regresses changes in q on changes in systematic risk, unsystematic risk, and control variables; the other model regresses changes in q on changes in total risk and control variables. Regression (1) uses no control variables. Regression (2) uses the same control variables as Fama and French (1998). Regression (3) uses industry dummy variables determined by the firm’s two-digit SIC code, the log of the firm's age, and the log of the firm's assets as control variables. Regression (4) uses control variables of Regression (3) as well as changes in earnings. Regression (5) uses a sample where the highest and lowest 5% of the variables are eliminated. Regression (6) uses a sample that eliminates financial firms and utilities. Regressions (5) and (6) also use control variables of Regression (3). Regressions are performed every year and the reported estimate is the average of the yearly coefficients, and the t-statistic is for the average coefficient.

		Systematic Risk		Unsystematic Risk		Total Risk	
		Mean	t(Mean)	Mean	t(Mean)	Mean	t(Mean)
(1)	Whole sample period	4.058	5.38	-0.621	-4.75	-0.444	-3.55
	Years between 65 and 78	2.181	2.74	-0.764	-3.18	-0.523	-2.25
	Years between 79 and 92	5.935	5.44	-0.477	-4.73	-0.364	-3.68
(2)	Whole sample period	2.489	5.16	-0.356	-4.04	-0.207	-2.62
	Years between 65 and 78	1.224	2.50	-0.464	-2.90	-0.250	-1.70
	Years between 79 and 92	3.755	5.41	-0.248	-3.56	-0.165	-2.59
(3)	Whole sample period	3.425	5.13	-0.510	-5.28	-0.393	-3.90
	Years between 65 and 78	1.590	2.64	-0.614	-3.47	-0.477	-2.53
	Years between 79 and 92	5.259	5.33	-0.407	-5.34	-0.310	-4.08
(4)	Whole sample period	3.101	5.03	-0.373	-4.66	-0.289	-3.37
	Years between 65 and 78	1.250	2.51	-0.424	-3.00	-0.345	-2.21
	Years between 79 and 92	4.953	5.52	-0.322	-4.10	-0.234	-3.06
(5)	Whole sample period	2.885	3.29	-0.523	-5.87	-0.283	-3.23
	Years between 65 and 78	1.930	2.36	-0.565	-3.42	-0.259	-1.60
	Years between 79 and 92	3.840	2.49	-0.480	-6.57	-0.308	-4.15
(6)	Whole sample period	3.510	5.18	-0.501	-5.25	-0.384	-3.81
	Years between 65 and 78	1.711	2.69	-0.609	-3.49	-0.463	-2.45
	Years between 79 and 92	5.309	5.29	-0.393	-5.28	-0.306	-4.16

Table 4. Change regressions of q on risks for sub-samples

The sample period is from 1965 to 1992. In Panel A, the sample is split into three groups of firms according to their leverage each year. The low (high) long-term debt ratio group includes firms in the bottom 30 (top 30) percentile of the sample in long-term debt ratio. Panel B divides the sample into two groups based on R&D investment. Panel C splits the sample according to the exchange on which firms are listed. Panel D splits firms according to the firms' q each year. The low (high) q group includes firms whose q is in the bottom 30 (top 30) percentile. Panel E splits the sample according to firm's total assets each year. The small (large) firm group includes firms whose book value of total assets are in the bottom 30th (top 30th) percentile in total assets. Regressions are performed every year and the reported estimator is the average of yearly coefficients, and the t-statistic is for the average coefficient. Control variables are industry dummy variables determined by the firm's two-digit SIC code, the log of firm's age, and the log of the firm's assets.

	Systematic Risk		Unsystematic Risk		Total Risk	
	Mean	t(Mean)	Mean	t(Mean)	Mean	t(Mean)
Panel A						
Low long-term debt ratio	6.375	5.32	-0.792	-5.40	-0.633	-3.14
Medium long-term debt ratio	2.641	4.13	-0.508	-5.11	-0.385	-3.86
High long-term debt ratio	1.669	2.74	-0.370	-4.06	-0.298	-3.40
Difference between low and high	4.706	3.50	-0.422	-2.44	-0.335	-1.52
Panel B						
Zero R&D or No R&D	3.108	4.80	-0.492	-5.42	-0.388	-3.95
With R&D	3.841	3.97	-0.854	-2.72	-0.464	-3.00
Difference	-0.733	-0.63	0.362	1.11	0.076	0.42
Panel C						
NASDAQ	5.731	4.91	-0.789	-4.14	-0.669	-3.47
NYSE & AMEX	1.977	3.37	-0.342	-3.23	-0.231	-2.20
Difference	3.755	2.87	-0.447	-2.05	-0.438	-1.99
Panel D						
Low q	0.869	3.00	-0.110	-4.78	-0.086	-3.36
Medium q	1.402	3.88	-0.224	-4.47	-0.138	-3.68
High q	6.586	5.97	-1.082	-5.78	-0.816	-3.77
Difference between low and high	-5.718	-5.02	0.972	5.15	0.731	3.35
Panel E						
Small Firms	8.587	4.91	-0.872	-6.04	-0.851	-4.22
Medium Firms	2.702	4.15	-0.303	-3.20	-0.131	-1.77
Large Firms	1.499	2.33	-0.040	-0.61	0.162	1.26
Difference between small and larg	7.089	3.81	-0.832	-5.26	-1.012	-4.24

Table 5. Change regressions of q on risks for small and large firms only

The sample period is from 1965 to 1992. The small (large) firm group includes firms whose book value of total assets are in the bottom 30th (top 30th) percentile in total assets among NYSE listed

	Systematic Risk		Non-Systematic Risk		Total Risk	
	Mean	t(Mean)	Mean	t(Mean)	Mean	t(Mean)
Panel A						
First half sub-period						
Small firms	2.430	2.44	-0.797	-3.49	-0.702	-2.68
Large firms	2.034	1.56	-0.296	-1.66	0.173	0.54
Difference	0.396	0.24	-0.501	-1.73	-0.875	-2.11
Second half sub-period						
Small firms	10.018	4.83	-0.582	-4.83	-0.453	-4.09
Large firms	1.371	2.19	-0.060	-0.75	0.117	1.52
Difference	8.647	3.99	-0.522	-3.61	-0.570	-4.22
Panel B						
First half sub-period						
Small firms	1.822	2.85	-0.606	-3.30	-0.414	-2.60
Large firms	0.621	1.17	-0.029	-0.20	0.122	0.94
Difference	1.201	1.45	-0.577	-2.46	-0.536	-2.61
Second half sub-period						
Small firms	6.598	4.58	-0.315	-3.89	-0.219	-3.08
Large firms	0.821	1.85	0.099	1.67	0.212	3.75
Difference	5.777	3.83	-0.415	-4.12	-0.431	-4.74
Panel C						
First half sub-period						
Small firms	2.008	2.17	-0.826	-3.52	-0.802	-2.75
Large firms	2.003	1.52	-0.196	-1.15	0.186	0.73
Difference	0.005	0.00	-0.631	-2.17	-0.988	-2.55
Second half sub-period						
Small firms	8.364	5.11	-0.517	-5.55	-0.413	-4.72
Large firms	1.068	1.86	-0.052	-0.95	0.090	1.70
Difference	7.296	4.20	-0.465	-4.29	-0.503	-4.91
Panel D						
First half sub-period						
Small firms	1.816	2.27	-0.606	-3.33	-0.615	-2.48
Large firms	2.036	1.97	-0.052	-0.32	0.329	1.42
Difference	-0.219	-0.17	-0.554	-2.28	-0.945	-2.78
Second half sub-period						
Small firms	7.991	5.16	-0.426	-4.78	-0.331	-4.16
Large firms	1.101	1.92	-0.026	-0.65	0.102	1.70
Difference	6.890	4.17	-0.400	-4.11	-0.433	-4.35

firms. NASDAQ listed firms are also included in the sample if their assets are less (greater) than the NYSE cutoff point. Cross-sectional regressions are estimated every year. The reported regression coefficients are obtained from the cross-sectional regressions. Control variables are industry dummy variables determined by the firm's two-digit SIC code, the log of firm's age, and the log of the firm's assets. Panel A uses no control variables. Panel B uses Fama and French (1998) control variables. Panel C uses industry dummy variables determined by the firm's two-digit SIC code, the log of the firm's age, and the log of the firm's assets as controls . Panel D uses the control variables of Panel C as well as changes in earnings.

Table 6. Change regressions of q on positive and negative risks

The sample period is from 1965 to 1992. In Panel A, the sample is split into three groups of firms according to their leverage each year. The low (high) long-term debt ratio group includes firms in the bottom 30 (top 30) percentile of the sample in long-term debt ratio. Panel B splits the sample according to firm's total assets each year. The small (large) firm group includes firms whose book value of total assets are in the bottom 30^{th} (top 30^{th}) percentile in total assets. Regressions are performed every year and the reported estimate is the average of the yearly coefficients, and the t-statistic computed following Fama and McBeth (1973). Control variables are industry dummy variables determined by the firm's two-digit SIC code, the log of firm's age, and the log of the firm's assets.

Regression		Change in Systematic Risk if Positive	Change in systematic risk if negative	Change in Unsystematic Risk if Positive	Change in Unsystematic Risk if Negative	Change in Total Risk if Positive	Change in Total Risk if Negative
Whole Sample	Mean(Coefficient)	6.291	1.037 [c]	-0.619	-0.346	-0.420	-0.300
	t(Mean)	3.39	0.81	-6.13	-2.52	-3.97	-1.28
Panel A.							
Low long-term debt ratio	Mean(Coefficient)	11.899	1.491 [a]	-1.246	-0.315 [c]	-0.767	-0.470
	t(Mean)	3.28	0.51	-5.54	-1.42	-3.99	-1.02
Medium long-term debt ratio	Mean(Coefficient)	6.067	-0.958 [a]	-0.500	-0.525	-0.315	-0.443
	t(Mean)	4.77	-0.89	-5.95	-3.54	-3.14	-2.16
High long-term debt ratio	Mean(Coefficient)	0.848	1.126	-0.293	-0.389	-0.242	-0.374
	t(Mean)	0.82	0.66	-3.40	-2.59	-1.74	-1.75
Panel B.							
Small Firm Sample	Mean(Coefficient)	11.102	9.530	-0.969	-0.884	-0.778	-0.896
	t(Mean)	2.49	1.61	-6.68	-3.84	-4.33	-2.27
Medium Firm Sample	Mean(Coefficient)	6.439	-0.087 [a]	-0.504	-0.031 [a]	-0.300	0.119 [c]
	t(Mean)	4.96	-0.08	-4.58	-0.24	-2.86	0.63
Large Firm Sample	Mean(Coefficient)	3.172	-1.990 [c]	-0.201	0.446 [c]	0.042	0.362 [c]
	t(Mean)	3.07	-0.89	-1.89	1.54	0.29	2.19

[a] indicates that the coefficient of negative change in risks is different from the coefficient of positive change in risks at 1% significance level.
[b] indicates that the coefficient of negative change in risks is different from the coefficient of positive change in risks at 5% significance level.
[c] indicates that the coefficient of negative change in risks is different from the coefficient of positive change in risks at 10% significance level.

Figure 1. Optimal amount of unhedged risk for a firm. It is assumed that the marginal cost of bearing unhedged risk is increasing in unhedged risk, while the marginal cost of hedging risk is decreasing in unhedged risk. The marginal cost of bearing risk as well as the marginal cost of hedging risk curves are drawn for given risk before hedging for the firm.

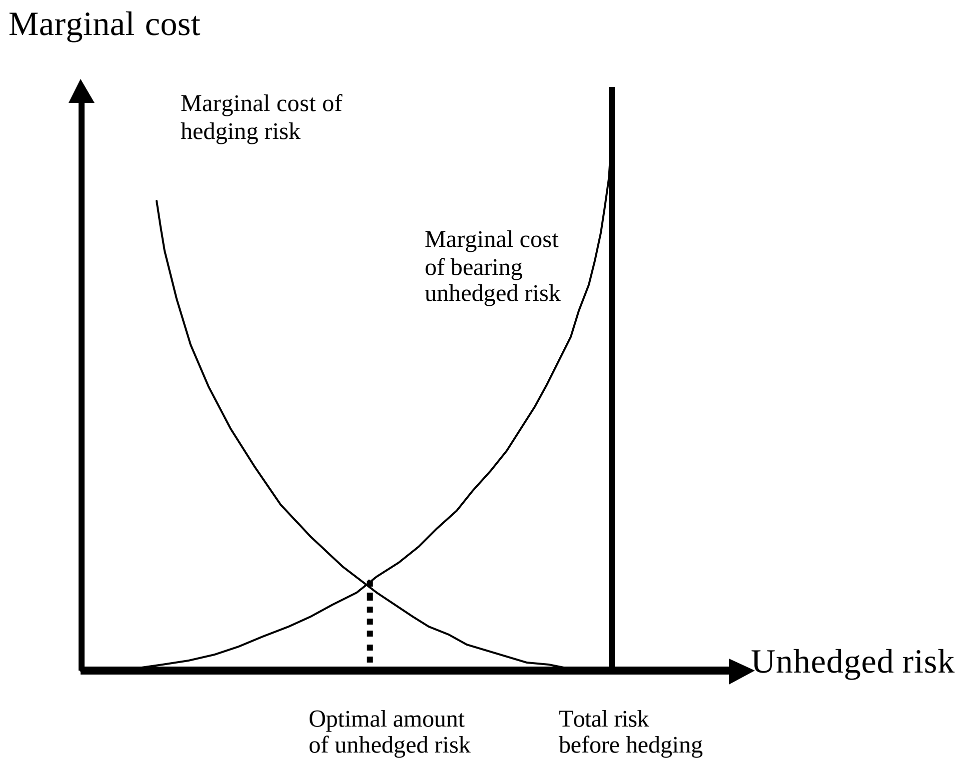

Figure 2. Total unhedged risk and marginal cost function of unhedged risk. It is assumed that the marginal cost of bearing unhedged risk is increasing in unhedged risk, while the marginal cost of hedging risk is decreasing in unhedged risk. In this figure, all firms have the same marginal cost function of hedging risk, but have different marginal cost functions of bearing unhedged risk.

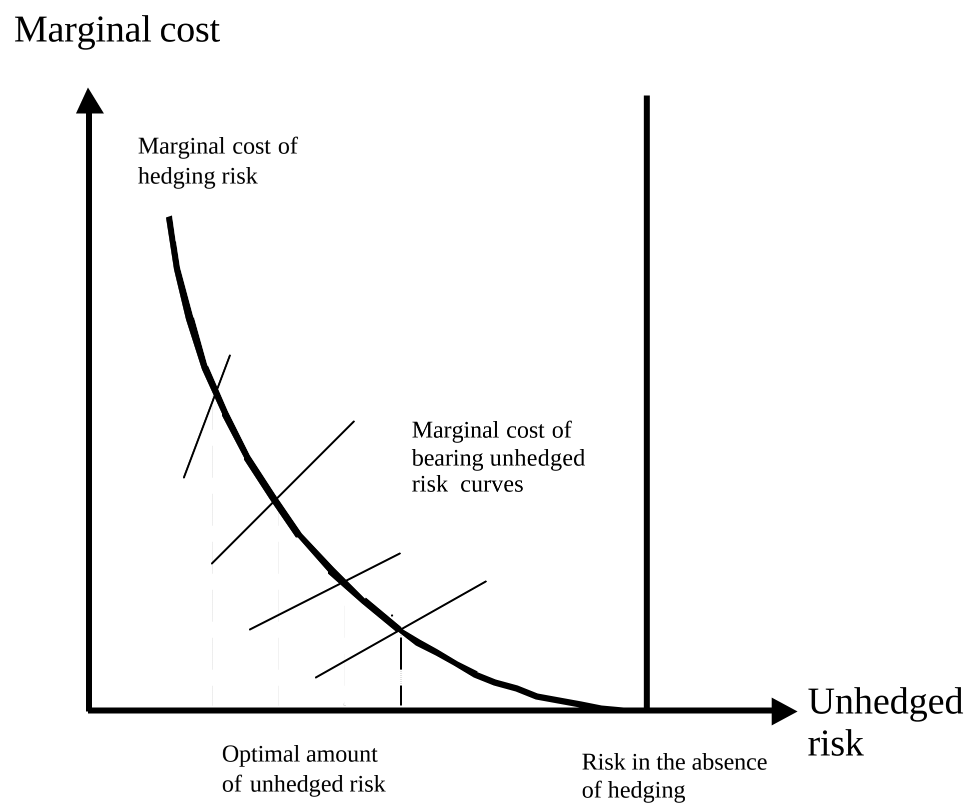

Figure 3. Impact on optimal unhedged risk of an increase in the firm's risk before hedging. It is assumed that the marginal cost of bearing unhedged risk is increasing in unhedged risk, while the marginal cost of hedging risk is decreasing in unhedged risk. The marginal cost of bearing unhedged risk as well as the marginal cost of hedging risk curves are assumed to depend only on unhedged risk. As the firm's unhedged risk increases, the marginal cost for a given amount of risk reduction is kept the same, so that the marginal cost curve of hedging risk shifts to the right. As the firm's unhedged risk increases, the marginal cost of bearing unhedged risk is kept constant for each level of unhedged risk, so that the marginal cost curve of bearing unhedged risk stays the same as risk before hedging increases.

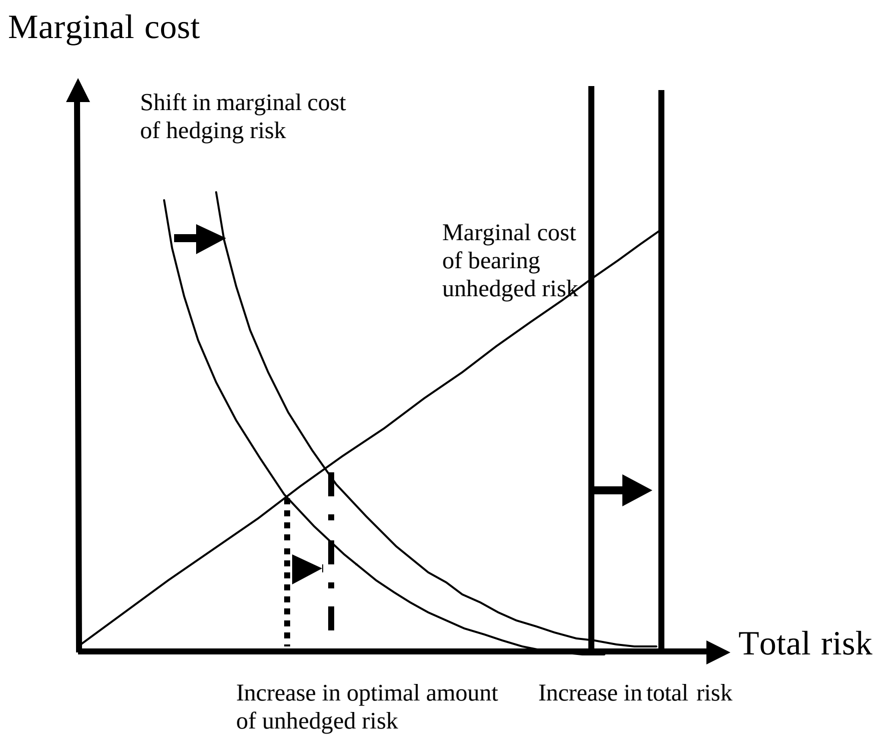

Figure 4. Impact of firm value and leverage on equity volatility. This figure assumes that Merton's model for the pricing of firm equity holds. The firm has discount debt maturing in five years, the interest rate is 5%, and firm volatility is 20%.