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Uncertainty and Valuations

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ABSTRACT

Pástor and Veronesi (2003) proposed the idea that uncertainty about a firm's profitability could increase its stock valuation, as an explanation for several phenomena in financial markets. We further examine this idea in a set-up with both stocks and bonds, and show that unless a firm is deeply in debt, the same logic implies that uncertainty increases a firm's stock valuation but decreases its bond valuation, and that the uncertainty's impact is stronger if the firm's leverage is higher. Using a number of existing uncertainty proxies in the literature and controlling for volatility, we empirically test these predictions. Our evidence based on some (but not all) proxies supports the positive association between stock valuation and uncertainty. However, our evidence generally does not support the negative association between uncertainty and bond valuation using existing uncertainty proxies, particularly firm age. These results challenge the interpretation of the existing uncertainty proxies and thus the results in the literature employing them.

Keywords: Uncertainty, convexity, valuation, technology bubble.

JEL Codes: G12.

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1 Introduction

Much progress has been made recently in exploring the idea that investors face uncertainty about parameter values in their model. In a recent survey paper, Pástor and Veronesi (2009b) note that, "many financial market phenomena that appear puzzling at first sight are easier to understand once we recognize that parameters in financial models are uncertain and subject to learning." A prominent idea in this literature is that the uncertainty about a firm's long-run profitability increases its stock valuation. This follows directly from the premise that the firm's future earnings are a convex function of the growth rate of its earnings. Due to Jensen's inequality, higher uncertainty in the growth rate implies higher expected future earnings, and so leads to a higher stock valuation. Pástor and Veronesi (2003) provide strong supportive empirical evidence that firms with high uncertainty (using firm age as a proxy) tend to have high market-to-book ratios. This argument may also have important implications for the "technology bubble" in late 1990s. Pástor and Veronesi (2006) argue that there was not necessarily a bubble, since in their calibrations a plausible amount of uncertainty about the profitability of the technology firms is sufficient to generate the high valuation observed at the peak of the "bubble" period. This argument offers a sharp contrast to the previously widely held view that the valuation of technology stocks was driven by irrational exuberance (see, e.g., Shiller, 2000).

Given the significant attention and success of this uncertainty-convexity argument, the goal of our paper is to further evaluate this idea. The main intuition of the uncertainty-convexity argument of Pástor and Veronesi (2003) is that large uncertainty about the profitability of a firm means it might be the next Google (i.e., very profitable), or it might be very unprofitable. If the firm's future earnings are a convex function of the growth rate, the impact of the prospect of being the next Google dominates and hence uncertainty increases the stock valuation. While this is intuitive, one can also imagine arguments implying the opposite: For example, if investors are ambiguity averse (e.g., Gilboa and Schmeidler (1989)), higher uncertainty reduces the stock valuation since ambiguity-averse investors make decisions based on the worst-case scenario. The validity of the idea in Pástor and Veronesi (2003) is thus an empirical question.

their uncertainty measures data. Yan received support from the National Natural Science Foundation of China (grant 70932003). We are responsible for any errors.

The idea of our paper is that the corporate bond market provides a great opportunity for an additional litmus test for the uncertainty-convexity argument in Pástor and Veronesi (2003), whose theoretical model only considers the case of an all-equity firm. Our main contribution is to consider the argument for firms financed by both equity and debt, and the implications for uncertainty on both. Intuitively, while equity holders capture the benefit in case the firm is indeed the 'next Google,' the upside for corporate bond holders is limited by the notional amount of the bond. However, bond holders would still suffer when the firm turns out to be very unprofitable. Therefore, by the same logic, while uncertainty increases the stock price, uncertainty generally decreases the bond price.

More specifically, let us consider a security that is a claim to some asset at the end of the period. Following Pástor and Veronesi (2003), we assume that the asset value is a convex function of the growth rate, which investors are uncertain about. The critical difference in our model set-up vis-á-vis Pástor and Veronesi (2003) is that the firm is now financed by both equity and a bond, rather than by only equity. At the end of the period, if the firm's asset is worth more than the notional value of the bond, the bond holders receive the bond's notional amount and the equity holders will get the residual value. If the firm's asset is worth less than the notional amount of the bond, however, the bond holders will get the whole firm and the equity holders receive nothing. This simple set-up leads to the following four implications.

First, the uncertainty about the earnings growth rate increases the stock's valuation. This is the main idea in Pástor and Veronesi (2003). Due to Jensen's inequality, the uncertainty in the growth rate of the profitability increases the expected profit of a firm and so increases the firm's value. We thus argue that our admittedly simplistic model set-up is sufficient to capture the main feature of their model. The same intuition leads to our second implication: unless firms are so deeply in debt that they are quite likely to default, the positive association of uncertainty and stock valuation tends to be stronger for firms with higher leverage.[1]

The third implication follows from the intuition that bond holders share downside risks but benefit less from the upside, the uncertainty about the

[1] Intuitively, if a firm is almost surely to go bankrupt, the equity value is close to zero and its sensitivity to uncertainty fades away. This extreme situation is not relevant in our empirical analysis, where we only focus on bonds with investment grade credit ratings.

firm's earnings growth rate decreases a firm's debt valuation, except in the extreme situation where the firm is very deeply in debt.[2] As will become clear, this extreme situation is not relevant in our empirical analysis, where we only focus on bonds with investment grade credit ratings.

This negative association between uncertainty and bond values offers an opportunity to distinguish the two competing viewpoints on the technology 'bubble' and subsequent crash. Shiller (2000) argues it was a bubble driven by an excess of optimism that subsequently evaporated. If it is optimism that drives up stock prices, it should also drive up bond prices. On the other hand, if it is convexity in expected earnings growth rates combined with uncertainty that drives up stock prices, as proposed in Pástor and Veronesi (2006), it should decrease bond prices.

The fourth implication from the model is that, again unless the firm is very likely to default, an increase of leverage increases the sensitivity of debt value to uncertainty (i.e., for firms with higher leverage, an increase in uncertainty decreases their debt value even more). To see the intuition, let us first consider the limit case where the firm has very little debt. In this case, it is almost certain that the firm is going to be able to pay back the debt. Hence, the debt value is very insensitive to the uncertainty. This sensitivity increases when the firm has more debt.

We test these implications using data on equity and bond prices from 1994-2006. For the equity valuation measure, we use the log of the ratio of the market value over the book value of equity from the Center for Research in Security Prices (CRSP) and Compustat, as in Pástor and Veronesi (2003). For the bond valuation measure, we use credit spreads based on bond transactions data from the National Association of Insurance Commissioners (NAIC) matched to the Fixed Income Securities Database (FISD, which contains bond issue and issuer characteristics). Given the holding restrictions of insurance companies, this database essentially only includes investment grade corporate bonds, where we focus on junior unsecured issues.

To take the model to the data, the main challenge is finding a good proxy for uncertainty. Our strategy here is to adopt a large number of different uncertainty proxies used in the literature, discussing the pros and cons of each measure. We first examine the proxy for uncertainty originally proposed by Pástor and Veronesi (2003): minus the reciprocal of one plus

[2] In the extreme case where the firm is deeply in debt, however, this relation is reversed because debt holders essentially own the firm.

firm age. The motivation is that investors learn about a firm's profitability over time. As a result, uncertainty over the earnings growth rate decreases over time. Pastor and Veronesi propose this specific functional form ('minus the reciprocal of one plus firm age') based on their model of a Bayesian investor. One drawback of using age as a proxy for uncertainty is that by design it implies that uncertainty can only decrease over time.

We first replicate the main empirical result in Pástor and Veronesi (2003) that firms with greater uncertainty (i.e., younger firms) tend to have a higher stock valuation. However, our empirical results, based on this uncertainty measure, fail to find support for any of the other implications of our model. In particular, we find that greater uncertainty, as proxied by firm age, is associated with higher bond prices (or smaller credit spreads).

All our empirical results are derived from pooled panel regressions with both firm- and year-fixed effects and standard errors clustered by firm. We test the model's first implication by regressing the log of market-to-book ratios on the measure of uncertainty (i.e., firm age) with standard firm-level controls. The coefficient for firm age is −2.71 with a t-statistic of 5.03. Consistent with the evidence in Pástor and Veronesi (2003), this result implies that firms tend to have higher market-to-book ratios when they are younger - and presumably have higher uncertainty - than when the same firm is older. Next, we test the second implication by interacting the uncertainty proxy with leverage. The association of firm age with stock valuation comes mainly from firms with low leverage, contradictory to the model implication that uncertainty should increase high leverage firms' valuation more strongly.[3]

For the third implication, we regress credit spreads on the measure of uncertainty, with and without firm- and issue-level controls, firm fixed effects and year fixed effects. We consider two bond samples, as in Campbell and Taksler (2003). The first sample only uses bond issues with longer maturity (at least five years) and the second sample only uses bond issues with shorter maturity (at least one year but less than five years). For the long maturity sample, without firm-level controls, the coefficient for firm age is 24.51 (t-statistic of 6.63), implying that lower age (i.e., higher uncertainty, under the interpretation in Pástor and Veronesi (2003)) is associated with lower credit spreads and so higher bond prices, contradictory to the third

[3] It is worth noting that there is no robust empirical association between firm age and leverage.

implication of our model. The coefficient remains significantly positive after including year and rating dummies, and only becomes insignificant after also including the rating × year dummy (or firm fixed effects). The results from the short maturity sample are similar. Finally, we test the fourth implication in credit spread regressions with interactions of the uncertainty measure with leverage and find that all the coefficients for the 'firm age × leverage' interaction terms are insignificant. The results across the two bond maturity samples are again very similar.

We also examine the robustness of our results by adopting various alternative proxies of uncertainty. First, we adopt two measures of uncertainty introduced by Pástor *et al.* (2009) that are based on stock market reactions to earnings announcement surprises. The results based on these two measures are generally insignificant in most stock and bond valuation regressions and/or have opposite signs.

Second, we repeat our analysis based on the uncertainty measures obtained in Korteweg and Polson (2008), who calibrate the Leland (1994) model to stock and bond prices to obtain the implied parameter uncertainty for firm asset value and for asset volatility, which we denote as Sigma1 and Sigma2, respectively. Although these two uncertainty measures are not designed to capture the uncertainty about the long-run profitability, they are likely to be positively correlated with such uncertainty and hence could be useful proxies. The results are mixed. In particular, higher uncertainty, as measured by either greater posterior parameter uncertainty about asset value and asset volatility, is associated with higher stock valuation. In our panel regressions with firm fixed effects, these two proxies are insignificantly associated with corporate bond yield spreads.[4]

Third and finally, we consider two proxies of uncertainty based on analyst forecasts of the quarterly earnings-per-share, namely analyst forecast dispersion (i.e., the normalized standard errors of the earnings-per-share) and analyst forecast error (i.e., the difference between the median forecast and the actual earnings-per-share). Guntay and Hackbarth (2010) find that analyst forecast dispersion is positively associated with credit spreads. In our sample, we indeed find that both analyst uncertainty proxies have positive relation with credit spreads, consistent with our model. How-

[4]If one includes industry fixed effect rather than firm fixed effect in the regressions, these two proxies become significant for the sample of bonds with maturities over five years, but have opposite signs, with only the sign of Sigma1 being consistent with the model prediction.

ever, neither the analyst forecast dispersion nor the analyst forecast error variables are positively associated with equity valuation. The coefficient of analyst forecast dispersion is strongly negative, both statistically and economically, in the stock valuation regressions. Analyst forecast errors are unrelated to stock valuation in our sample.

In conclusion, despite the success of the idea of uncertainty and convexity on both empirical and theoretical fronts, our analysis shows that it also faces a number of challenges, and so points to directions for future research. The existing evidence and validation of the idea of uncertainty and convexity is focused on the equity market. We re-examine this uncertainty/convexity mechanism: Our set-up has two convexities. The first convexity is that profitability is convex in the earnings growth rate, as in Pástor and Veronesi (2003). The second one is that equity payoffs are convex in firm value. The uncertainty/convexity mechanism is driven by the first convexity. The role of the second convexity is to offer an opportunity for an "out-of-sample" test of the uncertainty/convexity mechanism through implications on the relation between uncertainty and bond prices. In particular, our new predictions relative to Pástor and Veronesi (2003), the relation between uncertainty and bond prices, are derived from the interaction of both convexities.

Our empirical evidence, based on a plethora of uncertainty proxies, is far less encouraging for the uncertainty/convexity mechanism. How should we interpret these results?

It may simply be a measurement problem, i.e., the existing eight different measures in the literature that we consider in this paper simply cannot reliably measure uncertainty, or do so in a way that is distinct from volatility. A related important contribution of this paper is thus to warn for caution to be cautious in interpreting uncertainty proxies currently used in the literature, particularly firm age. For example, following Pástor and Veronesi (2003) many subsequent papers have used firm age as a proxy for uncertainty about growth prospects, see, e.g., Wei and Zhang (2006), Gaspar and Massa (2006), Brown and Kapadia (2007), and Cao *et al.* (2008). Other papers, like Adrian and Rosenberg (2008), employ Pastor and Veronesi's intuition linking firm age and higher uncertainty. Given our results and assuming the plausibility that increased uncertainty would be associated with lower bond prices, our paper is an important reminder to researchers that firm age could proxy for various different firm characteristics.

Another possibility is that equity and bond markets are not fully integrated. If so, it would be fruitful to search for the frictions preventing the force of arbitrage.[5] Another interpretation is that our results post a challenge to the view that greater uncertainty about the earnings growth rate increases the stock valuation.

In addition to the large literature on asset valuation, our paper is also broadly related to the literature that attempts to document and explain the technology bubble, see, e.g., Abreu and Brunnermeier (2003), Allen *et al.* (2006), Brunnermeier and Nagel (2004), Scheinkman and Xiong (2003), Cochrane (2003), Cooper *et al.* (2001), Hong *et al.* (2006) and Hong *et al.* (2008), Lamont and Thaler (2003), Ljungqvist and Wilhelm (2003), Ofek and Richardson (2003), Pástor and Veronesi (2006), Pástor and Veronesi (2009a), and Schultz and Zaman (2001), among others. Our paper adds to this literature by demonstrating the empirical challenges faced by one of the leading explanations, and so points to directions for improvement. Finally, our paper is related to the literature linking uncertainty to debt values, see, e.g., Duffie and Lando (2001) and David (2008). For example, Yu (2006) finds lower credit spreads for firms with better accounting disclosure, especially for short-term bonds, but does not consider equity valuation. Guntay and Hackbarth (2010) use analyst forecast dispersion to consider credit spreads and Korteweg and Polson (2008) analyze the impact of parameter uncertainty on corporate bonds. Among other things, they focus on the parameter uncertainty on firm value but stay away from the issue that firm value is a convex function of the earnings growth rate, which is the main focus in Pástor and Veronesi (2003), as well as our paper.

The rest of the paper is organized as follows. Section 2 presents a simple setup to develop the hypotheses, which are tested empirically in Section 3. Section 4 concludes. All derivations are provided in the Appendix.

[5]There is some evidence of limited and costly arbitrage between corporate bonds and credit default swaps (see, e.g., Blanco *et al.* (2005)) and between bond and equity markets (see, e.g., Mitchell *et al.* (2007), Yu (2006)), but it is unclear whether this would be enough to explain our results. On the other hand, there is also widespread evidence that information contained in equity and derivate prices is useful for bond valuation (see, e.g., Collin-Dufresne *et al.* (2001), Cremers *et al.* (2008), and Ericsson *et al.* (2005)). Furthermore, recent papers indicate that more elaborate models seem to be able to reconcile equity, bond (and derivative) prices (see, e.g., Bhamra *et al.* (2010), Chen *et al.* (2009), and Cremers *et al.* (2008)).

2 Hypotheses

This section presents a simple model to capture the convexity argument put forth in Pástor and Veronesi (2003), and to develop the hypotheses that we will test empirically.

2.1 Uncertainty and the Convexity Argument

Let us consider a one-period model ($t = 0, 1$). There is a firm whose asset in place at $t = 0$ has a value of $V_0 > 0$. The firm is financed only by equity and will be liquidated at $t = 1$. So the stock is a claim to the firm's liquidation value V_1 at $t = 1$:

$$\ln V_1 - \ln V_0 = u + \varepsilon, \tag{1}$$

where u is the mean growth rate of the firm and ε is normally distributed, and $\varepsilon \sim N(0, \sigma_\varepsilon^2)$. Note that in (1), we intentionally set the firm's liquidation value V_1 as a convex function of the mean growth rate u. This is intended to capture the main insights from Pástor and Veronesi (2003), which notes that a firm's cash flows in the long run are naturally a convex function of the mean growth rate in profitability. To see the uncertainty effect in Pástor and Veronesi (2003), we first look at the case without uncertainty, i.e., when investors know the true value of u. To simplify the calculation, we set the riskless interest rate at zero and assume that investors are risk-neutral. It is straightforward to calculate the stock price at $t = 0$,

$$S_0 = E[V_1] = V_0 e^{u + \frac{1}{2}\sigma_\varepsilon^2}. \tag{2}$$

The above expression for stock price shows that a higher mean earnings growth rate u naturally leads to a higher stock valuation. Moreover, a higher volatility in realized earnings σ_ε, due to Jensen's inequality, increases the expected dividend and hence also increases stock valuation.

We now introduce uncertainty about the mean growth rate u: Investors do not know its true value but have a belief that $u \sim N(\bar{u}, \sigma_u^2)$, where $\bar{u}$ and σ_u are constants. Investors' uncertainty about the mean growth rate is captured by σ_u. The higher σ_u, the higher the uncertainty. It is important to note that uncertainty and volatility are *not* the same in our model and, in principle, one *can* empirically identify σ_ε and σ_u separately. One can measure volatility σ_ε by estimating the volatility of a firm's realized earnings, e.g., the standard deviation of return on assets. The measurement for uncertainty σ_u is much more difficult and we will attempt to measure it using various proxies in the literature in our empirical analysis in Section 3.

In this case with uncertainty, the stock price is given by

$$S_0 = E[V_1] = V_0 e^{\bar{u}+\frac{1}{2}\sigma_u^2+\frac{1}{2}\sigma_\varepsilon^2}. \tag{3}$$

The above expression shows that the stock price also increases in the uncertainty σ_u. As shown in (2), the stock valuation is convex in u. As a result, greater uncertainty in u increases the stock valuation. This is the key intuition in Pástor and Veronesi (2003), Pástor and Veronesi (2006): Due to the higher uncertainty in the growth rate of profitability, young firms and technology firms have a higher stock valuation.

2.2 *Corporate Bonds*

The above insight has been shown to be important in understanding a number of intriguing empirical facts in the stock market (e.g., Pástor and Veronesi (2003), Pástor and Veronesi (2006), Pástor and Veronesi (2009a), and Johnson (2004)). In this paper, we argue that the corporate bond market provides a great opportunity for another test for this convexity argument. The idea is that the above convexity argument leads to an immediate implication for corporate bond valuation: Although equity holders can benefit from the prospects that the firm might be the next Google, the upside for corporate bond holders is capped by the notional amount of the bond. On the other hand, bond holders would still suffer from the downside when the firm turns out to be very unprofitable. Hence, bond value would seem to tend to decrease with uncertainty about the growth rate of profitability. Next, we formalize this idea by introducing a corporate bond into the baseline model.

Identical to the model in Section 2.1, the asset of the firm is V_1. However, the firm is now financed by both equity and a zero-coupon bond. The debt has a principle value of B and matures at t = 1. Hence, the equity claim receives $\max(V_1 - B, 0)$. Hence, at t = 0, the firm value is $F_0 = E[V_1]$ and the stock price is $S_0 = E[\max(V_1 - B, 0)]$. We show in the appendix that some algebra leads to the following four results:

Result 1 is $\partial S_0/\partial \sigma_u > 0$. That is, an increase in uncertainty increases the stock price. This is similar to the main point in Pástor and Veronesi (2003), who consider a model of an all-equity firm without leverage. Due to Jensen's inequality, the uncertainty in the growth rate of the profitability increases the expected profit of a firm and so increases the firm's value. The same intuition also works in our model with leverage: Since equity is a levered position in the firm's underlying asset, uncertainty increases firm value and thus increases the stock price. This naturally leads to the second result.

Result 2 is that $\partial^2 S_0/\partial\sigma_u\partial B > 0$ if $B < B^*$ and $\partial^2 S_0/\partial\sigma_u\partial B < 0$ if $B > B^*$, where $B^* \equiv V_0 e^{\bar{u}}$. That is, the impact of uncertainty on the stock price tends to be stronger when the leverage is higher. The exception is the extreme case where the firm is deeply in debt ($B > B^*$). This is intuitive: Suppose the firm is very deeply in debt and almost surely will default. Then, the equity value is close to zero and its sensitivity to uncertainty fades away when further debt is added. Note that B^* is the debt level such that if the firm grows at the expected rate $\bar{u}$ it will have just enough to pay back the debt and the equity is worth zero at $t = 1$. Since our empirical analysis will be focusing on investment grade bonds, the relevant case is $B < B^*$.

Result 3 is that $\partial D_0/\partial\sigma_u < 0$ if $B < B^{**}$ and $\partial D_0/\partial\sigma_u > 0$ if $B > B^{**}$, where B^{**} is a constant defined in the appendix and $B^{**} > B^*$. That is, as long as the firm's debt is less than B^{**}, an increase in uncertainty about the growth rate of profitability decreases the debt value. The intuition is the following. Having a high uncertainty implies that the firm may turn out to be extremely profitable or very unprofitable. Note that relative to equity holders, debt holders benefit much less from the prospect of the firm being extremely profitable: At the maximum, the debt holders receive the bond's notional amount. If the firm turns out to be unprofitable, however, the debt holders will suffer from default. As a result, uncertainty tends to hurt debt value. In the extreme case where the firm is deeply in debt ($B > B^{**}$), however, this result is reversed. Since in this case most of the firm value belongs to debt holders and the equity is basically worthless, an increase in uncertainty increases the firm value and so increases the debt value. Note that B^{**} is the debt level such that if the firm grows at the expected rate $\bar{u}$ it is expected to default at $t = 1$. Thus, this case is not relevant for our empirical analysis, which focuses on investment grade bonds.

Finally, result 4 is that $\partial^2 D_0/\partial\sigma_u\partial B < 0$ if $B < B^*$ and $\partial^2 D_0/\partial\sigma_u\partial B > 0$ if $B > B^*$. That is, unless the firm is deeply in debt (more than B^*), an increase of leverage increases the sensitivity of debt value to uncertainty (i.e., $\partial D_0/\partial\sigma_u$ becomes more negative). To see the intuition, let us first consider the limit case where the firm has very little debt (B is close to zero). In this case, it is almost certain that the firm is going to be able to pay back the debt. Hence, the debt value is very insensitive to the uncertainty ($\partial D_0/\partial \sigma_u$ is close to 0). This sensitivity increases when the firm has more debt ($\partial D_0/\partial \sigma_u$ becomes more negative).

It is worth clarifying that there are two different convexities in our model. The first one is that the firm's payoff V_1 is a convex function of the mean growth rate u. The second one is the convexity in the payoff from equity. The first convexity is the focus in Pástor and Veronesi (2003), while the second one, the convexity in equity's payoff and hence the concavity in debt's payoff, offers a useful set-up for further examining the implications from the convexity studied in Pástor and Veronesi (2003). Note that the result in Pástor and Veronesi (2003) depends on the assumption that the uncertainty is about the growth rate of the profitability, so that the firm value is a convex function of the variable with uncertainty. Our paper further explores this mechanism by examining the differential impacts of uncertainty on debt and equity values. The main new result in our paper - that uncertainty decreases bond valuation - is derived from the fact the debt holders do not benefit from the full upside.

The risk neutrality assumption rules out the impact of uncertainty on the discount rate. As noted in Pástor and Veronesi (2003), even if the growth rate of profitability is correlated with the exogenously specified stochastic discount factor, due to Bayesian learning, the uncertainty of the growth rate of the profitability is still idiosyncratic and commands no risk premium. So, the analysis is focused on cash flows rather than discount rates. If we would endogenize the stochastic discount factor, it is unclear how systematic uncertainty would affect the discount rate. For example, Veronesi (2000) shows that the impact of the aggregate uncertainty on the discount rate is mixed. Depending on parameter values, it may increase, decrease or have no impact on the risk premium.

3 Empirical Analysis

This section tests the four implications developed in the previous section. It is important to point out that although results 2 through 4 depend on the debt level, the more empirically relevant cases are those where $B < B^*$ and $B < B^{**}$. Note that $B^* < B^{**}$ and that B^* is the debt level such that if the firm grows at the expected rate $\bar{u}$ it will have just enough to pay back the debt and the equity is worth zero at $t = 1$. Such firms will most likely have credit ratings indicating a very high likelihood of default and surely be below investment grade. As explained in more detail below, our bond data do not contain such bond issues. Hence, in the rest of this section, we will thus test the following four hypotheses: (i) uncertainty increases stock valuation, (ii) the impact of uncertainty on the stock valuation is stronger if the firm's leverage is higher, (iii) uncertainty decreases bond valuation, (iv) the impact of uncertainty on the bond valuation is stronger if the firm's leverage is higher.

3.1 Data

The stock prices and accounting data are from CRSP and Compustat. We use all common stocks listed in the U.S. The variable definitions closely follow those in Pástor *et al.* (2009). Market value of equity equals the stock price at the end of the calendar quarter times the number of common stocks outstanding. Book value of equity follows Fama and French (1993) and equals stockholders' equity book value plus deferred taxes minus book value of preferred stock (the latter two are set at zero if missing).

We use the following firm-level controls. Stdev(Ret) is the standard deviation of daily firm returns in the previous 180 days, the same interval as in Campbell and Taksler (2003). ROE is return on equity and equals income before extraordinary items available for common stock plus deferred taxes, divided by the book value of equity. Std(ROE) equals the standard deviation of ROE based on the previous 12 quarters (if available, a minimum of four quarters is required). Assets measures the book value of total assets. Capex/Assets is the ratio of capital expenditures over the book value of total assets, set to zero if missing. Leverage is the ratio of the book value of long-term debt over total assets. R&D/Assets is the book value of research and development expenses over the book value of total assets, set to zero if missing. PPE/Assets equals property, plant and equipment book value divided by total assets. Dividend Paying is a dummy equal to one if the firm paid a cash dividend that period. We use quarterly observations, as Compustat data are updated in that frequency. We choose the sample period 1994-2006 to match with our corporate bond data.

Our corporate bond data come from the National Association of Insurance Commissioners (NAIC) transactions database. We match the NAIC database to the Fixed Investment Securities Database (FISD), CRSP and Compustat. The FISD database contains issue- and issuer-specific information such as the offering date, amount and whether the bond issue is enhanced, redeemable, puttable or convertable. The NAIC database consists of all transactions by life insurance companies, property and casualty insurance companies, and Health Maintenance Organizations (HMOs).

For the sample that could be matched to FISD, CRSP and Compustat, we apply various data screens, largely similar to Campbell and Taksler (2003) with some notable exceptions. We only consider fixed-rate U.S. dollar bonds that are non-puttable, non-convertible and non-asset-backed. We also discard all bonds that are exchangeable, or pay-in-kind, that have a non-fixed coupon, that are senior, secured or guaranteed or are zero-coupon bonds, exclusively focusing on junior unsecured debt. Different from Campbell and Taksler (2003), we do not remove redeemable (or enhanced) bonds as this would remove over half of our sample and we want to make sure our bond sample is as representative as possible, while controlling for this feature in our regressions (such that our longer sample is more than twice as big as the sample used in Campbell and Taksler (2003), adjusting their monthly to our quarterly frequency). Further, we only use issues whose average credit rating is between AA and BBB, using ratings from Standard and Poor's (S&P) and Moody's.[6] We end up with a credit spread sample that is considerably smaller than the equity sample, which is a consequence of the limited number of firms with actively traded corporate bonds.

Next, we create two samples of bond issues, one sample with longer maturity (five years or more) and another sample with shorter maturity bonds (maturity of no more than five years but at least one year). For each bond sample and in order to reduce the effect of over-representation of very liquid bonds, we make quarterly observations by only recording for each issue the last available daily average credit spread of every quarter. Finally, we make sure that each firm-quarter combination is unique by choosing the issue with the largest offering amount if there are multiple issues per firm in a quarter for a given sample.

For all bond trades in our sample, we calculate yields and credit spreads. The benchmark rate that is used to construct credit spreads is based on an interpolation of the yields of the two on-the-run government bonds

[6]As Campbell and Taksler (2003) discuss, bond issues with AAA ratings appear problematic and are also removed by them, as they are by Elton *et al.* (2001). Non-investment grade issues are also eliminated, because insurance companies rarely purchase such issues, as they are often expressly prohibited to do so. As a result, such transactions are unlikely to be representative of the overall bond market transactions for those issues.

bracketing the corporate bond with respect to duration. To avoid very small coefficients, we multiply the credit spreads by 100, such that all credit spreads are in percentage points.

The credit spread regressions have the following, additional firm- and issue-level controls (relative to the market-to-book regressions). ROA is the return on assets, calculated as the ratio of net income over book value of total assets. Log Maturity is the logarithm of maturity in months and (Log Maturity) ^2 is the square of Log Maturity. Log Offering Amount is the logarithm of the total notional amount sold. Enhanced is a dummy equal to one if there are any credit-enhancement features, and Redeemable is a dummy equal to one if the firm can call back the issue under some circumstance.[7]

To test those hypotheses, one has to confront the difficulty in measuring uncertainty about the growth rate of profitability. Our strategy is to adopt a number of proxies in the literature and discuss the pros and cons of each measure. In our baseline regressions, following Pástor and Veronesi (2003), we adopt −Inv(1+Age), i.e., minus the inverse of 1 + Age, as our main proxy for uncertainty. Here, Age is the number of years since the firm first appears on CRSP. The motivation is that the uncertainty about a firm's profitability decreases over time as investors learn about the firm. This specific functional form is taken from Pastor and Veronesi's model with a simple Bayesian learning structure. Results remain similar if we repeat the analysis using log(1+Age) as the proxy for uncertainty.

It is important to note the drawbacks of the measures based on firm age. It is not always the case that firms' uncertainty always decreases over time. One of the main reasons that we adopt Pastor and Veronesi's measure is to make it comparable to existing studies. However, we need to understand and take into account the imperfection of these measures when interpreting our empirical results. Moreover, we also attempt to complement our baseline regressions by adopting a number of other proxies of uncertainty.

As the first set of two alternative measures for uncertainty, we use Erc(1)+ and Erc(2)− as proposed by Pástor *et al.* (2009). The idea is that if investors are uncertain about the firm's profitability, i.e., if they have

[7]Results are robust to adding further controls, such as the age of the bond (i.e., time since the offering date), the square of the age of the bond, and stock returns. We also tried using or adding the square of −Inv(1+Age), which has a −85% correlation with −Inv(1+Age), but it is insignificant and does not change any results.

flatter priors about future earnings, they would respond more strongly to earnings surprises. Erc(1)+ and Erc(2)− are essentially earnings response coefficients: Erc(1)+ is the average of the firm's previous 12 stock price reactions to quarterly earnings surprises, excluding negative values. Erc(2)− is minus the regression slope of the firm's last 12 quarterly earnings surprises on its abnormal stock returns around earnings announcements, excluding positive values.

Next, we also adopt two measures of uncertainty from Korteweg and Polson (2008), who calibrate the Leland (1994) model to stock and bond prices to obtain the implied parameter uncertainty at the end of each year for 1994 to 2006.[8] We use Sigma1 to denote the posterior standard deviation of firm's asset value, and Sigma2 to denote the posterior standard deviation of firm's asset volatility. Although Sigma1 and Sigma2 are not the same as the uncertainty of the long-run profitability, they are likely to be positively correlated with it and hence may serve as useful proxies.

Our final uncertainty proxies are from the analyst forecast literature, see, e.g., Diether *et al.* (2002) and Guntay and Hackbarth (2010), from the Institutional Brokers' Estimate System (IBES) database. Analyst Dispersion is the standard deviation across all IBES analysts of their next-quarter earnings-per-share forecast, normalized (i.e., divided) by the end-of-quarter stock price. Analyst Error is the difference between the median next-quarter earnings-per-share forecast and the actual earnings-per-share.

Table 1 presents descriptive statistics for the market-to-book (M/B) sample as well as the combined (longer and shorter maturity) credit spread sample. Means and standard deviations are given in Panel A, and pair-wise correlations of the prime variables of interest in Panel B. −Inv(1+Age) has a standard deviation of 0.036, Log(1+Age) of 0.62 and their pair-wise correlation with each other equals 94%. Both Erc(1)+ and Erc(2)− have a small but positive correlations with −Inv(1+Age) and Log(1+Age), i.e., those correlations have the 'wrong' sign since higher Erc(1)+ and Erc(2)− mean to reflect higher uncertainty while higher −Inv(1+Age) and Log(1+Age) mean to reflect low uncertainty. However, in unreported results of pooled panel regressions of either Erc(1)+ or Erc(2)− on −Inv(1+Age) plus controls, the coefficient of −Inv(1+Age) is indeed negative and statistically significant, with or without firm fixed effects, and similarly for Log(1+Age).

[8]We thank Arthur Korteweg and Nick Polson for sharing their uncertainty measures data.

Panel A. Means and Standard Deviations

	Full Sample		*Credit Spread Sample*	
	Mean	Stdev	Mean	Stdev
MB	1.15535	1.756986	1.037006	1.27544
Log(1+Age)	3.116436	0.624015	3.552595	0.546936
−Inv(1+Age)	−0.05376	0.035513	−0.0335	0.020571
$Erc(1)^+$	6.96622	5.520539	7.112371	5.605849
$Erc(2)^-$	−0.06213	0.056133	−0.05245	0.051115
Sigma1	0.05150	0.01600	0.042721	0.008563
Sigma2	0.04744	0.08695	0.051764	0.015595
Analyst Dispersion	0.00175	0.00382		
Analyst Error	0.00160	0.76301		
Stdev(Ret)	0.026692	0.013611	0.020732	0.009263
Std(ROE)	0.086591	2.190707	0.048113	0.197091
Log(Assets)	6.898615	1.836477	8.870677	1.337479
ROE	0.02187	0.078108	0.033949	0.06621
Capex/Assets	0.038548	0.041716	0.034607	0.036592
Capex missing	0.013308	0.114593	0.019487	0.138237
Leverage	0.182192	0.155242	0.238748	0.128629
R&D/Assets	0.008526	0.021817	0.003917	0.009131
R&D missing	0.579324	0.493673	0.638949	0.480334
PPE/Assets	0.307448	0.227548	0.342085	0.235669
Dividend Paying	0.623693	0.484464	0.852094	0.355028
Credit Spread			0.017764	0.015675
ROA			0.011155	0.017415
Log Maturity			4.829621	0.570775
(Log Maturity) ^ 2			23.65099	5.862269
Log Offering Amount			12.22142	1.055126
Enhanced			0.097212	0.296262
Redeemable			0.554358	0.497062

Table 1: Descriptive Statistics.

Panel B. Pair-wise Correlations

	M/B	Log(Age)	−Inv(1+Age)	Erc(1)+	Erc(2)−	Stdev(Ret)	Std(ROE)	Credit Spread	Sigma1	Sigma2	Analyst Disp.
Log(Age)	−0.0021	1									
−Inv(1+Age)	−0.0162	0.9447	1								
Erc(1)+	−0.085	−0.0392	−0.0082	1							
Erc(2)−	−0.0558	−0.0708	−0.0374	0.2702	1						
Stdev(Ret)	0.2003	−0.2087	−0.2067	−0.0069	0.0149	1					
Std(ROE)	0.3708	0.0068	−0.0258	−0.0685	−0.0349	0.0394	1				
Credit Spread	−0.0131	−0.1275	−0.1274	−0.01	0.0399	0.5476	0.0568	1			
Sigma1	0.1374	−0.0308	−0.0432	−0.0163	−0.0009	0.2525	−0.0196	−0.1554	1		
Sigma2	0.0082	0.0261	0.0132	−0.0102	−0.0175	0.0514	−0.0028	0.0035	0.2325	1	
Analyst Disp.	−0.0381	−0.0467	−0.0658	−0.0769	−0.0583	0.2835	0.0498	0.4228	−0.1024	0.0212	1
Analyst Error	0.0327	0.0089	0.0092	−0.0064	−0.0256	0.0557	0.0172	0.0593	−0.0122	0.0082	0.0415

Table 1: *Continued*.

Description: This table presents the descriptive statistics for both the sample for the M/B regressions and the Credit Spread regressions. Panel A reports the mean and standard deviations (Stdev) for both dependent variables and all relevant firm and bond issue level controls. Panel B reports the pair-wise correlations between M/B, Credit Spread, four uncertainty proxies and two volatility proxies. M/B is the market-to-book ratio. Log(1+Age) is the log of one plus firm age, −Inv(1+Age) is minus the reciprocal of one plus firm age. Erc(1)+ is the average of the firm's previous 12 stock price reactions to earnings surprises, excluding negative values. Erc(2)− is minus the regression slope of the firm's last 12 earnings surprises on its abnormal stock returns around earnings announcements, excluding positive values. Sigma1 and Sigma2 are the estimates of parameter uncertainty from Korteweg and Polson (2008). Sigma1 is the posterior standard deviation of a firm's asset value, and Sigma2 is the posterior standard deviation of a firm's asset value volatility. Analyst Dispersion is the standard deviation across all IBES analyst of their next-quarter earnings-per-share forecast, normalized (i.e., divided) by the end-of-quarter stock price. Analyst Error is the difference between the median next-quarter earnings-per-share forecast and the actual earnings-per-share. Log(Assets) is the log of the book value of assets in millions. ROE is return on equity. Capex is capital expenditures. Leverage is book value of long-term debt over book value of total assets. R&D/Assets is research and development expenditures. PPE is plant, property and equipment expenditures. Credit Spread is the difference between the yield on the (long maturity) bond in excess of the yield of a duration-matched Treasury bond. ROA is return on assets. Maturity is the bond issue's maturity in months. Enhanced is a dummy equal to 1 if the bond issue includes special features making the bond safer. Redeemable is a dummy equal to 1 if the bond issue is redeemable.

In addition, the pair-wise correlation of Erc(1)+ and Erc(2)− equals 27%, which is very close to their correlation as reported in Pastor *et al.* (2009). Finally, Sigma1 and Sigma2 are negatively correlated with the −Inv(1+Age) and Log(1+Age), i.e., these uncertainty measures have the 'right' correlation. Notably, the correlation between Sigma2 and the age-based measures is much weaker.

3.2 Empirical Results

To test our first hypothesis, we regress log(M/B) on the measure of uncertainty in pooled panel regressions with standard firm-level controls, firm fixed effects and year fixed effects.[9] The results are summarized in column 1 of Table 2. The coefficient of the uncertainty proxy, −Inv(1+Age), is −2.71. The t-statistic based on robust standard errors clustered by firm is 5.03. This implies that firms with higher uncertainty (i.e., lower values of −Inv(1+Age)) tend to have higher market-to-book ratios, consistent with the evidence in Pástor and Veronesi (2003) that uncertainty increases stock valuation.

Next, we test the second hypothesis by interacting the uncertainty measure with dummies indicating whether the firm has low or high leverage. Specifically, we create a dummy Low (High) Leverage which equals one if the firm's leverage is in the lowest (highest) quartile that quarter. As shown in column 2 of Table 2, the association of uncertainty with stock valuation comes mainly from firms with low leverage: the coefficient for −Inv(1+Age) × Low Lev equals −1.10 (with a t-statistic of 3.02). On the other hand, the coefficient for −Inv(1+Age) × High Lev is 1.08 with a t-statistic of 3.10. As a result, relative to the group of high leverage firms, the association between log(M/B) and the uncertainty proxy is about two times as strong for the group of low leverage firms. This evidence is inconsistent with the second hypothesis that uncertainty should increase high leverage firms' valuation more strongly.

We also run the above regressions of log(M/B) on three subsamples, with the results presented in Table 3. The first subsample is for technology firms (i.e., 48 Fama-French industry groups #35, #36 and #37). In this

[9] We also run the regressions without firm-level controls and this has little impact on the estimates and significance of the coefficient for −Inv(1+Age). We also include high-order terms of the uncertainty measure in our regressions and this has little impact on our main results. These results are not shown to save space and are available upon request.

−Inv(1+Age) × Low Lev		−1.098
		(−3.02)
−Inv(1+Age)	−2.708	−2.487
	(−5.03)	(−4.54)
−Inv(1+Age) × High Lev		1.078
		(3.10)
Stdev(Ret)	6.765	6.773
	(7.86)	(7.87)
Log(Assets)	0.0589	0.0603
	(2.32)	(2.38)
ROE	0.708	0.710
	(8.40)	(8.44)
Capex/Assets	3.469	3.472
	(19.44)	(19.58)
Capex missing	−0.486	−0.486
	(−4.56)	(−4.59)
Leverage	0.253	0.497
	(2.56)	(4.39)
R&D/Assets	2.265	2.256
	(5.74)	(5.74)
R&D missing	0.0639	0.0644
	(2.71)	(2.73)
PPE/Assets	−1.391	−1.343
	(−8.67)	(−8.36)
Dividend Paying	0.0460	0.0495
	(1.40)	(1.51)
N	225,233	225,233
R^2	66%	66%

Table 2: Log(M/B) and Uncertainty.

Description: This table presents the results from pooled panel regressions of log(M/B) on proxies for uncertainty and firm-level controls. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. −Inv(1+Age) is minus the reciprocal of one plus firm age. 'Low (High) Lev' is a dummy equal to one if the firm's leverage is in the lowest (highest) 25% in the sample that year and 0 otherwise. For descriptions of the firm controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy −Inv(1+Age)) leads to a higher stock valuation.

	High-Tech Sample		Without High-Tech Sample		Credit Spread Sample	
−Inv(1+Age) × Low Lev		−0.960		−0.958		−1.020
		(−1.23)		(−2.40)		(−0.93)
−Inv(1+Age)	−4.213	−3.992	−2.233	−2.170	1.944	1.908
	(−2.44)	(−2.36)	(−3.99)	(−3.83)	(0.77)	(0.77)
−Inv(1+Age) × High Lev		0.525		1.131		1.164
		(0.57)		(3.07)		(1.07)
Stdev(Ret)	3.956	3.956	6.571	6.560	11.62	11.27
	(1.91)	(1.91)	(6.97)	(6.96)	(3.56)	(3.73)
Leverage	0.763	0.938	0.202	0.436	0.202	0.449
	(3.05)	(3.01)	(1.91)	(3.61)	(0.90)	(1.75)
N	28,641	28,641	196,592	196,592	34,571	37,166
R^2	63%	64%	65%	65%	72%	72%

Table 3: Log(M/B) and Uncertainty in Subsamples.

Description: This table presents the results from pooled panel regressions of log(M/B) on proxies for uncertainty and firm-level controls using subsamples. The first subsample only considers “High Tech Sample” firms (i.e., using 48 Fama-French industry groups #35, #36 and #37 only, or 329 firms). The second “Credit Spread Sample” uses only firms for which our credit spread sample contains data for that same quarter (667 firms). The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. −Inv(1+Age) is minus the reciprocal of one plus firm age. For descriptions of the firm controls, see Table 1. The other controls included but now shown to save space are ROE, Capex/Assets, Capex missing, Log(Assets), R&D/Assets, R&D missing, PPE/Assets, and Dividend Paying. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy −Inv(1+Age)) leads to a higher stock valuation in High-Tech Sample but not in Credit spread Sample.

'High-Tech' subsample, uncertainty also has a significant impact on the stock valuation: The coefficient for −Inv(1+Age) equals −4.21 (t-statistic of 2.44). The second subsample is the full sample excluding technology firms. The coefficient for −Inv(1+Age) is greatly reduced at −2.23, with a t-statistic of 3.99. The third and final subsample considered is a 'Credit-Spread' subsample, including only firms for which we have corporate bond data, and only using those quarters for which we have credit spreads data in our sample. In this subsample, however, the coefficient for −Inv(1+Age) is no longer significant and has the opposite sign (with a positive coefficient of 1.94 and a t-statistic of 0.77). Note that from Table 1, firms in this Credit-Spread subsample tend to have higher leverage, and that from Table 2, the impact of uncertainty (as measured by firm age) decreases with leverage. Hence, it is not very surprising that the uncertainty impact disappears in this Credit-Spread subsample.

To test hypothesis 3, we regress credit spreads on the uncertainty proxies with firm fixed effects. The results are reported in Table 4. The regressions are run on two samples. The first sample only uses bond issues with long maturity (at least five years). The second sample only uses bond issues with short maturity (at least one year but less than five years). For the long maturity sample in Panel A, in the first column without firm-level controls, the coefficient for −Inv(1+Age) equals 24.51 (t-statistic of 6.63). This coefficient remains positive and significant even after including firm-level controls, year fixed effects and rating dummies. This implies that contradictory to hypothesis 3, higher uncertainty is associated with smaller credit spreads, or that firm age is perhaps a poor proxy for uncertainty.

This coefficient is still positive, though statistically insignificant, after including the rating × year dummy. The results from the short maturity sample are similar: As shown in Panel B, the coefficients for −Inv(1+Age) imply that high uncertainty (low −Inv(1+Age)) is associated with low spread, contradictory to the model implication. Finally, we test hypothesis 4 by interacting the uncertainty measure with the Low and High Leverage dummies. All the coefficients for the interaction terms are insignificant and the results are omitted for brevity.

In summary, *if one interprets the firm age as a measure of uncertainty*, our evidence in Tables 2 through 4 implies the following. Consistent with the existing evidence, the uncertainty measure, based on firm age, is positively associated with the stock valuation. However, contradictory to the uncertainty-convexity argument, this impact appears stronger for firms with

Panel A: Maturity over 60 months

−Inv(1+Age)	24.51	8.281	6.377	3.745
	(6.63)	(2.49)	(2.27)	(1.46)
Stdev(Ret)		52.26	46.22	40.52
		(10.51)	(10.15)	(9.36)
Bond Age		0.140	0.139	0.139
		(9.55)	(10.21)	(10.61)
Log Market Cap		−0.431	−0.384	−0.339
		(−11.54)	(−11.19)	(−10.44)
Leverage		0.605	0.121	0.236
		(1.86)	(0.41)	(0.84)
ROA		−4.128	−3.566	−3.593
		(−4.47)	(−4.09)	(−4.51)
Log(Assets)		−0.0507	0.0938	0.104
		(−0.77)	(1.66)	(1.98)
R&D/Assets		−3.680	−4.285	−4.045
		(−1.89)	(−2.23)	(−2.13)
R&D missing		−0.151	−0.163	−0.165
		(−5.56)	(−6.00)	(−6.16)
PPE/Assets		−0.627	−0.170	−0.292
		(−1.46)	(−0.49)	(−0.85)
Dividend Paying		−0.201	−0.153	−0.0707
		(−1.85)	(−1.56)	(−0.72)
Log Maturity		0.975	0.962	0.950
		(2.99)	(3.13)	(3.24)
(Log Maturity)^2		−0.0724	−0.0686	−0.0672
		(−2.28)	(−2.31)	(−2.37)
Redeemable		0.237	0.235	0.255
		(4.64)	(5.50)	(6.42)
Year Dummies	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes
N	14352	9801	9801	9801
R^2	0.474	0.686	0.714	0.741

Panel B: Maturity between 12 and 60 months

−Inv(1+Age)	12.71	8.325	4.306	6.700
	(3.44)	(1.99)	(1.16)	(1.83)
Stdev(Ret)		98.57	93.97	84.96
		(7.84)	(7.66)	(7.69)
Bond Age		0.143	0.129	0.0976
		(6.32)	(5.91)	(4.82)
Log Market Cap		−0.630	−0.585	−0.462
		(−8.92)	(−8.37)	(−7.41)

Table 4: Credit Spreads and Uncertainty.

Leverage		0.818	0.500	0.536
		(1.92)	(1.27)	(1.55)
ROA		−5.054	−4.522	−4.401
		(−2.66)	(−2.33)	(−2.44)
Log(Assets)		0.199	0.307	0.203
		(2.31)	(3.72)	(2.58)
R&D		−6.714	−7.901	−6.092
		(−2.34)	(−2.99)	(−2.35)
R&D missing		−0.113	−0.111	−0.125
		(−2.39)	(−2.47)	(−2.73)
PPE/Assets		−1.023	−0.566	−0.590
		(−1.54)	(−1.00)	(−1.25)
Dividend Paying		−0.0854	0.00417	0.256
		(−0.39)	(0.02)	(1.27)
Log Maturity		−0.356	−0.298	0.149
		(−0.41)	(−0.35)	(0.18)
(Log Maturity)^2		0.0725	0.0606	−0.00102
		(0.59)	(0.50)	(−0.01)
Redeemable		0.254	0.256	0.238
		(3.22)	(3.39)	(3.25)
Year Dummies	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes
N	10266	7417	7417	7417
R^2	0.423	0.656	0.666	0.700

Table 4: *Continued.*

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty and firm-level and bond issue-level controls, using two samples. The first sample only uses bond issues with maturity of at least five years. The second sample only uses bond issues with maturity of at least one year and less than five years. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. The uncertainty proxy is −Inv(1+Age). Bond Age is the log of one plus the age of the bond. Also included but not reported to save space are the following controls: ROE, Stdev(ROE), Log(Assets), Capex Missing, Log Offering Amount, and Enhanced dummy. For descriptions of the uncertainty proxies and the firm and bond issue-level controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy −Inv(1+Age)) leads to a lower credit spread.

low leverage. Moreover, younger firms (i.e., firms with higher uncertainty under this interpretation) have lower credit spreads, contradictory to the implication from the uncertainty-convexity argument. Note that in the above analysis, we control for stock return volatility and Std(ROE), the standard deviation of ROE. It is likely that stock return volatility may partly capture the uncertainty of the long-run profitability. In fact, consistent with the uncertainty argument, stock return volatility is positively related to the stock valuation and negatively related to the bond valuation.

3.3 Robustness

We redo our analysis and find our previous results are robust to the following specifications. First, instead of clustering standard errors by firm, we also cluster standard errors by both firm and year and the results remain the same. Second, instead of using the log of the market-to-book ratio as the stock valuation measure, we also obtain similar results by using the market-to-book ratio directly. Third, we use Log(1+Age) as the proxy for uncertainty. Motivated by their learning model, Pástor and Veronesi (2003) propose the uncertainty measure −Inv(1+Age), and prefer it over the measure Log(1+Age). Nevertheless, as a robustness check we also redo the analysis using Log(1+Age) as the uncertainty measure and find the main results remain the same.

One might suspect that the uncertainty impact in Pástor and Veronesi (2003) is mainly driven by very young firms, and that the firms in our Credit Spread subsample tend to be older. Hence, we examine the firm age distribution for our overall sample and the Credit Spread subsample. While firms issuing bond tend to be older, the firm age distributions for very young firms (where uncertainty may matter most) across these two samples are quite similar. Figure 1 plots the cumulative distribution function of firm age for our overall sample, and the Credit Spread subsample. It shows the age distributions for very young firms are similar across the subsamples: For our overall sample (labeled as M/B Sample in the plot), 12% of the observations are from firms that are five years old or younger; for the high (low) duration Credit Spread subsample, those firms contribute 11%(8%) of the observations.

Another related concern is that firms' capital structure choice is endogenous. To the extent that this choice is related to uncertainty, it might affect our regression results. For example, suppose firms with high uncertainty choose to issue less debt. This makes their corporate debt safer and so leads to lower credit spreads. Therefore, firms with high uncertainty may have

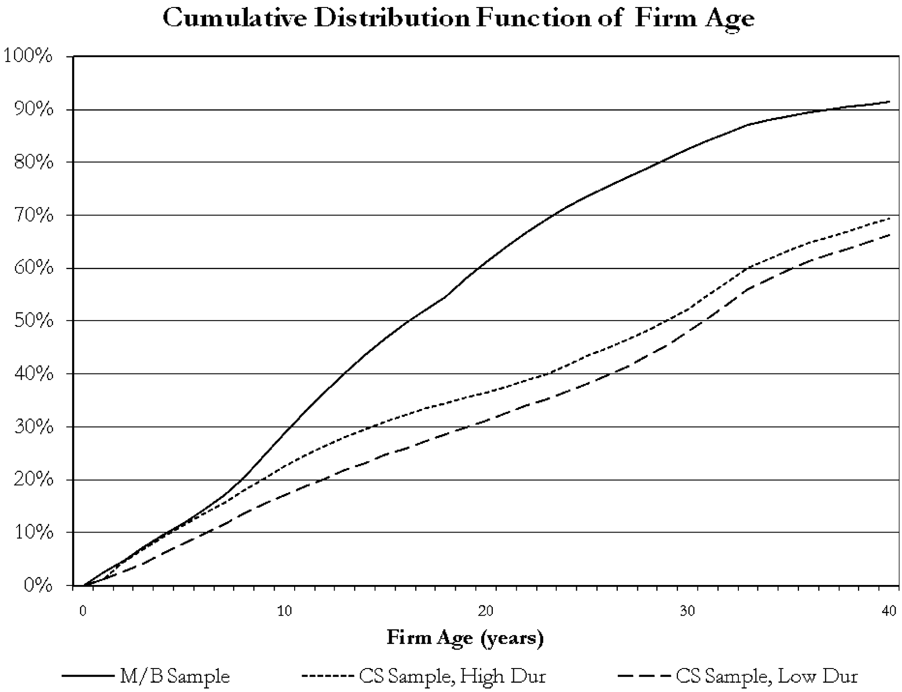

Figure 1: Firm Age Distribution.

Description: This figure plots the cumulative distribution function of firm age for our samples. M/B Sample is our full sample, "CS Sample, High Dur" is our credit Spread Sample of bonds with a maturity of 12 to 60 months, "CS Sample, Low Dur" is our credit Spread Sample of bonds with a maturity of less than 12 months.

low credit spreads, as we observe in the tests for implication 3 (Table 4). Moreover, this also implies that firms with low leverage tend to be firms with high uncertainty, or that are younger. Hence, we may observe that low leverage firms have higher market-to-book ratios, as in our tests of implication 2 (Table 3). Lacking instruments providing us with exogenous variation in either uncertainty or leverage, we address the above concern by running a panel regression of leverage on our uncertainty measure –Inv(1+Age), with firm fixed effects. It shows that firms with higher uncertainty (lower –Inv(1+Age)) tend to have higher leverage, which goes against the above concern on endogeneity.[10]

[10]We acknowledge that this entails only a very preliminary analysis of endogeneity of

Due to different business environments, some industries are inherently more uncertain than others. Hence, a feasible conjecture is that the age-based measures may fail to capture the variation in uncertainty in our pooled panel regressions, and that those measures might be better at capturing uncertainty for those industries with high uncertainty in the first place. To examine this conjecture, we repeat our analysis on a subsample of firms in more uncertainty industries. We adopt three proxies for the uncertainty of industries: The industries with below median firm age, below median asset size, and above median stock return volatility are indentified as those with higher uncertainty. In general, there is no or opposite evidence for this conjecture and that results on the subsample of more uncertain industries are inconsistent with the model predictions either.

3.4 Alternative Uncertainty Proxies

Firm age seems an imperfect proxy for uncertainty about the future growth rate of profitability. By design, firm age as a proxy for uncertainty implies that uncertainty always decreases over time. In practice, however, the uncertainty of a firm's profitability does not necessarily have to decrease over time. A negative shock to the economy or specific industries can easily increase firms' uncertainty, as seen, for example, in the current financial crisis. Or, investors may indeed learn over time about the profitability of different firms, but may do so at very different speeds, depending on a firm's and its industry's life cycle (see, e.g., Gort and Klepper (1982), Klepper and Graddy (1990) and Jovanovic and MacDonald (1994) for discussion of such industry dynamics). In addition, Chun *et al.* (2008) offer an alternative interpretation of firm age as related to creative destruction, such that younger firms can grow faster. This harkens back to Schumpeter (1912), where "new, initially small, firms are better able to explore and exploit the opportunities brought about by new technology because innovators can better protect their property rights over their innovations by organizing their own firms. King and Levine (1993), Fogel *et al.* (2008), and others provide empirical support for this view. This alternative interpretation could potentially also explain the higher market-to-book ratios and higher bond prices for younger firms. However, a full exploration of the

leverage, which is a very difficult problem for which good instruments are lacking. The details of these results are omitted for brevity and to save space, and are available upon request.

interpretation of the firm age results falls outside the scope of this paper.

Given the difficulty and importance of measuring uncertainty, we also try to use other uncertainty proxies proposed in the literature. In particular, Pástor *et al.* (2009) propose two measures for uncertainty, labelled Erc(1)+ and Erc(2)−. However, these two proxies are contaminated by volatility of the profitability. A higher volatility in profitability reduces these two uncertainty measures. That is, a higher value of these two measures means either high uncertainty or low volatility. Note that high uncertainty and low volatility have opposite impacts on the valuation of stocks and bonds. Therefore, these two measures are not ideal for our tests. With this concern in mind, we redo the analysis based on these two measures and report the results in Tables 5-7.

Overall, these two measures' impacts are often insignificant and have opposite signs. For example, in the first two columns of Table 5, the two uncertainty measures have insignificant impacts on the stock valuation with opposite signs. The results are similar if we restrict our sample to the High-Tech firms (the last two columns in Table 5). In the tests of implication 3 (Table 6), Panels A and B show that the coefficients for Erc(1)+ and Erc(2)− are only significantly positive in specifications without any control (columns one and five for each panel). Once standard controls are included in the regressions, the coefficients for Erc(1)+ and Erc(2)− become insignificant. Similarly, in specifications with the interactions of uncertainty and leverage, both these two measures and their interactions terms are insignificant once controls are included (Table 7).

Next, we adopt the measures of uncertainty from Korteweg and Polson (2008), who calibrate the Leland (1994) model to stock and bond prices to obtain the implied posterior standard deviation for the asset value and for asset value volatility (Sigma1 and Sigma2) at the end of each year during 1994 to 2006. We use these two measures as proxies for uncertainty since they are likely to be positively correlated with the uncertainty about the long-run profitability. That is, these two measures can only serve as proxies for uncertainty in our paper to the extent that they are correlated with the uncertainty of firm profitability. We combine these measures with our stock and bond prices and firm-level controls to repeat our analysis.[11]

[11] As the posterior volatility measures are estimated using data over the whole calendar year, we employ annual observations in these regressions, as opposed to quarterly observations everywhere else in the paper. We also found that the main results from our other regressions do not change when we repeat the analysis using annual data.

	Whole Sample		High-Tech Sample	
Erc(1)+	0.04		0.97	
	(0.25)		(2.02)	
Erc(2)−		−0.43		−0.81
		(1.72)		(1.01)
Stdev(Ret)	12.26	13.71	11.44	14.23
	(9.96)	(10.66)	(4.26)	(5.22)
Std(ROE)	0.00	0.00	0.17	0.10
	(1.15)	(0.96)	(8.75)	(3.39)
Log(Assets)	−0.02	−0.06	−0.06	−0.03
	(0.64)	(1.65)	(0.81)	(0.43)
ROE	0.83	0.77	0.60	0.68
	(8.75)	(8.14)	(3.34)	(4.15)
Capex/Assets	3.31	3.14	3.41	2.57
	(16.13)	(15.73)	(5.11)	(4.03)
Capex missing	−0.35	−0.29	−0.49	−0.41
	(4.37)	(3.91)	(0.98)	(1.47)
Leverage	0.21	0.22	0.80	0.89
	(1.82)	(1.90)	(2.92)	(3.12)
R&D/Assets	2.04	2.12	1.22	1.42
	(3.39)	(3.27)	(2.44)	(1.94)
R&D missing	0.05	0.06	0.14	0.17
	(1.94)	(2.06)	(1.48)	(1.79)
PPE/Assets	−1.32	−1.26	−3.00	−2.61
	(6.88)	(6.04)	(6.16)	(4.94)
Dividend Paying	0.04	0.07	0.17	0.18
	(0.94)	(1.69)	(1.58)	(1.62)
N	43,032	42,755	5,476	5,273
R^2	70%	71%	70%	71%

Table 5: log(M/B) and Erc.

Description: This table presents the results from pooled panel regressions of log(M/B) (first two columns) and M/B (last two columns) on proxies for uncertainty and firm-level controls, using the alternative uncertainty proxies Erc(1)+ and Erc(2)−. Erc(1)+ is the average of the firm's previous 12 stock price reactions to earnings surprises, excluding negative values, and Erc(2)− is minus the regression slope of the firm's last 12 earnings surprises on its abnormal stock returns around earnings announcements, excluding positive values. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. For descriptions of the firm controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: The link between log(M/B) and the uncertainty proxy Erc is weak.

Panel A: Erc(1)+ as the proxy for uncertainty

	Maturity over 60 months				Maturity between 12 and 60 months			
Erc(1)+	1.855	0.188	0.244	0.0715	0.0202	0.00307	0.00364	−0.00134
	(3.33)	(0.52)	(0.72)	(0.21)	(1.87)	(0.43)	(0.52)	(−0.19)
Stdev(Ret)		57.96	52.17	45.92		95.79	90.54	81.34
		(11.17)	(11.05)	(11.35)		(6.58)	(6.56)	(6.63)
Bond Age		0.135	0.139	0.135		0.154	0.133	0.102
		(7.94)	(8.98)	(9.20)		(5.79)	(5.27)	(4.16)
Log Market Cap		−0.440	−0.389	−0.337		−0.589	−0.525	−0.434
		(−10.51)	(−9.92)	(−8.76)		(−7.67)	(−7.16)	(−5.89)
Other Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	8939	7441	7441	7441	6345	5642	5642	5642
R^2	0.478	0.681	0.710	0.738	0.423	0.638	0.653	0.689

Panel B: Erc(2)− as the proxy for uncertainty

Erc(2)−	2.353	−1.141	−0.682	−0.603	3.133	0.212	0.505	−0.315
	(3.16)	(−1.97)	(−1.32)	(−1.22)	(3.31)	(0.28)	(0.69)	(−0.48)
Stdev(Ret)		48.24	43.40	38.69		82.37	78.47	70.99
		(11.30)	(11.28)	(11.91)		(7.46)	(7.55)	(7.28)
Bond Age		0.142	0.142	0.141		0.134	0.129	0.103
		(8.94)	(9.66)	(10.10)		(5.90)	(6.01)	(5.12)
Log Market Cap		−0.402	−0.360	−0.318		−0.570	−0.531	−0.423
		(−10.24)	(−9.94)	(−9.23)		(−7.56)	(−7.38)	(−6.21)
Other Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	9884	8168	8168	8168	6993	6161	6161	6161
R^2	0.501	0.698	0.722	0.750	0.476	0.662	0.671	0.702

Table 6: Credit Spreads and Erc.

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty and firm-level and bond issue-level controls, using two samples. The first sample only uses bond issues with maturity of at least five years. The second sample only uses bond issues with maturity of at least one year and less than five years. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. The alternative uncertainty proxies are Erc(1)+, the average of the firm's previous 12 stock price reactions to earnings surprises, excluding negative values, and Erc(2)−, minus the regression slope of the firm's last 12 earnings surprises on its abnormal stock returns around earnings announcements, excluding positive values. Also included but not reported to save space are the following controls: Leverage, ROA, Capex/Assets, R&D, R&D missing, PPE/Assets, Dividend Paying, Log Maturity, Log Maturity^2, Redeemable, ROE, Stdev(ROE), Log(Assets), Capex Missing, Log Offering Amount and Enhanced dummy. For descriptions of the uncertainty proxies and the firm and bond issue-level controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: The link between the credit spread and the uncertainty proxy Erc is weak.

Panel A: Erc(1)+ as the proxy for uncertainty

Erc(1)+ × Low Lev	−0.200	0.471	0.475	0.410
	(−0.21)	(0.78)	(0.90)	(0.83)
Erc(1)+	1.614	0.0419	0.113	−0.0943
	(2.54)	(0.10)	(0.30)	(−0.26)
Erc(1)+ × High Lev	1.395	0.0795	0.0122	0.250
	(1.28)	(0.10)	(0.02)	(0.36)
Stdev(Ret)	57.99	52.20	45.90	57.99
	(11.19)	(11.09)	(11.37)	(11.19)
Controls + Year Dummies	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes
N	8927	7441	7441	7441
R^2	0.479	0.681	0.710	0.738

Panel B: Erc(2)− as the proxy for uncertainty

Erc(2) − ×Low Lev	0.200	0.124	−0.137	−0.224
	(0.20)	(0.16)	(−0.19)	(−0.33)
Erc(2)−	3.024	−1.016	−0.506	−0.440
	(3.92)	(−1.67)	(−0.91)	(−0.83)
Erc(2) − ×High Lev	−2.802	−0.649	−0.590	−0.453
	(−2.82)	(−0.73)	(−0.74)	(−0.66)
Stdev(Ret)		48.25	43.39	38.67
		(11.35)	(11.32)	(11.94)
Controls + Year Dummies	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes
N	9872	8168	8168	8168
R^2	0.503	0.698	0.723	0.750

Table 7: Credit Spreads and Erc Interacted with Leverage.

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty and firm-level and bond issue-level controls. The sample includes bond issues with maturity of at least five years. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm- or industry-fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. The uncertainty proxies, Erc(1)+ and Erc(2)−, are interacted 'Low (High) Lev,' a dummy equal to one if the firm's leverage is in the lowest (highest) 25% in the sample that year and 0 otherwise. The alternative uncertainty proxies are Erc(1)+, the average of the firm's previous 12 stock price reactions to earnings surprises, excluding negative values, and Erc(2)−, minus the regression slope of the firm's last 12 earnings surprises on its abnormal stock returns around earnings announcements, excluding positive values. Firm and issue-level controls are the same as those in Tables 4. For descriptions of the uncertainty proxies and the firm and bond issue-level controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: The interaction effect between uncertainty proxy Erc and leverage on credit spreads.

	Whole Sample				Credit Sample			
Sigma1 × Low Lev		0.03				−0.06		
		(0.02)				(0.06)		
Sigma1	6.13	6.27			5.37	5.02		
	(4.95)	(4.76)			(3.82)	(3.54)		
Sigma1 × High Lev		−0.43				1.84		
		(0.42)				(1.59)		
Sigma2 × Low Lev				−0.42				−0.11
				(0.17)				(0.08)
Sigma2			8.06	8.39			7.46	7.16
			(3.89)	(4.06)			(3.47)	(3.45)
Sigma2 × High Lev				−1.07				2.69
				(0.85)				(1.77)
N	2,611	2,611	2,651	2,651	1,629	1,629	1,663	1,662
R^2	79%	79%	79%	79%	81%	81%	80%	80%

Table 8: Log(M/B) and Sigma.

Description: This table presents the results from pooled panel regressions of log(M/B) (first two columns) and M/B (last two columns) on proxies for uncertainty and firm-level controls, using the alternative uncertainty proxies Sigma1 and Sigma2, which are defined in Table 1. The uncertainty proxies, Sigma1 and Sigma2, are interacted 'Low (High) Lev,' a dummy equal to one if the firm's leverage is in the lowest (highest) 25% in the sample that year and 0 otherwise. The data is annual from 1994-2006. "Credit Sample" only includes firms for which our credit spread sample contains data for that same quarter. All specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. All specifications also include all of the firm and issue-level controls in Tables 2. For descriptions of the firm controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy Sigma) leads to a higher stock valuation.

We run market-to-book regressions similar to those in Tables 2 and 3, using the two new uncertainty proxies, Sigma1 and Sigma2. As shown in Table 8 for the market-to-book regressions, the coefficients of Sigma1 and Sigma2 are significantly positive. This is consistent with the first implication from our model that firms with higher uncertainty tend to have higher market-to-book ratios. Interestingly, we also find that the stock valuation increases with these two uncertainty proxies in the credit spread subsample.[12] This is in contrast with the results based on firm age measures in Table 3, perhaps suggesting that these two measures from Korteweg and Polson (2008) are more effective at capturing uncertainty than the firm age-based measures. Moreover, in the Credit Spread sample, the coefficients for the interaction term of uncertainty and High Lev are positive and marginally significant, consistent with the second implication that the uncertainty impact is stronger for firms with higher leverage. However, our evidence from the bond markets is mixed. As reported in Table 9, the association between these two proxies, Sigma1 and Sigma2, and corporate bond yields is only significant in specifications without any firm-level control. Once standard controls are included, the coefficients for Sigma1 and Sigma2 all become insignificant.[13]

Finally, we consider uncertainty proxies based on analyst forecast of quarterly earnings-per-share, Analyst Dispersion and Analyst Error. While both are proxies for the general information environment, it seems reasonable to expect that either would be increasing in uncertainty about the growth rate of future earnings. Indeed, Guntay and Hackbarth (2010) argue that Analyst Dispersion proxies for future cash flow uncertainty, and consistent with their interpretation and our model, find a positive association between Analyst Dispersion and credit spreads.

However, Table 10 shows that Analyst Dispersion is negatively related to Log(M/B), while the coefficient of Analyst Error is insignificant, inconsistent with the first implication. In Panel A of Table 11, we replicate the positive association between Analyst Dispersion and credit spreads documented in Guntay and Hackbarth (2010). We also find that Analyst Error has generally a positive coefficient, although the coefficient becomes insignificant for bonds with maturities over 60 months (Table 11, Panel B). Moreover, Panel

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[12] While both Sigma1 and Sigma2 are only calculated for firms with bonds that are included in the same NAIC database, Korteweg and Polson (2008) are considerably more inclusive in their data screens. This explains why the sample of all firms for which their proxies are available (Table 8) is considerably larger than the sample of all firms for which their proxies are available that also survives our bond data screens (Table 9).

[13] We also conduct a number of robustness analyses. For example, if one includes industry rather than firm fixed effects in the regressions, these two proxies become significant only for the sample of bonds with maturities over five years, but with opposite signs. In particular, the coefficient of Sigma1 is positive, consistent with the model implication that higher uncertainty leads to higher bond yield spreads, but the coefficient of Sigma2 is significantly negative. In unreported credit spread regressions, we also interact these two uncertainty proxies with leverage and the coefficients for the interaction terms are insignificant.

Panel A: Sigma1 as the proxy for uncertainty

	Maturity over 60 months				*Maturity between 12 and 60 months*			
Sigma1	37.23	2.287	−0.185	−5.139	34.17	−8.323	−8.181	−1.444
	(7.22)	(0.45)	(−0.04)	(−0.94)	(4.31)	(−0.88)	(−0.87)	(−0.14)
Stdev(Ret)		44.3	42.65	40.13		84.55	84.07	77.87
		(3.94)	(4.00)	(4.11)		−3.19	−3.08	−2.63
Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	1608	1208	1208	1208	1115	878	878	878
R^2	0.623	0.779	0.802	0.848	0.631	0.811	0.815	0.846

Panel B: Sigma2 as the proxy for uncertainty

Sigma2	444.0	−90.93	27	65.58	247.9	−56.88	57.32	556.2
	(1.63)	(−0.35)	(0.10)	(0.26)	(0.68)	(−0.13)	(0.13)	(0.96)
Stdev(Ret)		45.69	42.87	37.64		82.03	80.99	74.93
		(4.21)	(4.27)	(4.09)		(3.34)	(3.21)	(2.74)
Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	1650	1229	1229	1229	1145	891	891	891
R^2	0.595	0.78	0.803	0.849	0.618	0.811	0.815	0.847

Table 9: Credit Spreads and Sigma.

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty and firm-level and bond issue-level controls, using two samples. The first sample only uses bond issues with maturity of at least five years. The second sample only uses bond issues with maturity of at least one year and less than five years. The data is annual from 1994-2006, and all specifications include year fixed effects and firm- or industry-fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. The alternative uncertainty proxies are Sigma1 and Sigma2, which are defined in Table 1. Firm and issue-level controls are the same as those in Tables 4. For descriptions of the uncertainty proxies and the firm and bond issue-level controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: The link between the credit spread and the uncertainty proxy Sigma is weak.

Analyst Dispersion ×		−2.279		
Low Lev		(−0.47)		
Analyst Dispersion	−46.60	−50.45		
	(−20.67)	(−15.23)		
Analyst Dispersion ×		11.65		
High Lev		(2.72)		
Analyst Error ×				−0.0232
Low Lev				(−1.88)
Analyst Error			−0.00542	0.000554
			(−1.14)	(0.09)
Analyst Error ×				−0.00272
High Lev				(−0.25)
N	160,254	160,254	194,909	194,909
R^2	71%	71%	69%	69%

Table 10: Log(M/B) and Analyst Uncertainty.

Description: This table presents the results from pooled panel regressions of log(M/B) (first two columns) and M/B (last two columns) on proxies for uncertainty and firm-level controls, using the alternative uncertainty proxies Analyst Dispersion and Analyst Error, which are defined in Table 1. The uncertainty proxies, Analyst Dispersion and Analyst Error, are interacted 'Low (High) Lev,' a dummy equal to one if the firm's leverage is in the lowest (highest) 25% in the sample that year and 0 otherwise. The data is annual from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. All specifications also include all of the firm and issue-level controls in Tables 2. For descriptions of the firm controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy Analyst Uncertainty) leads to a lower stock valuation.

C shows that the interactions between Analyst Dispersion and leverage are insignificant, both economically and statistically. Since leverage might not be effective in capturing the default probability, we also repeat the analysis using "Better (Worse) Rating" dummies to replace the "High (Low) Lev" dummies. The "Better (Worse) Rating" dummy equals one if the firm's credit rating is in the top (bottom) quartile in that year.[14] As shown in Panel

[14]For the other uncertainty proxies, results using the leverage and rating dummies-interactions are typically quite similar.

D, the coefficients for "Analyst Dispersion × Worse Rating" are significantly positive, consistent with the implications from our model.

3.5 Using Log(M/B) as an Uncertainty Proxy

Suppose we take the view that uncertainty increases stock valuation but that we do not have a good proxy for uncertainty. Then we can simply use Log(M/B) as the proxy for uncertainty, and use it to test the relation between credit spreads and uncertainty. In particular, we regress credit spreads on the Log(M/B) with firm fixed effects, year fixed effects and

Panel A: Analyst Dispersion as the proxy for uncertainty

	Maturity over 60 months				Maturity between 12 and 60 months			
Analyst Dispersion	23735.5	12645.8	11037.7	9708.8	31870.0	11404.0	10051.4	9841.2
	(10.23)	(6.57)	(6.76)	(6.61)	(6.71)	(4.48)	(4.18)	(4.11)
Stdev(Ret)		41.37	36.88	30.67		87.93	84.76	75.27
		(8.65)	(8.14)	(6.88)		(7.46)	(7.14)	(6.80)
Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	12096	8317	8317	8317	8732	6377	6377	6377
R^2	0.530	0.700	0.724	0.750	0.486	0.663	0.672	0.705

Panel B: Analyst Error as the proxy for uncertainty

Analyst Error	0.0886	0.0167	0.0124	0.00880	0.162	0.135	0.142	0.136
	(2.42)	(0.51)	(0.40)	(0.29)	(2.01)	(2.02)	(2.15)	(2.05)
Stdev(Ret)		49.46	43.99	37.21		93.17	89.02	79.31
		(9.70)	(9.31)	(8.20)		(7.98)	(7.62)	(7.32)
Controls + Year Dummies	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Rating Dummies	No	No	Yes	Yes	No	No	Yes	Yes
Rating × Year Dummies	No	No	No	Yes	No	No	No	Yes
N	12445	8556	8556	8556	8920	6513	6513	6513
R^2	0.494	0.695	0.721	0.748	0.469	0.670	0.679	0.711

Table 11: Credit Spreads and Analyst Uncertainty.

Panel C: Analyst Dispersion Interacted with Leverage

Analyst Dispersion × Low Lev	−77.58	21.56
	(−1.28)	(0.53)
Analyst Dispersion	24475.7	7514.0
	(7.49)	(3.41)
Analyst Dispersion × High Lev	9.597	43.82
	(0.25)	(1.44)
Stdev(Ret)		31.03
		(7.30)
Controls + Year Dummies	No	Yes
Rating Dummies	No	Yes
Rating × Year Dummies	No	Yes
N	12068	8317
R^2	0.532	0.750

Panel D: Analyst Dispersion Interacted with Rating

Analyst Dispersion × Better Rat	−94.43	−67.37
	(−2.31)	(−2.82)
Analyst Dispersion	6688.9	4371.2
	(2.74)	(2.32)
Analyst Dispersion × Worse Rat	240.5	85.16
	(6.54)	(3.17)
Stdev(Ret)		29.90
		(6.58)
Controls + Year Dummies	No	Yes
Rating Dummies	No	Yes
Rating × Year Dummies	No	Yes
N	12096	8317
R^2	0.546	0.752

Table 11: *Continued.*

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty and firm-level and bond issue-level controls, using two samples. The first sample only uses bond issues with maturity of at least five years. The second sample only uses bond issues with maturity of at least one year and less than five years. The data is annual from 1994-2006, and all specifications include year fixed effects and firm- or industry-fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. The alternative uncertainty proxies are Analyst Dispersion and Analyst Error, which are defined in Table 1. Firm and issue-level controls are the same as those in Tables 4. For descriptions of the uncertainty proxies and the firm and bond issue-level controls, see Table 1. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: An increase in uncertainty (based on proxy Analyst Uncertainty) leads to a higher credit spread.

	Maturity over 60 months		Maturity between 12 to 60 months	
Log(M/B)	0.606	0.464	0.537	0.281
	(6.57)	(5.94)	(4.45)	(2.79)
Stdev(Ret)		49.61		96.85
		(10.44)		(7.71)
N	9805	9805	7417	7417
R^2	0.654	0.691	0.583	0.657

Table 12: Log(M/B) and Credit spreads.

Description: This table presents the results from pooled panel regressions of credit spreads on proxies for uncertainty Log(M/B) and firm-level and bond issue-level controls that are the same as those in Table 4. The data is quarterly from 1994-2006, and all specifications include year fixed effects and firm fixed effects. T-statistics based on robust standard errors clustered by firm are given between parentheses. N is the number of observations and R^2 is percentage of explained variation.

Interpretation: Using Log(M/B) as a proxy for uncertainty.

firm-level controls. The results are reported in Table 12. For both the long and short maturity samples, the coefficient for Log(M/B) is positive and highly significant. This evidence is certainly encouraging for the uncertainty argument, since it is consistent with higher uncertainty decreasing bond valuations, as the model suggests. However, our aim was to test the association between uncertainty and valuations, such that all we can really conclude from Table 12 is that there appear to be omitted variables that cause a negative correlation between stock and bond prices. These omitted variables may or may not be related to uncertainty.

4 Conclusion

This paper further examines the uncertainty-convexity idea in Pástor and Veronesi (2003) in an environment where firms are financed by both equity and bonds. The uncertainty-convexity idea has four predictions. First, uncertainty about a firm's earning growth rate increases its stock price. Second, this impact is stronger for firms with higher leverage ratios. Third, higher uncertainty decreases the firm's bond price. Fourth, the impact on bond prices is stronger if the firm's leverage is higher. We first test these four implications using the firm-age-based measure for uncertainty originally proposed by Pástor and Veronesi (2003). Consistent with the existing evidence in the literature, our empirical results support the first implication. However, the other three implications are shown to be inconsistent with our empirical evidence. In particular, we find strong evidence that younger firms tend to have lower credit spreads. We also adopt a number of alternative proxies for uncertainty used in the literature. However, the evidence based on these measures is generally inconsistent across the four implications we consider.

In conclusion, existing proxies for uncertainty may not reliably measure uncertainty, and our results thus post a challenge to the interpretation in the literature employing these measures. This includes the literature exploring how uncertainty/convexity relates to firm value, as well as many other studies on uncertainty.

Finally, we would like to stress that rather than viewing our study as a critique of Pástor and Veronesi (2003), it is perhaps more appropriate to view it as a reminder of the difficulty in measuring uncertainty, and the necessary caution in our interpretation of existing evidence of how uncertainty is related to the valuation of stocks and bonds.

A. Appendix

The firm value at t = 0, denoted as F_0, is

$$F_0 = E[V_1] = V_0 e^{\bar{u}+\frac{1}{2}\sigma_u^2+\frac{1}{2}\sigma_\varepsilon^2}. \tag{1}$$

The stock price is given by $S_0 = E[\max(V_1 - B, 0)]$. Simply by taking the expectation, we obtain

$$S_0 = e^{\bar{u}+\frac{1}{2}(\sigma_u^2+\sigma_\varepsilon^2)} V_0 N(d_1) - BN(d_2), \tag{2}$$

where $N(\cdot)$ is the cumulative distribution function for a standard normal random variable, and

$$d_1 = \frac{\ln\frac{V_0}{B} + \bar{u} + \sigma_u^2 + \sigma_\varepsilon^2}{\sqrt{\sigma_u^2 + \sigma_\varepsilon^2}}, \quad \text{and} \quad d_2 = d_1 - \sqrt{\sigma_u^2 + \sigma_\varepsilon^2}. \tag{3}$$

Then, the debt value is

$$D_0 = F_0 - S_0. \tag{4}$$

Define $\sigma^2 \equiv \sigma_u^2 + \sigma_\varepsilon^2$. Substituting it into (2) and differentiating S_0 with respect to σ, after some algebra, we obtain

$$\frac{\partial S_0}{\partial \sigma} = V_0 e^{\bar{u}+\frac{\sigma^2}{2}} \left(N(d_1)\sigma + n(d_1)\right) > 0, \tag{5}$$

where $n(\cdot)$ is the probability density function of a standard normal distribution. Equation (5) implies result 1. Differentiating (5) with respect to B, we obtain result 2.

Substituting (1) and (2) into (4), and differentiating D_0 with respect to σ, we obtain

$$\frac{\partial D_0}{\partial \sigma} = V_0 e^{\bar{u}+\frac{\sigma^2}{2}} f, \tag{6}$$

where $f \equiv \sigma - N(d_1)\sigma - n(d_1)$. As a result, the sign of $\partial D_0/\partial \sigma$ is the same as that of f. From the definition of f, we can obtain that

$$\lim_{B\to\infty} f = \sigma > 0, \tag{7}$$

$$\lim_{B\to 0} f = 0. \tag{8}$$

$$\frac{\partial f}{\partial B} = -n(d_1)\frac{\ln V_0 - \ln B + \bar{u}}{B\sigma^2} \tag{9}$$

Therefore, we have

$$\partial f/\partial B < 0 \quad \text{if } B \in [0, B^*), \tag{10}$$

$$\partial f/\partial B > 0 \quad \text{if } B \in [B^*, \infty). \tag{11}$$

Equations (8) and (10) imply

$$f(B) < 0, \quad \text{if } B \in [0, B^*). \tag{12}$$

Since f is continuous and monotonically increasing in B if $B \in [B^*, \infty)$ (see (11)), together with equations (7) and (12), this implies that there exists a unique value $B^{**} \in [B^*, \infty)$, such that $f(B^*) = 0$, and $f < 0$ if $B < B^{**}$ and $f > 0$ if $B > B^{**}$. Hence, equation (6) implies that $\partial D_0/\partial \sigma < 0$ if $B < B^{**}$ and $\partial D_0/\partial \sigma > 0$ if $B > B^{**}$. Note that the sign of $\partial D_0/\partial \sigma_u$ is the same as that of $\partial D_0/\partial \sigma$. This proves result 3. Note also that the sign of $-\partial^2 D_0/\partial \sigma_u \partial B$ is the same as that of $\partial f/\partial B$. Hence, equations (10) and (11) lead to result 4.

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