Can Growth Options Explain the Trend in Idiosyncratic Risk?

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While recent studies document increasing idiosyncratic volatility over the past four decades, an explanation for this trend remains elusive. We establish a theoretical link between growth options available to managers and the idiosyncratic risk of equity. Empirically both the level and variance of corporate growth options are significantly related to idiosyncratic volatility. Accounting for growth options eliminates or reverses the trend in aggregate firm-specific risk. These results are robust for different measures of idiosyncratic volatility, different growth option proxies, across exchanges, and through time. Finally, our results suggest that growth options explain the trend in idiosyncratic volatility beyond alternative explanations.

Campbell, Lettau, Malkiel, and Xu (2001) document increasing firm-level return volatility but stable market and industry return volatilities over the last four decades. Subsequently, there has been a flurry of work attempting to characterize the upward trend in idiosyncratic volatility.[1] We now know that increasing idiosyncratic volatility is: (1) related to the level and variance of profitability (Pastor and Veronesi 2003 and Wei and Zhang 2006); (2) positively related to institutional ownership and expected earnings growth (Malkiel and Xu 2003); (3) negatively related to firm age

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We are grateful to Choong Tze Chua, Keith Crocker, Craig Dunbar, Dong Hong, Eric Jacquier, Patrick Kelly, Bill Kracaw, Roger Loh, Michael Long, James Miles, Chris Muscarella, Dennis Sheehan, Chris Ting, Jun Tu, Mitch Warachka, Joe Zhang, and the seminar participants at the 2006 FMA conference, Pennsylvania State University, the University of Texas at Dallas, the University of Western Ontario, HEC Montreal, the University of Amsterdam, the Norwegian School of Management, and the University of Copenhagen for their helpful comments and suggestions. We also thank the Third NTU International Conference on Economics, Finance, and Accounting (IEFA) for financial support through their 2005 best paper award. Special thanks to Matt Spiegel and an anonymous referee for insights that greatly improved the quality of our paper. Send correspondence to Timothy Simin, Department of Finance, Pennsylvania State University, 345 Business Building, University Park, PA 16802.
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[1] Goyal and Santa-Clara (2003) and Malkiel and Xu (1999, 2003) confirm this result using different definitions of idiosyncratic volatility.

doi:10.1093/rfs/hhl039 Advance Access publication October 25, 2006

(Pastor and Veronesi 2003); (4) negatively related to expected returns in the cross-section (Ang, Hodrick, Xing, and Zhang 2005); (5) correlated with business cycles (Brown and Ferreira 2003); and (6) often a stronger predictor of the cross-section of returns than is liquidity (Spiegel and Wang 2006). While these characterizations help in understanding the nature and impact of the trend, a theory-based explanation is still lacking.

In this article we use a classic model from the corporate finance literature posited by Galai and Masulis (1976) to relate the increase in average idiosyncratic volatility to the level and variance of growth options. To explicitly tie the idiosyncratic component of volatility to the investment decisions of corporate managers, we focus on the Galai and Masulis result that managers of levered firms are motivated to select those investment projects from their menu of growth opportunities that increase the idiosyncratic variance of the firm.[2] Increasing firm-level idiosyncratic risk benefits shareholders by increasing the value of equity while at the same time reducing the market risk of equity. Within the Galai and Masulis model it is straightforward to connect firm-level idiosyncratic risk and the idiosyncratic risk of equity.

Consistent with the predictions of the model, when we include growth options in the regressions, the coefficient on the time trend becomes indistinguishable from zero or significantly negative, indicating that after controlling for growth options idiosyncratic volatility has remained stable or even decreased over time. The growth-options proxies and their time-series variances are positively related to idiosyncratic risk and explain more than 63% of the variation in idiosyncratic volatility.

We demonstrate the ability of growth options to explain more of the trend in idiosyncratic volatility than previously posited explanations. Pastor and Veronesi (2003) relate firm-specific volatility to firm profitability measured by return-on-equity (ROE). They find that idiosyncratic return volatility tends to be higher for firms with more uncertainty about future profitability and with more volatile profitability, and for firms that pay no dividends, suggesting that a partial explanation for the increase in idiosyncratic volatility is due to increases in the number of firms listed at earlier ages (Fama and French 2004).

We find significant trends in idiosyncratic volatility even in samples of only mature firms, indicating that changes in the cross-sectional distribution of firm age across time do not fully account for the trend. In these samples, growth option proxies again eliminate the trend. Wei and Zhang (2006) build on Pastor and Veronesi (2003) to show that declining ROE and increasing ROE volatility contribute to the upward trend in idiosyncratic volatility. We demonstrate that return-on-equity and its time-series variance lose their explanatory power in the presence of growth

[2] See also Jensen and Meckling (1976).

options. Removing profitability from average idiosyncratic volatility consistently leaves a significant trend component that is explainable by any of the growth option proxies we consider. Conversely, removing the growth option component never leaves a significant trend.

The results are robust across exchanges. Schwert (2002) shows that higher *total* volatility of firms listed on NASDAQ relative to S&P 500 firms is driven by their technology focus rather than the size or age of the firms. Our results corroborate Schwert's findings, that is, the upward trend in idiosyncratic volatility is nearly 4 times larger for NASDAQ firms. Both the level and variance of growth options are significant in explaining the trend in NYSE/AMEX firm-specific risk, while only the level of growth options is significant for NASDAQ firms. These results suggest that large firms with sufficient cash flow take advantage of transient investment opportunities unlike smaller cash-constrained firms on NASDAQ. Variance in growth opportunities impacts the idiosyncratic risk of equity only for firms that can take advantage of short-lived windows of opportunity.

The results are robust across time. To evaluate the ability of growth options through time, we perform a subsample analysis by rolling regressions through the data sample using 100-month windows. We find a significantly positive trend in 90 of the 217 overlapping samples. Proxies for growth options eliminate the trend for 83 (92%) of those 90 samples. In the remaining 127 samples the trend is never significantly different from zero, indicating a degree of time-variation in idiosyncratic volatility.

The results are robust across measures of idiosyncratic volatility. We calculate aggregate idiosyncratic volatility in five different ways. First we follow the method in Campbell, Lettau, Malkiel, and Xu (2001), which is based on the unconditional version of the capital asset pricing model (CAPM). This method does not require estimating individual firm betas, but it relies on an asset pricing model that is unable to explain the cross-section of returns as well as the multifactor models suggested by Fama and French (1992, 1993) and Carhart (1997). The Campbell et al. method also ignores evidence supporting conditional versions of asset pricing models that better account for time-variation in expected returns. For the alternative measures of idiosyncratic volatility we use both conditional and unconditional versions of the Fama–French three-factor model and the Carhart extension that includes a factor related to momentum. The conditional versions of the model allow for time-variation in the coefficients of the model. We find significant trends for each of these alternative definitions of idiosyncratic volatility that are explainable by our growth option proxies.

In the first section we develop the link between growth options and idiosyncratic volatility and develop testable hypotheses. Section 2 details the measures of idiosyncratic variance and the explanatory variables. Section 3 describes the data and Section 4 contains the main empirical findings. Section 5 examines the explanatory power of growth options relative to alternative explanations. In Section 6 we assess how our results hold through time and across exchanges. We conclude in the final section.

1. Connecting Growth Options to Idiosyncratic Volatility

In the model of Galai and Masulis (1976), returns are generated by the continuous time version of the CAPM of Merton (1973, 1974), while at the same time the value of equity, S, is considered equivalent to the value of a European call option on the value of the firm. Stock-holders have a twofold incentive to increase the variance of the firm, σ, since doing so increases the value of the equity while reducing the market risk of equity, β_s. That is, moral hazard occurs because $\frac{\partial S}{\partial \sigma} > 0$ while $\frac{\partial \beta_S}{\partial \sigma} < 0$ (if the market risk of the firm's assets is stationary and positive).[3] One way managers, acting on behalf of equity holders, influence the idiosyncratic variance of the firm is to choose investments from their opportunity set with the most nonsystematic risk.

Within the model it is straightforward to show that the idiosyncratic volatility of equity, $\sigma^2_{\varepsilon_S}$, is a function of the interaction between the idiosyncratic volatility of firm-level returns, $\sigma^2_{\varepsilon_A}$ and η_S, the elasticity of equity value with respect to firm value (see Appendix A),

$$\sigma^2_{\varepsilon_S} = \eta^2_S \sigma^2_{\varepsilon_A}. \tag{1}$$

This leads to the empirical specification where we model time-variation in $\sigma^2_{\varepsilon_A}$ as a linear function of growth options, GO, and use a predetermined estimate of the elasticity of equity value with respect to firm value, $\tilde{\eta}^2_S$,

$$\sigma^2_{\varepsilon_S} = \alpha\tau + \beta_0 \tilde{\eta}^2_S + \beta_1[\tilde{\eta}^2_S \times GO]. \tag{2}$$

Here we test for the presence of a significant positive trend, τ. We find that the estimated η_S is very close to 1 throughout the sample. To relate our results to previously posited explanations of the trend in idiosyncratic volatility, we also conduct tests assuming $\eta_S = 1$. This restriction has the added advantages of reducing estimation error and simplifying the interpretation of the parameter estimates.

For managers disposed to increasing idiosyncratic risk, more growth opportunities provide a larger menu of projects from which to choose those with higher variance. This leads to our first hypothesis:

[3] It is important to note that both derivatives are taken fixing the value of the firm, the debt to equity ratio (DTE), and the market risk of the firm. Any change in the total variance of the firm must be due to changes in the idiosyncratic risk of firm-level returns. See the discussion of the Galai and Masulis model in Copeland and Weston (1988).

Hypothesis 1. *Aggregate idiosyncratic volatility is positively related to the level of growth options.*

For firms that can capitalize on transient opportunities, variance in the set of growth options may impact the idiosyncratic variance of equity. Intuitively, firms with high variance in their expenditures for research and development or in their capital investments will be those taking advantage of growth options. This leads to our second hypothesis:

Hypothesis 2. *Aggregate idiosyncratic volatility is positively related to the variance of growth options.*

2. Idiosyncratic Volatility, Growth Options, and Controls

2.1 Idiosyncratic volatility

We calculate aggregate idiosyncratic volatility in five different ways. First we use the beta-free method based on the unconditional single factor CAPM of Campbell, Lettau, Malkiel, and Xu (2001). While this method of estimating idiosyncratic volatility does not require estimating individual firm betas, which reduces estimation error, it relies on an asset pricing model that cannot explain the cross-section of returns as well as multifactor regression models can, such as those suggested by Fama and French (1992, 1993) and Carhart (1997). In addition, empirical evidence suggests that conditional versions of asset pricing models account better for time-variation in expected returns. Besides the Campbell, Lettau, Malkiel, and Xu (2001) measure, other measures have been developed in other studies. For example, Spiegel and Wang (2006) show how a conditional measure of idiosyncratic risk, based on the Fama–French three-factor model, dominates liquidity in explaining cross-sectional stock returns.[4] For these reasons we calculate aggregate idiosyncratic volatility using both unconditional and conditional versions of the Fama–French three-factor model with and without a factor related to momentum.

To calculate idiosyncratic volatility following Campbell, Lettau, Malkiel, and Xu (2001), start with the CAPM of Sharpe and Lintner:

$$R_{it} = \beta_{im} R_{mt} + \varepsilon_{it}. \tag{3}$$

Here R_{it} is the excess return of firm i at time t over the Treasury bill rate, R_{mt} is the value-weighted market excess return, β_{im} is the market beta of firm i, and ε_{it} captures firm-specific shocks. To get to the measure of aggregate idiosyncratic volatility used in Campbell, Lettau, Malkiel, and Xu (2001), consider the alternative decomposition of returns for firm i into

[4] See also Malkiel and Xu (2003).

a market return and an idiosyncratic return, υ_{it},

$$R_{it} = R_{mt} + \upsilon_{it}. \tag{4}$$

Subtracting Equation (4) from Equation (3) and solving for the idiosyncratic return yields

$$\upsilon_{it} = \varepsilon_{it} + (\beta_{im} - 1)R_{mt}. \tag{5}$$

Let w_{it} denote the weight on stock i in the market portfolio at time t. From Equation (4), the weighted average variance across all (N) firms is then

$$\begin{aligned}
\sum_{i=1}^{N} w_{it} Var(R_{it}) &= Var(R_{mt}) + \sum_{i=1}^{N} w_{it} Var(\upsilon_{it}) + 2\sum_{i=1}^{N} w_{it} Cov(R_{mt}, \upsilon_{it}) \\
&= Var(R_{mt}) + \sum_{i=1}^{N} w_{it} Var(\upsilon_{it}) \\
&\quad + 2\sum_{i=1}^{N} w_{it} Cov(R_{mt}, \varepsilon_{it} + (\beta_{im} - 1)R_{mt}) \\
&= Var(R_{mt}) + \sum_{i=1}^{N} w_{it} Var(\upsilon_{it}).
\end{aligned} \tag{6}$$

That is, the average cross-sectional variance of returns is the sum of the market-level stock return volatility and average firm-specific volatility. The third equality holds on account of Equation (5), the fact that ε_{it} and R_{mt} are orthogonal, and because the weighted average beta equals one.[5]

Using Equation (6) we are able to estimate the idiosyncratic volatility of firm i in month t, V_{it}, using daily returns within month t as

$$V_{it} = Var(\hat{\upsilon}_{it}) = D[Var(R_{is} - R_{ms})], \tag{7}$$

where R_{is} is firm i's daily excess return for each trading day s in month t and R_{ms} is the cross-sectional average of returns for all stocks available on day s in our sample weighted by the market capitalization on day s.[6] More succinctly, we measure V_{it} for stock i in month t as the number of trading days, D, in month t times the sample variance of market adjusted daily returns of stock i within month t. We then take the value-weighted average

[5] The restriction that the sample of assets being considered are beta weighted is important when calculating the idiosyncratic variance of portfolios. We thank Eric Jacquier for this insight.

[6] We do not extract the industry average return from individual stock return as in Campbell, Lettau, Malkiel, and Xu (2001). Since the industry component constitutes a relatively small part of the individual stock return and has remained stable over time, its effect is negligible.

of V_{it} across all stocks in month t and construct the monthly time-series of idiosyncratic volatility V_t for month t as

$$V_t = \sum_{i=1}^{N} w_{it} V_{it}. \tag{8}$$

Here w_{it} is a weight based on the market capitalization of stock i at the end of month $(t-1)$. The correlation between our idiosyncratic volatility measure and the Campbell, Lettau, Malkiel, and Xu (2001) measure is 0.98 for the overlapping time period from January 1971 to December 1997.

To calculate aggregate idiosyncratic volatility based on the unconditional and conditional versions of the Fama–French and Carhart models we use the value-weighted cross-sectional average of the variance of the error terms from regressions of the model for each firm that has at least 25 monthly observations within the past 5 years.[7] In the conditional versions of the model we use four instrumental variables meant to proxy for the information set available to investors. The conditional versions of the model allow for time-variation in the coefficients of the model. The coefficients are assumed to be deterministic linear functions of the instruments, which result in an interactive regression such as in Ferson and Harvey (1999).

The instrumental variable data employed consist of four series typically used in asset pricing studies. These include the dividend yield of the Standard and Poor's 500 Index (DivYld), the spread between the lagged Moody's Composite Average of Yields on Corporate Bonds from the industrial manual and the U.S. 3-Month T-Bill from the CRSP Risk-Free file as a measure of the term structure (Term), the difference between the Moody's BAA and AAA corporate bond yield as a measure of quality (Junk), and the return on the consumer price index. See Appendix B for formal definitions of the conditioning variables.

2.2 Growth options and their proxies

Using investment opportunities to explain different dimensions of return variance is not unusual. The relation between investment opportunities and firm variance can be traced back to other classic corporate theory besides Galai and Masulis such as Myers (1977). More recently, Schwert (2002) suggests that growth options of large firms in NASDAQ high-tech industries may explain more volatile earnings and hence higher *total* equity return volatility. Miles (1987); Berk, Green, and Naik (1999); Jacquier, Titman, and Yalcin (2001); and Carlson, Fisher, and Giammarino (2003)

[7] The value-weighted aggregate idiosyncratic variance for all four models experiences a dramatic increase in the period January 2000 through December 2002. To avoid biasing our results toward finding an upward trend in idiosyncratic volatility we exclude that period from our sample for these models.

argue that the exercise of growth options changes a firm's exposure to *systematic* risk. Our innovation is to connect growth options to *nonsystematic* risk.

Indirect evidence also indicates a positive relation between growth options and firm-specific risks. Chan, Lakonishok, and Sougiannis (2001) find a positive relation between firm return volatility and research and development (R&D) intensity. Apedjinou and Vassalou (2004) show that firms with larger corporate "innovations" (the change in gross profit margins not explained by changes in capital and labor utilized) have higher firm-specific volatility. Since firm innovations and R&D both proxy for growth options, this evidence suggests idiosyncratic volatility is associated with growth options.

We use five proxies for growth options that have been widely used in the corporate finance literature. These include an estimate of Tobin's Q, the ratio of the market value to book value of assets (MABA), the debt to equity ratio (DTE), the ratio of capital expenditures to fixed assets (CAPFIX), and a direct measure of the present value of growth options (PVGO). See Appendix B for formal definitions of these growth option proxies. We note that growth opportunities are not directly observable and every proxy is prone to criticism. We attempt to overcome the individual shortcomings of the proxies by using a range of previously studied variables for the bulk of our analysis.

The *MABA* ratio proxies for corporate growth options since the market value of assets captures the market's anticipation of future growth opportunities within the firm while book value does not. Tobin's Q is the ratio of the market value of assets to the replacement costs of assets. Both ratios should be positively related to the growth options of a firm. While these ratios have a long history as proxies for growth options (e.g., Collins and Kothari 1989, Chung and Charoenwong 1991, Smith and Watts 1992, and Goyal, Lehn, and Racic 2002) more recent theoretic work by Berk, Green, and Naik (1999) and Carlson, Fisher, and Giammarino (2003) explicitly links book-to-market ratios to growth options. The link is empirically confirmed in Anderson and Garcia-Feijóo (2006). Shin and Stultz (2000) provide empirical evidence relating Tobin's Q to the variance of equity.

Even so, there are a number of interpretations for the informational content of book-to-market and its variants. The success of the Fama–French factor model has prompted a large body of literature debating economic explanations for the ability of book-to-market ratios to explain the cross-sectional variation of equity returns, for example, Lettau and Ludvigson (2001a, 2001b), Liew and Vassalou (2000), Vassalou (2003), Petkova and Zhang (2005), Xing and Zhang (2004), Daniel and Titman (1997), and Ferson, Sarkissian, and Simin (1999), to name a few. Our focus is on the time-series relation between aggregate idiosyncratic volatility and aggregate growth option variables. Another motivation for using the errors from the Fama–French factor model is to insulate our results from the cross-sectional book-to-market effect. These versions of idiosyncratic variance should be orthogonal to the book-to-market effect captured by the Fama–French model.

We also use the *DTE* and the *CAPFIX* as a means of checking that our results hold for *nonprice* based growth option proxies. *DTE* represents growth options since firms with significant growth opportunities may have lower financial leverage. Lower leverage occurs because financing projects with equity attenuates the under-investment problem associated with financing with debt, pointed out by Myers (1977), while very high levels of *DTE* may also proxy for financial distress. *CAPFIX* acts as a proxy for growth options since the discretionary nature of capital expenditures leads to new investment opportunities. However, the relationship between capital expenditures and the value of the investment options may not be linear (see Goyal, Lehn, and Racic 2002).

Finally, we reproduce a direct measure of the *PVGO* used by Long, Wald, and Zhang (2005). To estimate the portion of the firm's value that results from the *PVGO*, we first compute the firm's projected earnings from assets in place using historical earnings, and then capitalize those earnings. The *PVGO* is estimated as the difference between the firm's market value of equity and the value of the asset-in-place (e.g., the nongrowth part of equity value) scaled by the firm's market value of equity.[8]

2.3 The elasticity of equity value to total firm value

Our estimate of elasticity, η_S, is a cross-sectional value-weighted average of individual firm η_S's. To generate a time-series of η_S for firm i, we roll the regression of the natural logarithm of the value of equity, S (measured as shares outstanding $\times$ share price), on the natural logarithm of an estimate of firm value, $\tilde{A}$,

$$\ln S_{i,t} = \alpha_i + \beta_i \ln \tilde{A}_{i,t} + \varepsilon_{i,t}, \tag{9}$$

through the sample for each firm using the past 36 months of data. The β_i coefficient is the elasticity $\eta_{S,i}$ for firm i.

Our procedure for estimating firm value $\tilde{A}$ using the Black–Scholes model is adopted from the procedure used by Moody/KMV and outlined

[8] Other proxies for growth options are dividend yields, R&D expenditures/total assets, and earnings-per-share/share price. We do not use these proxies for several reasons. In our sample negative earnings appear in approximately 27% of nonmissing firm-months, making them difficult to interpret in terms of growth options. Dividend yields are zero in 63% of the sample. Jacquier, Titman, and Yalcin (2001) note that a low or zero dividend yield may proxy for financial distress, making it a poor proxy for growth opportunities. Quarterly R&D expenditures have been available on *COMPUSTAT* only since 1989, with many missing observations.

in Vassalou and Xing (2004).[9] We assume that the capital structure of the firm includes both equity and debt, and the market value of a firm's assets follows a standard geometric Brownian motion. In this setting, the market value of equity can be thought of as a call option on the asset value with time-to-maturity equal to T, and the strike price equal to the book value of debt (see Appendix A). Specifically, we use market capitalization at the end of each month as the value of equity, S. The exercise price K is approximated by the book value of bonds. The risk-free rate r is the monthly 1-year Treasury Constant Maturity Rate from the Board of Governors of the Federal Reserve System. In the Black–Scholes model, the volatility σ_A^2 is the realized variance of firm value.

The maturity of the call option, T, should be close to the lifetime of the firm. Since we do not observe default *ex ante*, we calculate the average years (among firms delisted from the CRSP) that a firm is listed on CRSP. During our entire sample period, there are 14,151 unique firms. 9,935 firms are delisted, and only 111 firms have been listed from 1972 through 2002. The average age of these 9,935 firms is 9.7 years, while the median age is 7 years. For this reason, we choose T to be 10 years.[10] The book value of bonds is defined as the "Debt in One Year" plus one-half of the "Long-Term Debt," where both variables are from the merged CRSP/COMPUSTAT annual file. We follow Moody/KMV and Vassalou and Xing (2004) and use 50% of the long-term debt in the calculation of book value of the debt.

We adopt an iterative procedure to estimate the value of each firm. In each month we:

(1) Estimate the volatility of equity, σ_S^2, by using previous 36 months of market capitalization, and set the initial value of σ_A^2 to be σ_S^2;
(2) Use the Black–Scholes model to estimate the firm value A for each month;
(3) After obtaining a monthly time-series of A, compute its variance and use it as the input to the Black–Scholes model for the next round iteration;
(4) Repeat steps (2) and (3) until the difference in σ_A^2 between two iterations is no larger than 0.0001;
(5) Back out the value of the firm by using the final estimate of σ_A^2 and the Black–Scholes model in Equation (A1).

[9] Duan, Gauthier, and Simonato (2005) show how this method of estimating the unobserved asset value, within the context of Merton's (1974) model, is identical to maximum likelihood estimation.

[10] To check whether our results are robust, we performed two sensitivity tests. Specifically, we define the book value of bonds as the "Debt in One Year" plus 40% (or) 60% of the "Long-Term Debt." Next, we use $T = 7$ years in the calculation of the firm value. Overall, alternative proxies of input variables do not change the qualitative results so that the cross-sectional average of elasticity η's is close to 1, although estimates of individual firm's asset value vary with inputs.

We remove 80 firms (0.73% of the sample) that did not achieve convergence for at least 25% of their sample data. These are small firms with large amounts of debt. For the entire sample, the average ratio of debt-to-market capitalization is about 10%, while the average debt-to-market cap ratio is 99% for the 80-firm sample. While the Black–Scholes model worked reasonably well for 99.3% sample firms, it does not appear to work well for firms close to bankruptcy. The time-series average of our value-weighted cross-sectional η_S is 0.998 with a standard deviation of 0.023, ranging from 0.99 to 1.005 across all individual 120-month periods.

3. Data

Daily stock returns are from CRSP. The accounting data are from the merged CRSP/COMPUSTAT quarterly industrial file. The COMPUSTAT quarterly files start in 1971 and we include data through 2002.[11] We include only common shares listed on the NYSE, AMEX, and NASDAQ. We exclude financial service firms since their growth opportunities and capital structure differ from most firms. In each month all the stocks included must have a nonmissing return for the current month, nonmissing market capitalization at the end of the previous month, and nonnegative book value of common equity. Finally, we delete the last quarter of data for any firm delisted before our sample period ends.

To eliminate any look-ahead bias we match the COMPUSTAT quarterly accounting variables with the monthly return variances, calculated using daily stock returns from CRSP, by the earnings report date in COMPUSTAT. Firms typically report earnings within three months after the end of the current fiscal quarter. For any firm-quarter that has nonmissing accounting variables but a missing earnings report date, we assume that the firm reports its quarterly earnings at the end of the third month after the end of the fiscal quarter. As is commonly done with these data, we winsorize the firm-month panel data at both the upper and lower 2.5% levels to mitigate the impact of outliers. The original panel consists of 1,242,983 firm-month observations over the period of 1971 through 2002.

Table 1 reports the descriptive statistics of monthly idiosyncratic return variance (V) at the firm-month panel level. The mean is 3.7% and the median is 1.7%. The value-weighted average variance has a standard deviation of 5.4%, is moderately skewed to the right, and has relatively fat tails. The monthly idiosyncratic variance from the different versions of the Fama–French model all have slightly lower means and tighter distributions

[11] At the beginning of the sample there are many missing values. We use the sample period from 1974 to 2002 in the subsequent analysis. Since we require 3 years of data to estimate time-series variance of growth options variables, the sample period for the time-series analysis is from September 1976 to December 2002.

Table 1
Panel data summary statistics

Statistics	Firm-months	Mean	Median	Std. Dev	Skewness	Kurtosis
V	1,242,983	0.037	0.017	0.054	2.607	9.804
FF3	1,177,406	0.025	0.015	0.028	2.183	7.783
FF4	1,177,406	0.025	0.015	0.028	2.174	7.739
CFF3	1,177,406	0.024	0.014	0.027	2.181	7.750
CFF4	1,177,406	0.023	0.013	0.026	2.202	7.835
SIZE	1,242,983	942.6	67.9	7217.1	30.5	1397.7
MABA	1,176,690	1.786	1.280	1.354	2.373	8.600
Q	1,117,736	1.215	0.784	1.359	2.282	8.335
CAPFIX	873,298	0.178	0.122	0.169	1.475	4.688
DTE	974,513	0.547	0.218	0.836	2.524	9.671
PVGO	654,493	0.121	0.311	0.730	−1.823	6.689
ROE	1,238,385	0.003	0.024	0.089	−2.211	8.762

Summary statistics of monthly average idiosyncratic return variance, size, growth options, and return-on-equity at the firm-month panel level. *V* denotes the CAPM-based monthly average idiosyncratic return variance. *FF3, FF4, CFF3, CFF4* denote the Fama–French 3 factor, 4 factor, unconditional and conditional model-based monthly average idiosyncratic return variance; *SIZE*: the previous month-end market capitalization in million dollars; *MABA*: market value to book value of assets; *Q*: Tobin's Q; *CAPFIX*: the capital expenditures to fixed assets ratio; *DTE*: the debt to equity ratio; *PVGO*: the present value of growth options; and *ROE*: return-on-equity. All variables are winsorized at the 2.5% and 97.5% levels. *CAPFIX, DTE*, and *PVGO* cover the period 1981/01 thru 2002/12; the remaining variables cover the entire sample period 1971/07 thru 2002/12.

than *V* and are slightly less skewed and fat tailed. The conditional versions of the model produce variances with marginally smaller means and standard deviations than their unconditional counterparts.

Table 1 also presents summary statistics of the growth-options variables *MABA*, *Q*, *CAPFIX, DTE*, and *PVGO*, as well as *ROE*, and firm *SIZE* at the panel level. *MABA* averages 1.8 with a median of 1.3. The maximum (minimum) value of *MABA* is about 7 (0.7), which is within the usual (0.01, 100) interval. *MABA* is positively skewed, fat tailed, and volatile with a standard deviation of 1.35. Similar patterns appear for *Q* with the exception that *Q* is on average smaller with a mean (median) at 1.2 (0.7) and slightly more volatile than *MABA*. Our samples of *MABA* and *Q* are consistent with series used in other work, e.g., Jacquier, Titman, and Yalcin (2001). *CAPFIX, DTE*, and *PVGO* are reasonably distributed. These series are all fat tailed with some skewness where *PVGO* exhibits negative skewness.

ROE measures profitability of a firm. In general, the firms in our sample are profitable with positive mean *ROE* of 0.3%. A median firm has a *ROE* of about 2.4%, which is about 8 times as high as the mean *ROE*, implying that there exist some extremely poor performers in our sample. This is corroborated by both the minimum value of *ROE* at −34% and the negative skewness of −2.2. Firm size, measured by the previous month-end market capitalization, has a mean and median of \$943 million and \$68 million, respectively.

For each month, we calculate the value-weighted averages of the variables across all firms in the original firm-month panel and construct a value-weighted monthly time-series in which the weight is the market capitalization evaluated at the end of the previous month. To calculate the time-series variance of the growth-options variables we require that each firm have at least eight quarterly values within the past 3 years. Because of these restrictions we use *MABA* and *Q* from 1976/09 through 2002/12, *DTE* and *PVGO* from 1985/01 through 2002/12, and *CAPFIX* from 1985/09 through 2002/12.

4. Empirical results

4.1 Growth options and idiosyncratic volatility: ($\eta_S = \tilde{\eta}_S$)

To evaluate the impact of growth options on the idiosyncratic variance of equity returns we estimate a regression following the specification laid out in Equation (2),

$$\begin{aligned} V_t = \beta_0 + \beta_1 \tau + \beta_2 \tilde{\eta}^2_{S,t-1} \\ + \beta_3 [\tilde{\eta}^2_{S,t-1} * GO_{t-1}] \\ + \beta_4 [\tilde{\eta}^2_{S,t-1} * GOTSV_{t-1}] + \varepsilon_t, \end{aligned} \tag{10}$$

where V_t is the value-weighted idiosyncratic return variance as defined in Equation (8), τ is a time trend, $\tilde{\eta}^2_S$ is the squared elasticity of equity value with respect to firm value, and GO_t is the value-weighted average of the growth option in month t. We also include a measure of the variance of growth options to test our second hypothesis. $GOTSV_t$ is the value-weighted average of individual firm time-series variances of the growth option in month t. All the regressions are estimated using the generalized method of moments (GMM) and the t-statistics are computed using the heteroscedasticity- and autocorrelation-consistent standard errors of Newey and West (1987) with 12 lags.

Table 2 contains a panel for each of the five growth option proxies. Each panel contains the results from regressing the CAPM-based measure of idiosyncratic volatility on (1) a time trend alone and (2) the specification of Equation (10). The number of firm-month observations varies across panels because of the filters used to create the growth option proxies. In each panel we find the time trend is positively and significantly related to idiosyncratic volatility and explains almost a third of the variation in idiosyncratic volatility. For the specification of Equation (10) we find that in all panels the upward trend in idiosyncratic volatility is statistically zero or significantly negative, supporting our hypothesis that the upward trend in firm idiosyncratic volatility is

Table 2
Time-series regressions of idiosyncratic variance on time trend, elasticity of equity to firm value, and the interaction of elasticity and growth options

Panel A: *MABA*

	Intercept	τ	η_S^2	$\eta_S^2 \times MABA$	$\eta_S^2 \times MABAV$	Adj. R^2
1	0.01	3.91*				0.32
	−1.91	(3.73)				
2	−0.06	−3.83*	0.06	0.01*	0.02*	0.63
	(−1.82)	(−3.16)	(1.79)	(3.35)	(2.65)	

Panel B: *Q*

	Intercept	τ	η_S^2	$\eta_S^2 \times Q$	$\eta_S^2 \times QV$	Adj. R^2
1	0.01	4.08*				0.32
	(1.77)	(3.71)				
2	−0.06	−4.02*	0.07	0.01*	0.02*	0.62
	(−1.81)	(−3.03)	(1.88)	(3.12)	(2.63)	

Panel C: *CAPFIX*

	Intercept	τ	η_S^2	$\eta_S^2 \times CAPFIX$	$\eta_S^2 \times CAPFIXV$	Adj. R^2
1	0.01	6.68*				0.30
	(1.94)	(3.28)				
2	0.12	−0.38	−0.14*	0.02	3.14*	0.60
	(1.99)	(−0.27)	(−2.28)	(1.55)	(5.66)	

Panel D: *DTE*

	Intercept	τ	η_S^2	$\eta_S^2 \times DTE$	$\eta_S^2 \times DTEV$	Adj. R^2
1	0.01	6.53*				0.32
	(1.65)	(3.47)				
2	0.08	−0.33	−0.05	−0.05*	0.10	0.42
	(1.16)	(−0.21)	(−0.75)	(−2.43)	(0.90)	

Panel E: *PVGO*

	Intercept	τ	η_S^2	$\eta_S^2 \times PVGO$	$\eta_S^2 \times PVGOV$	Adj. R^2
1	0.01	6.06*				0.31
	(1.46)	(3.39)				
2	−0.08	0.80	0.08	0.03*	0.08*	0.38
	(−0.83)	(0.49)	(0.81)	(2.21)	(1.97)	

Time-series regressions of idiosyncratic return variance on a time trend and the explanatory variables suggested by the Galai and Masulis model. The dependent variable is the monthly average idiosyncratic return variance, V, formed as in Campbell, Lettau, Malkiel, and Xu (2001). The independent variables include a time trend, the elasticity of equity value with respect to firm value, η_S^2, as well as the products of the elasticity and the level (time-series variance) of each growth option proxy, market-to-book value of assets, *MABA (MABAV)*, Tobin's Q, *Q (QV)*, capital to fixed expenditures, *CAPFIX* (*CAPFIXV*), Debt to Equity, *DTE* (*DTEV*), and the present value of growth options, *PVGO* (*PVGOV*). We use the generalized method of moments (*GMM*) to estimate the model. The t-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags. *Indicates significance at 5% level using a two-sided t-test.

related to the time-series dynamics in growth options and growth-options volatility.

Except when using *CAPFIX*, the elasticity term is insignificantly associated with firm-specific risk. For *MABA*, *Q*, and *PVGO* both the level and the time-series variance of growth options are significantly related to V, while only the level of *DTE* and only the time-series variance of *CAPFIX* are significant at the 5% level. Comparing the regressions (1) and (2) in each panel we find that for *MABA*, *Q*, and *CAPFIX,* adjusted R-squares nearly double. *DTE* and *PVGO* produce smaller increases in adjusted R-square. The results based on all the proxies for growth options support our hypotheses that the products of elasticity of equity value with respect to total firm value and growth options as well as the product of elasticity and the time-series variances of growth options are positively related to the upward trend in firm idiosyncratic volatility. In every case, once the growth-options variables are considered, the time trend becomes insignificantly different from zero or negative.[12]

4.2 Growth options and idiosyncratic volatility: ($\eta_S = 1$)

While the results in the previous table clearly support the connection between growth options and idiosyncratic volatility suggested by the Galai and Masulis model, the interactive regression specification is not easily comparable to alternative explanations such as the profitability hypothesis explored by Wei and Zhang (2006). Given that the estimated value of η_S is close to 1 throughout the sample, we set η_S^2 in Equation (10) equal to 1 and estimate the following regression,

$$V_t = \beta_0 + \beta_1 \tau + \beta_2 GO_{t-1} + \beta_3 GOTSV_{t-1} + \varepsilon_t, \tag{11}$$

making the assumption that $\eta_S = 1$ has only a marginal impact on the analysis. In Table 3 there is some variation in the estimated parameters, but no qualitative impact. Overall, the results support our hypotheses that both the level and time-series variances of growth options are positively related to the upward trend in firm idiosyncratic volatility. In every case once the growth-options variables are considered, the time trend becomes insignificantly different from zero or negative. Together, the level and time-series variance of growth options account for as much as 61% of the time-series variation of aggregate idiosyncratic volatility.

[12] In unreported regressions we find that for *MABA* and *Q* both the levels and variances of the growth options are significant individually. For *DTE* and *PVGO* only the levels and for *CAPFIX* only the variances are significant. In all these cases, when the level or variance is significant the trend coefficient is zero or negative.

Table 3
Time-series regressions of idiosyncratic variance on a time trend and growth options

Panel A: *MABA*

	Intercept	τ	*MABA*	*MABAV*	Adj. R^2
1	0.01	3.91*			0.32
	(1.91)	(3.73)			
2	0.01	−3.15*	0.01*	0.02*	0.61
	(−0.64)	(−2.49)	(3.04)	(2.43)	

Panel B: *Q*

	Intercept	τ	*Q*	*QV*	Adj. R^2
1	0.01	4.08*			0.32
	(1.77)	(3.71)			
2	0.01*	−3.75*	0.01*	0.01*	0.61
	(2.41)	(−2.69)	(3.25)	(2.87)	

Panel D: *CAPFIX*

	Intercept	τ	*CAPFIX*	*CAPFIXV*	Adj. R^2
1	0.01	6.68*			0.30
	(1.94)	(3.28)			
2	−0.02*	−0.17	0.02	3.12*	0.60
	(−4.02)	(−0.13)	(1.63)	(5.71)	

Panel C: *DTE*

	Intercept	τ	*DTE*	*DTEV*	Adj. R^2
1	0.01	6.53*			0.32
	(1.65)	(3.47)			
2	0.03*	−0.17	−0.05*	0.10	0.43
	(3.11)	(−0.10)	(−2.41)	(0.94)	

Panel E: *PVGO*

	Intercept	τ	*PVGO*	*PVGOV*	Adj. R^2
1	0.01	6.06*			0.31
	(1.46)	(3.39)			
2	0.01	0.76	0.03*	0.08*	0.38
	(−0.97)	(0.46)	(2.27)	(2.01)	

Time-series regressions of idiosyncratic return variance on a time trend and the explanatory variables suggested by the Galai and Masulis model setting $\eta_S^2 = 1$. The dependent variable is the monthly average idiosyncratic return variance, *V*, formed as in Campbell, Lettau, Malkiel, and Xu (2001). The independent variables include a time trend and the level (time-series variance) of each growth option proxy, market-to-book value of assets, *MABA (MABAV)*, Tobin's Q, *Q (QV)*, capital to fixed expenditures, *CAPFIX* (*CAPFIXV*), Debt to Equity, *DTE* (*DTEV*), and the present value of growth options, *PVGO* (*PVGOV*). We use the generalized method of moments (*GMM*) to estimate the model. The *t*-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags.
*Indicates significance at 5% level using a two-sided *t*-test.

4.3 Alternative measures of idiosyncratic volatility and growth options

In Sections 4.1 and 4.2, we obtained our primary results relying on the definition of idiosyncratic volatility adopted by Campbell, Lettau, Malkiel, and Xu (2001). This subsection contains an assessment of the impact of alternative definitions of idiosyncratic volatility (or growth option proxies) on the results. We first consider the four additional ways to calculate idiosyncratic volatility by using both unconditional and conditional versions of the Fama–French three-factor model with and without a factor related to momentum described in Section 2.1. Then we take a closer look at how the different growth option proxies impact the results.

For the purpose of illustration, we fix the growth option variable as *MABA* and report the regression results with alternative definitions of volatility in Table 4. Regardless of which definition is used, when idiosyncratic volatility is regressed on only a time trend, the coefficient is significant and positive. The adjusted R-squares are close to 30% for the idiosyncratic volatility based on the CAPM, FF-3, and FF-4 models, while the adjusted R-squares are slightly higher for conditional volatility based

Table 4
The impact of alternative definitions of idiosyncratic volatility

Idiosyncratic volatility	Intercept	τ	*GO*	*GOV*	Adj. R^2
CAPM	0.01	3.91*			0.32
	(1.91)	(3.73)			
	−0.01	−3.15*	0.01*	0.02*	0.61
	(−0.64)	(−2.49)	(3.04)	(2.43)	
Unconditional *FF3*	0.06*	3.27*			0.29
	(44.33)	(2.95)			
	0.06*	−2.46*	−0.01	0.06*	0.68
	(18.88)	(−2.54)	(−0.49)	(3.79)	
Conditional *FF3*	0.06*	4.49*			0.42
	(39.91)	(4.14)			
	0.06*	−2.05*	−0.01	0.06*	0.69
	(18.24)	(−2.08)	(−0.51)	(3.74)	
Unconditional *FF4*	0.06*	3.57*			0.32
	(41.20)	(3.22)			
	0.06*	−0.56	−0.01	0.07*	0.70
	(16.35)	(−0.55)	(−0.99)	(3.92)	
Conditional *FF4*	0.05*	5.11*			0.49
	(38.32)	(4.73)			
	0.06*	−0.13	0.01	0.06*	0.74
	(15.42)	(−0.13)	(−0.71)	(3.71)	

Time-series regressions of idiosyncratic return variance on a time trend and the explanatory variables suggested by the Galai and Masulis model setting $\eta_S^2 = 1$. The dependent variable is the monthly average idiosyncratic return variance formed using the CAPM-based on the method of Campbell, Lettau, Malkiel, and Xu (2001), unconditional Fama–French 3 or 4 factor model, and the conditional version of the models. The independent variables include a time trend and the level, *GO* and time-series variance, *GOV* of the *MABA* growth option proxy. The instrumental variables used in the conditional versions of the models are described in the text. We use the generalized method of moments (*GMM*) to estimate the model. The t-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags. *Indicates significance at 5% level using a two-sided t-test.

on the FF-3 and FF-4 models, suggesting that the time trend documented in Campbell, Lettau, Malkiel, and Xu (2001) is robust with respect to alternative definitions of idiosyncratic volatility. After including the level and variance of *MABA*, the trend becomes insignificant or negative and the increase in adjusted R-square is substantial for each definition of idiosyncratic volatility. Finally, we find the interaction between growth options and the five definitions of idiosyncratic volatility is slightly different. When the CAPM is used to calculate idiosyncratic volatility, both the level and the time-series variance of *MABA* are significant. For the definitions of idiosyncratic volatility based on the Fama–French model, only the time-series variance of *MABA* is significant.

To examine the impact of alternative definitions of growth options on our results we first focus on the CAPM-based idiosyncratic volatility and take a closer look at the results in Table 3. Both *MABA* and Tobin's *Q*, the two proxies that cover the whole sample, provide similar results: the level and the variance of *MABA* (or *Q*) are significant and the adjusted R-square increases from 32% to 61% when *MABA* (or *Q*) and its variance are included in the regression. Panels C, D, and E of Table 3 show that each growth option proxy, *CAPFIX, DTE*, or *PVGO*, all of which start in the early 1980s, is significant and eliminates the significance of the time trend. The only noticeable difference among these three proxies is that while both the level and the variance of *PVGO* are significant, only the time-series variance of *CAPFIX* (or the level of *DTE*) is significant.

Finally, on the basis of the idiosyncratic volatility estimated from the unconditional Fama–French three-factor model, we compare results among the five growth option proxies in Table 5. The economic content of

Table 5
The impact of alternative definitions of growth options

GO	Intercept	τ	*GO*	*GOV*	Adj. R^2
MABA	0.06*	−2.46*	−0.01	0.06*	0.68
	(18.88)	(−2.54)	(−0.49)	(3.79)	
Q	0.06*	−2.31*	−0.01	0.05*	0.65
	(29.97)	(−2.36)	(−0.27)	(3.32)	
CAPFIX	0.04*	3.17	−0.01	3.94*	0.91
	(7.53)	(1.71)	(−0.57)	(4.71)	
DTE	0.09*	−1.27	−0.04*	−0.04	0.61
	(14.07)	(−0.60)	(−3.14)	(−0.77)	
PVGO	0.06*	2.71	0.02*	0.01	0.60
	(12.42)	(1.22)	(2.30)	(0.09)	

Time-series regressions of idiosyncratic return variance on a time trend and the explanatory variables suggested by the Galai and Masulis model setting $\eta_S^2 = 1$. The dependent variable is the monthly average idiosyncratic return variance formed using the unconditional Fama–French three-factor model. The independent variables include a time trend and the level, *GO* and time-series variance, *GOV* of each growth option proxy. We use the generalized method of moments (*GMM*) to estimate the model. The t-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags.

*Indicates significance at 5% level using a two-sided t-test.

these results is that, irrespective of the definition of growth option proxies, once growth options are controlled for, either the trend in aggregate idiosyncratic volatility is nonexistent or the firm-specific risk has decreased over time. In summary, these results suggest that after we control for book-to-market and size through the different versions of the Fama–French model, the upward trend in idiosyncratic volatility documented in Campbell, Lettau, Malkiel, and Xu (2001) remains significant. More importantly for our story, the trend in the time-series of aggregate idiosyncratic volatility can be explained by the growth option proxies commonly used in the literature.

5. Alternative Explanations

There are two plausible alternative explanations for the increase in idiosyncratic volatility in the literature to date. In a model of investor learning, Pastor and Veronesi (2003) show that idiosyncratic volatility is higher for younger firms with more uncertainty about future profitability (ROE) and more volatile profitability, which they suggest partially explains increasing idiosyncratic volatility since more firms have listed at younger ages. Along the same lines, Vuolteenaho (2004) concludes that variance of cash flow news is more than twice that of expected return news and that cash flow shocks are largely firm specific. Since ROE is actually scaled earnings (i.e., corporate cash flows) this implies that the variations in ROE are predominantly firm specific and will be reflected in idiosyncratic risk. Wei and Zhang (2006) analyze the relations between idiosyncratic volatility and ROE, as well as firm age. They show that aggregate return-on-equity and ROE volatility contribute to the upward trend in idiosyncratic volatility, although they do not find the firm age to be important. Given the significance of ROE and the mixed results on age we include both as control variables below.[13]

5.1 Profitability versus growth options: round one

We explore the relationship between the trend in firm-specific risk and growth options controlling for ROE and its time-series volatility, using the following regression:

$$V_t = \beta_0 + \beta_1 \tau + \beta_2 GO_{t-1} + \beta_3 GOTSV_{t-1} + \beta_4 ROE_{t-1} + \beta_5 ROETSV_{t-1} + \varepsilon_t. \quad (12)$$

[13] Return-on-equity (ROE) is defined as earnings divided by book value of common equity.

Here ROE_t is the weighted average of ROE in month t and $ROETSV_t$ is the weighted average of the three-year time-series variance of return-on-equity in month t, created following the same procedure used to define the time-series volatility of growth options.

Table 6 reports the regression results for each growth option proxy controlling for *ROE*.[14] The time trend is insignificant in all 12 specifications except the first, where it is significantly negative, and when only the level of *ROE* and *CAPFIX* is included in the regression. *ROE* never enters significantly and *ROETSV* is significant only in the second regressions of Panels D and E. Additionally, both *ROE* and *ROETSV*, which have significant explanatory power for firm-specific risk in the absence of the growth option proxies, are consistently insignificant after including both the levels and variances of the growth option proxies. Comparing these results to those in Table 3, adding *ROE* and *ROETSV* in the regressions only marginally improves the adjusted R-square for any of the growth option proxies, indicating little additional explanatory power over the growth-options variables alone.

5.2 Profitability versus growth options: round two

In this section we provide additional evidence that the growth option proxies play a more significant role in explaining the trend in idiosyncratic variance than does profitability using the following procedure.

(1) Regress idiosyncratic volatility on a constant and *ROE* to remove any variation in the volatility explained by *ROE*.
(2) Take the residuals from step (1) and run two regressions:
  (a) First, regress the residuals on an intercept and the time trend and test if the trend remains significant.
  (b) Second, add a growth option proxy to the regression in step (a) and test if the trend remains significant.
(3) Repeat steps (1–2) switching the roles of the growth option and *ROE*.

If the time trend is significant in part (a) of step (2), then we have evidence that *ROE* fails to capture the trend. If the trend is insignificant in part (b), then we can conclude that the growth option explains the trend in idiosyncratic variance that cannot be explained by *ROE*. We reverse the process in step (3) to check that we are not generating a spurious result, that is, a trend exists after first removing the growth option component.

[14] In unreported results we duplicate the results for *ROE* in Wei and Zhang (2006) by regressing the value-weighted average variance on an intercept, trend, and ROE. Our estimate of the coefficient on *ROE* is 0.186 with a Newey–West t-statistic using three lags of 2.213. As in their results, the trend is significant and positive in this regression.

Table 6
Time-series regressions of idiosyncratic variance on a time trend, return-on-equity, and growth options

Panel A: *MABA*

	Intercept	τ	*ROE*	*ROEV*	*MABA*	*MABAV*	Adj. R^2
1	−0.01	−2.55*	−0.04		0.01*		0.58
	(−0.96)	(−1.98)	(−0.65)		(4.46)		
2	0.010*	−3.39		4.41		0.03*	0.56
	(5.46)	(−1.77)		(1.22)		(2.80)	
3	−0.010	−1.81	0.07	−3.74	0.01*	0.02*	0.62
	(−0.90)	(−0.90)	(0.81)	(−0.84)	(2.77)	(2.73)	

Panel B: *Q*

	Intercept	τ	*ROE*	*ROEV*	*Q*	*QV*	Adj. R^2
1	0.01	−2.70	−0.06		0.01*		0.58
	(0.59)	(−1.92)	(−0.86)		(4.28)		
2	0.01*	−4.08		5.38		0.03*	0.56
	(5.34)	(−1.95)		(1.38)		(2.80)	
3	0.01	−2.38	0.04	−2.36	0.01*	0.02*	0.61
	(0.03)	(−1.07)	(0.48)	(−0.48)	(2.33)	(2.72)	

Panel C: *CAPFIX*

	Intercept	τ	*ROE*	*ROEV*	*CAPFIX*	*CAPFIXTV*	Adj. R^2
1	0.01	5.26*	0.07		0.04		0.35
	(−0.61)	(4.42)	(0.66)		(1.90)		
2	−0.02*	−0.45		0.65		3.22*	0.59
	(−4.16)	(−0.25)		(0.25)		(4.60)	
3	−0.02*	−0.28	0.13	−1.50	0.02	3.26*	0.61
	(−2.92)	(−0.16)	(0.99)	(−0.42)	(1.65)	(4.89)	

Panel D: *DTE*

Reg.	Intercept	τ	*ROE*	*ROEV*	*DTE*	*DTEV*	Adj. R^2
1	0.03*	0.03	−0.06		−0.04*		0.42
	(3.44)	(0.02)	(−0.52)		(−2.72)		
2	0.01	−2.90		13.06*		−0.09	0.42
	(0.14)	(−0.92)		(2.19)		(−1.43)	
3	0.02*	−4.43	−0.07	10.04	−0.04*	0.06	0.46
	(2.22)	(−1.39)	(−0.69)	(1.73)	(−1.99)	(0.50)	

Panel E: *PVGO*

Reg.	Intercept	τ	*ROE*	*ROEV*	*PVGO*	*PVGOV*	Adj. R^2
1	0.01	0.70	0.10		0.02		0.37
	(−0.38)	(0.36)	(0.99)		(1.80)		
2	−0.01	−1.47		16.86*		0.05*	0.39
	(−1.59)	(−0.39)		(2.17)		(2.07)	
3	−0.01	−3.43	0.09	11.42	0.02*	0.10*	0.42
	(−1.67)	(−0.98)	(0.83)	(1.45)	(1.99)	(2.60)	

Time-series regressions of idiosyncratic return variance on time trend, return-on-equity, growth options, and the time-series variances of return-on-equity and growth options. The dependent variable is monthly average idiosyncratic return variance, V. The independent variables include a time trend, return-on-equity (*ROE*), the time-series variance of *ROE* (*ROEV*), the level (time-series variance) of market-to-book value of assets, *MABA (MABAV)*, Tobin's Q, *Q (QV)*, capital to fixed expenditures, *CAPFIX* (*CAPFIXV*), Debt to Equity, *DTE* (*DTEV*), and the present value of growth options, *PVGO* (*PVGOV*). We use the generalized method of moments (*GMM*) to estimate the model. The t-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags. *Indicates significance at 5% level using a two-sided t-test.

Table 7 contains the results of this test. The left two cells of Panel A show the results of steps (1) and (2) when we consider *MABA* as a proxy for growth options. In the cell labeled Step 1 we report the regression of the idiosyncratic variance on *ROE*. Here *ROE* is significantly different from zero at the 5% level. In the cell labeled Step 2 we first report the regression of the orthogonalized errors on the time trend. The trend remains a significant explanatory variable of idiosyncratic variance after controlling for profitability. The second regression in the Step 2 cell adds the proxy for growth options to the previous regression. In Panel A, *MABA* is significantly positive while the trend becomes significantly negative.[15] In the right two cells we reverse the roles of *ROE* and the growth options, and in no case is the trend significant in step (2) after controlling the growth-option component. Adding the variance of the growth options in Panel B to the regressions has little impact on these results.

We repeat but do not report the same experiment for each of the other growth option proxies. For *Q* and *DTE* we find qualitatively identical results as in Table 7. Removing *ROE* leaves a significant trend, which is explained by the level and the combination of the level and variance of growth options, while removing the growth option proxies does not leave a trend. For the *CAPFIX* sample, removing *ROE* leaves a significant trend, which is explained by the combination of the level and variance of growth options. Removing the level and variance of growth options of *DTE* does not leave a trend. For the *PVGO* sample, removing *ROE* leaves a trend that is positive but insignificant, that is, the coefficient on the trend when it is the only regressor is 2.74 with a t-statistic of 1.55. After including the level and variance of *PVGO* the trend coefficient falls to -0.52 with a t-statistic of -0.22. However, removing the level or the combination of the level and variance of *PVGO* eliminates the significant trend.

Overall, we see that removing profitability from idiosyncratic variance leaves a significant trend component that is explainable by any of the growth option proxies we consider. Accounting for both the level and variance of growth options reveals that the trend is insignificant. Conversely, taking the growth option component out of the idiosyncratic variance never leaves a significant trend. This evidence, together with the evidence in Table 6, provides convincing support to the predictions of the Galai and Masulis model versus the profitability-based explanations in the literature.

5.3 Firm age

Besides cash flow variability, firm age has been suggested as a possible explanation of the trend in idiosyncratic volatility. Some authors argue

[15] Including the variance of ROE does not change the results qualitatively.

Table 7
Two-step sensitivity test

Panel A: Market Value to Book Value of Assets *(MABA)*

First on *ROE* then on *MABA*						First on *MABA* then on *ROE*					
Step 1: $V_t = \beta_0 + \beta_1 ROE_{t-1} + \varepsilon_t$		Step 2: $\varepsilon_t = \alpha_0 + \alpha_1 \tau + \alpha_2 GO_{t-1} + \eta_t$				Step 1: $V_t = \beta_0 + \beta_1 GO_{t-1} + \varepsilon_t$			Step 2: $\varepsilon_t = \alpha_0 + \alpha_1 \tau + \alpha_2 ROE_{t-1} + \eta_t$		
Intercept	*ROE*	Intercept	τ	*MABA*	*MABAV*	Intercept	*MABA*	*MABAV*	Intercept	τ	*ROE*
−0.01	0.40*					−0.01	0.01*				
(−1.40)	(2.40)					(−1.77)	(5.14)				
		−0.01*	2.63*						0.01	−0.59	
		(−3.91)	(2.60)						(1.06)	(−0.84)	
		−0.01*	−2.05	0.01*					0.01	−0.68	0.03
		(−3.83)	(−1.38)	(2.78)					(−0.07)	(−1.24)	(0.36)

Panel B: Market Value to Book Value of Assets *(MABA)* and it Variance *(MABAV)*

First on *ROE* then on *MABA* and *MABAV*						First on *MABA* and *MABAV* then on *ROE*					
Step 1: $V_t = \beta_0 + \beta_1 ROE_{t-1} + \varepsilon_t$		Step 2: $\varepsilon_t = \alpha_0 + \alpha_1 \tau + \alpha_2 GO_{t-1} + \alpha_3 GOTSV_{t-1} + \eta_t$				Step 1: $V_t = \beta_0 + \beta_1 GO_{t-1} + \beta_2 GOTSV_{t-1} + \varepsilon_t$			Step 2: $\varepsilon_t = \alpha_0 + \alpha_1 \tau + \alpha_2 ROE_{t-1} + \eta_t$		
−0.01	0.40*										
(−1.40)	(2.40)										
		−0.01*	2.63*								
		(−3.91)	(2.60)								
		−0.01	−3.12*	0.01	0.03*	−0.01	0.01*	0.01			
		(−1.60)	(−2.34)	(0.98)	(4.29)	(−0.41)	(2.01)	(1.48)			
									0.01	−0.70	
									(1.31)	(−1.04)	
									−0.01	−0.97	0.09
									(−0.63)	(−1.93)	(1.06)

Regression results of the two-step sensitivity tests. In the left two cells of each panel we do the following: In step 1 we regress idiosyncratic return variance on an intercept and return-on-equity (*ROE*). In step 2 we (a) regress the residual from step 1 regression on an intercept and a time trend, then (b) add a growth option proxy to the regression in (a). In the right two cells we reverse the roles of *ROE* and the growth options and repeat each regression. Definitions of the variables are provided in Tables 2 and 6. *Indicates significance at 5% level using a two-sided *t*-test.

that the value of equity for younger firms depends on more distant and hence uncertain future cash flows than those of older firms, indicating that a decrease in the average age of firms over time would contribute to increasing firm-specific volatility. This suggests that aggregate idiosyncratic volatility has increased through time because the number of riskier firms in the market has increased rather than because firms have become riskier. If increases in idiosyncratic volatility are due solely to additional younger firms in the sample, it should be the case that removing young firms from the sample would eliminate the trend in idiosyncratic volatility.

We test if changes in the cross-sectional distribution of firm age over time accounts for the trend in idiosyncratic volatility by restricting the age of the firms in each of our samples. In this test we focus on a subsample of firms that have been exchange-listed over the entire sample period. This sample selection procedure ensures that no new firms and no riskier firms are added to the sample over time. For firms that have sufficient data to calculate *MABA* and *Q* we eliminate any firm with less than 25.5 years of data. This leaves 110 firms in the *MABA* sample and 107 firms in the *Q* sample. For the proxies *CAPFIX*, *DTE*, and *PVGO* our samples start in the mid-1980s. For these samples we eliminate all firms that have less than 12 years of data, leaving 1361, 838, 1259 firms in these samples, respectively.

In Table 8 the rows labeled (1) contain the results from regressing the aggregate idiosyncratic volatility for the age-restricted samples on a time trend. In each of the five samples the coefficient on the time trend is positive and significant. The rows labeled (2) contain the coefficients and t-statistics from the regressions of the age-restricted sample idiosyncratic volatility on a time trend and the level and variance of the growth options for these samples. In every case the inclusion of the growth option proxies eliminates the significance of the time trend. These results indicate, first, that increasing the number of younger firms is not a sufficient explanation of the trend and, second, that even for samples of older firms, growth options are able to explain the trend in idiosyncratic volatility.

In unreported tests we repeat the experiment in Table 4 using other proxies for the age of firms. These include the number of initial public offerings in each year and eight other age-related variables: the number of firms with age less than 1 year, less than 3 years, less than 5 years, and less than 10 years, as well as the percentage of the sample that fell in those age buckets.[16] The results overwhelmingly indicate that these proxies for firm age are unable to explain the trend in idiosyncratic volatility, i.e., the trend remains significant and positive. In the presence of the growth option proxies and their time-series variances, none of the age variables increases the amount of explained variation by more than 1% and in some

[16] The initial public offerings data can be found on Jay Ritter's web site at http://bear.cba.ufl.edu/ritter/.

Table 8
Time-series regressions of idiosyncratic variance on a time trend and growth options: age-restricted samples

Panel A: *MABA*

	Intercept	τ	*MABA*	*MABAV*	Adj. R^2
1	0.01*	2.20*			0.24
	(2.27)	(3.33)			
2	0.01	0.46	0.01	0.05*	0.46
	(−0.24)	(0.99)	(0.66)	(2.82)	

Panel B: *Q*

	Intercept	τ	*Q*	*QV*	Adj. R^2
1	0.01	2.31			0.24
	(2.19)*	(3.37)*			
2	0.01	0.13	0.01	0.05	0.53
	(1.15)	(0.21)	(0.13)	(3.77)*	

Panel C: *CAPFIX*

	Intercept	τ	*CAPFIX*	*CAPFIXV*	Adj. R^2
1	0.01*	4.95*			0.26
	(2.19)	(3.01)			
2	−0.02*	0.21	0.01	4.38*	0.56
	(−3.78)	(0.18)	(1.64)	(4.52)	

Panel D: *DTE*

	Intercept	τ	*DTE*	*DTEV*	Adj. R^2
1	0.01	4.82*			0.28
	(1.94)	(3.21)			
2	0.02*	0.14	−0.03*	0.02	0.36
	(3.06)	(0.11)	(−2.35)	(0.38)	

Panel E: *PVGO*

	Intercept	τ	*PVGO*	*PVGOV*	Adj. R^2
1	0.01	4.99*			0.29
	(1.42)	(3.20)			
2	−0.01*	1.58	0.02*	0.12*	0.36
	(−1.97)	(1.25)	(2.57)	(3.52)	

Time-series regressions of idiosyncratic return variance on time trend, growth options, and time-series variances of growth options. Here the samples for *MABA* and *Q* are restricted to firms with more than 25.5 years of data. The shorter samples for *CAPFIX*, *DTE*, and *PVGO* are restricted to firms with at least 12 years of data. The dependent variable is the monthly average idiosyncratic return variance, *V*. The independent variables include a time trend and the level (time-series variance) of each growth option proxy, market-to-book value of assets, *MABA* (*MABAV*), Tobin's *Q*, *Q* (*QV*), capital to fixed expenditures, *CAPFIX* (*CAPFIXV*), Debt to Equity, *DTE* (*DTEV*), and the present value of growth options, *PVGO* (*PVGOV*). We use the generalized method of moments (*GMM*) to estimate the model. The *t*-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags. *Indicates significance at 5% level using a two-sided *t*-test.

cases their inclusion decreases the adjusted R-square. The ability of growth options to explain the upward trend in idiosyncratic volatility is not due to growth options acting as a proxy for firm age, and controlling for firm age fails to eliminate the explanatory power of growth options.

6. Subsample Analysis

While growth options have proven to be an important component of the long-run trend in idiosyncratic volatility, it is important to assess if this is a consistent phenomenon through time and across different markets. Given the similarity of the results for the five proxies for growth options and the results of Adam and Goyal (2003), which suggest that *MABA* is the most informative growth options proxy, we conserve space by focusing on *MABA* as the growth option proxy and the Campbell, Lettau, Malkiel, and Xu (2001) version of idiosyncratic volatility.

6.1 Rolling through time

Our subsample analysis consists of rolling our regression (Equation 11) through the data using 100-month windows. The trend in idiosyncratic volatility is significantly positive in 89 (41%) of the 217 overlapping samples; in the remaining samples the trend is never significantly different from zero. For the 89 sample windows exhibiting a positive trend, *MABA* is significantly positive and eliminates the trend in 92% of the windows. When the time-series variance of the growth option is included in the regression, the trend is explained in 62% of the samples.

We repeat the above test replacing October 1987 in the idiosyncratic volatility series with the average of the September and November values. This large and unique value impacts the trend coefficient in just under half the trend estimates. The trend in idiosyncratic volatility is significantly positive in 48% of the overlapping samples after removing the October 1987 outlier. *MABA* is significantly positive and eliminates the trend for 98% of these samples. In this case, when the time-series variance of the growth option is included in the regression, the trend becomes insignificant in 68% of the samples and becomes significantly negative in 15% of the samples. Both with and without the large outlier in October 1987, the growth option proxies consistently explain the trend in periods when idiosyncratic volatility contains a positive trend.

6.2 NYSE/AMEX versus NASDAQ firms

Schwert (2002) documents unusually high volatility of NASDAQ firms compared with NYSE/AMEX firms over the 6-year period between 1995 and 2001. Comparing large and small firm portfolios on the three national markets, he concludes that the substantial increase in total return volatility of NASDAQ stocks is due to the type of firms (hi-tech firms with more growth options) rather than to the firm size or the immaturity of the firm. Motivated by this finding, we investigate the ability of growth options to explain the firm-specific risk of NASDAQ versus NYSE/AMEX firms. *A priori*, we could argue that the small, high-tech firms with large growth options listed on NASDAQ will be more sensitive to the level and volatility of growth options. On the other hand, the larger NYSE/AMEX firms may have more free cash flow and more flexibility in choosing risky projects that increase the idiosyncratic variance of the firm, thereby increasing the value of their equity. We explore these issues by separating firms listed on NASDAQ from those listed on the NYSE and AMEX.

Table 9 presents the summary statistics for the two samples, respectively. Between 46 and 49% of all firm-months in our full sample are from NYSE/AMEX while the rest come from NASDAQ. Idiosyncratic volatility is on average more than 2 times higher for NASDAQ firms. The mean (median) of V is 2% (0.9%) for NYSE/AMEX firms versus 5.4% (2.9%) for NASDAQ firms. The standard deviation of V is also much higher for NASDAQ (6.4%) versus NYSE/AMEX firms (3.4%). In both samples V is positively skewed with heavy tails indicating some firms with large idiosyncratic volatility in both samples.

Table 9
Summary statistics of idiosyncratic variance, growth options, and return-on-equity: NYSE/AMEX versus NASDAQ firms

	V	*SIZE*	*ROE*	*MABA*
NYSE/AMEX Firms				
No. of Firm-months	605,911	605,911	604,654	540,804
% No. Obs.	49	49	49	46
Mean	0.020	1564.1	0.023	1.430
Median	0.009	148.1	0.030	1.157
Std. Dev.	0.034	8737.8	0.060	0.880
Skewness	4.333	21.4	−3.009	3.388
Kurtosis	25.78	737.7	18.06	17.89
NASDAQ Firms				
No. of Firm-months	637,072	637,072	633,731	635,886
% No. Obs.	51	51	51	54
Mean	0.054	351.5	−0.016	2.089
Median	0.029	39.5	0.015	1.470
Std. Dev.	0.064	5319.4	0.106	1.591
Skewness	1.935	57.5	−1.654	1.822
Kurtosis	6.102	4115.7	5.611	5.660

Summary statistics of idiosyncratic return variance, growth options, and return-on-equity for firms listed on NYSE/AMEX versus firms on NASDAQ at the firm-month panel level from January 1971 to December 2002. We split the full sample into two subsamples: NYSE/AMEX and NASDAQ firms, according to the exchange on which a firm is listed each month. Both samples are winsorized at the 2.5 and 97.5% levels for all variables. The definitions of the variables are provided in Tables 1 and 6.

Table 10
Time-series regressions of idiosyncratic variance on a time trend and growth options: NYSE/AMEX versus NASDAQ firms

	NYSE/AMEX firms					NASDAQ firms				
	Intercept	τ	*MABA*	*MABAV*	Adj. R^2	Intercept	τ	*MABA*	*MABAV*	Adj. R^2
1	0.01*	2.40*			0.21	0.01*	8.40*			0.47
	(3.29)	(3.02)				(2.57)	(6.32)			
2	−0.01	−2.23	0.01*		0.44	−0.01	1.14	0.01*		0.54
	(−1.73)	(−1.91)	(3.52)			(−0.30)	(0.57)	(2.65)		
3	0.01*	−1.18		0.03*	0.46	0.01*	5.61*		0.01	0.48
	(6.14)	(−1.93)		(4.15)		(4.42)	(2.40)		(0.85)	
4	0.01	−2.28*	0.01	0.02*	0.49	−0.01	−2.02	0.01*	0.01	0.55
	(0.11)	(−2.16)	(1.71)	(3.14)		(−0.09)	(−0.52)	(2.78)	(1.18)	

Time-series regressions of idiosyncratic return variance on time trend, market-to-book assets (*MABA*), and time-series variance of *MABA* (*MABAV*) for NYSE/AMEX versus NASDAQ firms. The dependent variable is monthly average idiosyncratic return variance (V). We use the generalized method of moments (*GMM*) to estimate the model. The t-statistics (in parentheses) are calculated using Newey and West (1987) heteroscedasticity and autocorrelation-consistent standard errors with 12 lags.
*Indicates significance at 5% level using a two-sided t-test.

NYSE/AMEX firms on average are 3–4 times larger than NASDAQ firms in their market capitalization. The standard deviation for NYSE/AMEX firms is about 6 times its mean, while that for NASDAQ firms is about 15 times its mean value, reflecting the size variation of firms listed on NASDAQ. In addition, *SIZE* is more skewed to the right with heavier tails for NASDAQ firms. Profitability for NYSE/AMEX firms is on average positive and less variable than that of NASDAQ firms, which average a *ROE* of −1.6%. *MABA* for NASDAQ firms is slightly larger (median of 1.5) than that for NYS/AMEX firms (median of 1.2).

Table 10 provides the regression results for the analysis of the two samples, respectively. There are distinct differences between the average idiosyncratic variances and the ability of growth options to explain firm-specific risk on different exchanges. Regression (1) in Table 10 indicates that, while the trend is significant for both samples, it is much more prevalent in the idiosyncratic variance of NASDAQ firms. The coefficient on the trend is nearly 4 times larger for the NASDAQ sample and the trend alone explains more than twice the variability of the firm-specific risk of that sample. Even though we cannot conclude that NASDAQ firms are driving the trend in idiosyncratic volatility in the full sample, it is apparent that the upward drift of idiosyncratic variance is more pronounced for NASDAQ firms.

While *MABA* is significant and drives out the trend for both exchanges, the time-series variance of *MABA* is important only for the NYSE/AMEX sample. Adding the variance of *MABA* as an explanatory variable doubles the explanatory power in the NYSE/AMEX sample but has little impact on the adjusted R-squares for the NASDAQ samples. In regression (4) when both the level and variance of *MABA* are included in the regressions, the level is significant in the NASDAQ sample while both the level and the variance are significant in the NYSE/AMEX sample for the one-sided test. In support of our first hypothesis, growth options are related to the idiosyncratic variance of firms in both samples. The result that the variance of growth options is more important for NYSE/AMEX firms is consistent with larger firms having more flexibility in their choice and timing of investments and supports our second hypothesis.

Overall the exercise of breaking up the sample based on exchanges adds more support for the implications of the Galai and Masulis model. Firms with more growth options exhibit a stronger trend in their idiosyncratic volatility. Growth options are important in explaining the significant trends in firm-specific risk across exchanges, while the variance of growth options plays a significant role for larger firms that have more ability to take advantage of changes in their investment opportunity set.

7. Conclusions

This paper provides a theory-based explanation of why individual stocks have become more volatile over time, by linking the trend in equity return volatility to the investment decisions of corporate managers. We use the classic corporate finance model of Galai and Masulis (1976) to argue that a significant portion of the trend in aggregate idiosyncratic volatility can be explained by the level and variance of growth options. We maintain that a moral hazard problem present in levered firms motivates managers acting on behalf of shareholders to select investment projects that increase the idiosyncratic variance of the firm at the expense of debt holders. The empirical evidence supports the hypotheses that both the level and variance of aggregate growth options are positively related to the upward trend in idiosyncratic volatility. After controlling for growth options, the trend in idiosyncratic volatility disappears or becomes negative. Our results are robust to the definition of idiosyncratic volatility and across different exchanges as well as subsamples, and the data clearly support growth options over alternative explanations of the trend in idiosyncratic volatility.

Showing that growth options play an important role in explaining the trend in firm-specific risk leads to the question of why the level and variance of growth options have changed. Zingales (2000) discusses how the nature of firms has changed; for example, large conglomerates have broken up and vertically integrated manufacturers have resigned direct control of suppliers. Intuitively, if we view a firm as a portfolio of investment opportunities, divestitures increase the focus of firms. The decline in diversification of both assets and investment possibilities increases the riskiness of the investment opportunity set. An obvious source of increased growth options is the trend toward more open capital and goods markets. Globalization of the world's economies provides managers with more opportunities for growth while at the same time increasing competition. Li, Morck, Yang, and Yeung (2004) show that lower market model R^2 is associated with greater capital market openness. Since easier access to capital broadens the menu of growth opportunities, this is additional evidence supporting a tie between growth options and idiosyncratic risk. Fama and French (2004) argue that decreasing costs of capital have induced smaller firms to seek financing to capture riskier growth opportunities.

Zingales (2000) points out that increased worldwide competition increases the demand for process innovation and improvements in quality. Our results are consistent with globalization of markets providing more opportunities for growth and more competition, which forces managers to seek out riskier projects to increase shareholder value. While Irvine and Pontiff (2004) show that increasing competition can raise the variability of cash flows, thereby increasing idiosyncratic volatility, the variability of cash flows in part comes from riskier growth options. Beck, Demirgüç-Kunt, and Maksimovic (2005) suggest that the legal and institutional structures that are more favorable to investment contribute to the availability of growth opportunities in the economy. As more so-called "third world" economies mature into stable marketplaces, the menu of growth options for many firms continues to increase, suggesting that our results may hold internationally as well.

The strong results linking idiosyncratic risk and growth options following from the Galai and Masulis model have implications for the development of incentive packages for corporate managers and for the understanding of risks faced by debt holders. Brisley (2006) argues that firms with risky and valuable growth options must properly incentivize conservative managers to take risks. From an investor's perspective our results suggest consideration of growth options is important for understanding time-variation in the covariance structure of returns. Alternatively, the results suggest an important role for firm-specific information in the information set of conditional asset pricing models.

Appendix A: The Galai and Masulis Model and Idiosyncratic Volatility

In the Galai and Masulis framework the total value of a firm's assets, A, is the sum of the value of equity, S, and debt, D. The instantaneous expected return of the firm is therefore the value-weighted sum of the ROE and the return on debt. Here each of the instantaneous expected return components, $(\overline{r}_A, \overline{r}_S, \overline{r}_D)$, is a linear function of instantaneous systematic risk β_i and the instantaneous market risk premium, for example, $\overline{r}_i = r_f + \beta_i(\overline{r}_M - r_f)$, where $\beta_i = \frac{\mathrm{cov}(\tilde{r}_i;\tilde{r}_M)}{\sigma^2(\tilde{r}_M)}$, $i = A, S$, or D.

Under the assumptions in Galai and Masulis, the value of equity can be considered equivalent to the value of a European call option on the value of the firm so that S is determined by the Black–Scholes (1973) option pricing model

$$S = A \times N(d_1) - ke^{-r_f T} \times N(d_2), \tag{A1}$$

where $d_1 = \frac{\ln(A/k)+(r_f+\sigma^2/2)T}{\sigma\sqrt{T}}$, $d_2 = d_1 - \sigma\sqrt{T}$, $N(\cdot)$ is the standard normal cumulative probability density function, k the exercise price of the option, T the time to maturity, and σ^2 the instantaneous variance of percentage changes in A. Galai and Masulis show that as the time increment goes to zero, the dollar ROE is proportional to the dollar return on the value of the firm,

$$\tilde{r}_S = \frac{\Delta S}{S} = \frac{S_A}{S}A\frac{\Delta A}{A} = \frac{S_A}{S}A\tilde{r}_A = \eta_S\tilde{r}_A. \tag{A2}$$

Substituting Equation (2) into the CAPM yields a relation between the systematic risk of equity and the systematic risk of the total value of the firm,

$$\beta_S = S_A\frac{A}{S}\beta_A = \eta_S\beta_A. \tag{A3}$$

Here η_S is the elasticity of equity value with respect to firm value. The moral hazard occurs because from (1), $\frac{\partial S}{\partial\sigma} > 0$ while from (3), $\frac{\partial\beta_S}{\partial\sigma} < 0$ (if β_A is stationary and >0). It is important to note that since both these derivatives are taken holding the value of the firm, the DTE, and the market risk of the firm constant, any change in the total variance of the firm must be due to changes in the idiosyncratic risk of firm-level returns; that is, $\frac{\partial S}{\partial\sigma} \equiv \frac{\partial S}{\partial\sigma\varepsilon_A}$ and $\frac{\partial\beta_S}{\partial\sigma} \equiv \frac{\partial\beta_S}{\partial\sigma\varepsilon_A}$.[17] One way managers influence the idiosyncratic variance of the firm is to choose investments from their opportunity set with the most nonsystematic risk.

Galai and Masulis stress that since the investment decisions of a levered firm are controlled by stockholders, a project requiring an initial investment of I, will be undertaken as long as $\partial S/\partial I = (\partial S/\partial A)(dA/dI) + (\partial S/\partial\sigma^2)(d\sigma^2/dI) \geqslant 0$ (even if $dA/dI<0$). Stockholders are willing to take on a project that has a negative impact on firm value as long as the benefit from increasing the idiosyncratic variance outweighs the cost. For our purposes consider a levered firm with a choice between two mutually exclusive projects, X and Y, with equal profitability in terms of expected net cash flow discounted for systematic risk, $dA/dI_X = dA/dI_Y$, where $\sigma_X^2<\sigma_Y^2$. Managers always choose Y since $(\partial S/\partial\sigma^2)(d\sigma^2/dI_Y) > (\partial S/\partial\sigma^2)(d\sigma^2/dI_Y)$. The costs of increasing nonsystematic risk are borne by the holders of the firm's debt.

Similar to the relationship between the market risk of equity and the market risk of the firm in Equation (3), the idiosyncratic volatility of equity is a function of the interaction between the idiosyncratic volatility of firm-level returns and η_S, the elasticity of equity value with respect to firm value. To see this, let ε_i represent the idiosyncratic part of returns. Adding ε_i to the CAPM equation implies that the total variance of equity can be written as $\sigma_S^2 = \beta_S^2\sigma_{\tilde{r}_M}^2 + \sigma_{\varepsilon_S}^2$. Substituting in Equation (A3) for β_S and using the implication from Equation (2) that $\sigma_S^2 = \eta_S^2\sigma_A^2$ reveals that

$$\sigma_{\varepsilon_S}^2 = \eta_S^2(\sigma_A^2 - \beta_A^2\sigma_{\tilde{r}_M}^2) = \eta_S^2\sigma_{\varepsilon_A}^2. \tag{A4}$$

Idiosyncratic risk of equity is a function of the idiosyncratic variance of firm and through η_S, the firm's capital structure and the slope of the function relating equity values and total firm value.

[17] See the discussion of the Galai and Masulis model in Copeland and Weston (1988).

Appendix B: Data Definitions

B.1 Growth option proxies

Using the merged Center for Research in Stock Prices (*CRSP*) and *COMPUSTAT* quarterly industrial and research files data items, we define the growth option proxies as

$MABA$ = [Total Assets (data44) − Total Common Equity (data59) + Price (data14) × Common Shares Outstanding (data61)] / Total Assets (data44)

Q = [Price (data14) × Common Shares Outstanding (data6) + Preferred Stock (data55) + Current Liabilities (data49) − Current Assets Total (data40) + Long-Term Debt (data51)] / Total Assets (data44)

DTE = [Debt in Current Liabilities (data45) + Total Long-Term Debt (data51) + Preferred Stock (data55)]/[Common Shares Outstanding (data61) × Price (data14)]

$CAPEX$ = Capital Expenditures (data90) / Property, Plant, and Equipment (data42)

$PVGO$ = The present value of growth options in Long, Wald, and Zhang (2005).

Following Brealey and Myers (2000), we define $PVGO$ as the option value of equity, not of the firm. The $PVGO$ of the firm can be approximated by the $PVGO$ of equity as long as the probability of bankruptcy is low. We obtain the $PVGO$ as follows:

(1) Estimate the annual (*ROE*) by the operating cash flow divided by the beginning period book value of long-term liability not including debt.
(2) Use previous four years' (*ROE*) to compute a weighted average (*ROE*) for year t: Average $ROE_t = \text{w1} \times ROE_{t-1} + \text{w2} \times ROE_{t-2} + \text{w3} \times ROE_{t-3} + \text{w4} \times ROE_{t-4}$, where w1= 40%, w2 = 30%, w3 = 20%, and w4 = 10%. This weighting scheme gives greater weights to more recent observations.
(3) Obtain the projected earning by multiplying average *ROE* by the end-of-period nondebt long-term liability.
(4) Estimate the value of asset-in-place, defined as the discounted projected-cash-flows. The discount rate is computed by using the CAPM model, the one-month risk-free rate, and the previous 60-month historical stock return.
(5) Obtain the $PVGO$, the total market value of equity minus the value of asset-in-place divided by the total market value of equity.

While there are several ways to define *ROE*, our definition, in step 1, of operating cash flow divided by nondebt long-term liability can capture the actual economic *ROE* better than accounting definitions can. We tested other weighting schemes used in step 2 such as equally weighting each of the four years. We found qualitatively similar results. Lastly, to check the robustness of our results with respect to alternative definitions of discount rate, we experimented with several definitions of betas and discount rates, including (1) historical betas, (2) value line estimates of betas, and (3) setting beta to be 1 for all firms and estimating the discount rate as the sum of risk-premium on the S&P 500 index portfolio and the one-month risk-free rate over the previous 60-month period. Our results reaffirm the finding of Long, Wald, and Zhang (2005) that the calculation of the PVGO is insensitive to alternative definitions of discount date.

B.2 Conditioning variables

The dividend yield is calculated by summing up 12 lags of $[I_{NYSE,t} \times (1 + R_{NYSE,t+1}) - I_{NYSE,t+1}]$ and then dividing by $(I_{NYSE,t+12})$, where I_{NYSE} is the level of the value-weighted NYSE index excluding dividends and R_{NYSE} is the return on the value-weighted NYSE index including dividends found in the CRSP indices files. Junk is the difference between Moody's BAA and AAA corporate bond yields (percent/annum) divided by 100. Term is the spread between the lagged Moody's Composite Average of Yields on Corporate Bonds (industrial Manual)/1200 and U.S. 3-Month T-Bill from the risk-free CRSP file described above. Returns on the consumer price index are found in the CRSP Treasury and Inflation files.

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