Inflation Risk in Corporate Bonds

Johnny Kang

Carolin E. Pflueger

JOB MARKET PAPER

December 1, 2011

Abstract

Do corporate bond spreads reflect fear of debt deflation? Most corporate bonds have fixed nominal face values, so unexpectedly low inflation raises firms' real debt burdens and increases default risk. We develop a real business cycle model with time-varying inflation risk and optimal, but infrequent, capital structure choice. In this model, more volatile or more procyclical inflation lead to quantitatively important credit spread increases. This is true even with inflation volatility as moderate as that in developed economies since 1970. Intuitively, this result obtains because inflation persistence generates large uncertainty about the price level at long maturities and because firms cannot adjust their capital structure immediately. We find strong empirical support for our model predictions in a panel of six developed economies. Both inflation volatility and the inflation-stock return correlation have varied substantially over time and across countries. They jointly explain as much variation in credit spreads as do equity volatility and the dividend-price ratio. Credit spreads rise by 15 basis points if either inflation volatility or the inflation-stock return correlation increases by one standard deviation. Firms counteract higher debt financing costs by adjusting their capital structure in times of higher inflation uncertainty.

Kang: Harvard Business School, Boston MA 02163. hjkang@hbs.edu. Pflueger: Harvard Business School, Boston MA 02163. cpflueger@hbs.edu. We are grateful to Shai Bernstein, Josh Coval, Ben Friedman, Josh Gottlieb, Francois Gourio, Robin Greenwood, Robert Hall, Sam Hanson, Stephanie Hurder, Jakub Jurek, Jacob Leshno, Yoichi Matsubayashi, Robert Merton, Alp Simsek, Jeremy Stein, Jim Stock, Adi Sunderam, participants at the HBS-Harvard Economics Finance Lunch and participants at the Harvard Macro Lunch for helpful comments and suggestions. We are especially grateful to John Campbell, Erik Stafford, and Luis Viceira for invaluable advice and guidance.

1 Introduction

Corporate bonds in the developed world overwhelmingly carry fixed nominal face values and thus their real face values fluctuate with inflation. The nominal nature of these liabilities means that firms can be driven into default by either a decrease in real cash flows or an increase in real liabilities. The literature has argued that real firm cash flow risk is priced into corporate bond spreads. We find that inflation risk plays at least as large a role in explaining variation in credit spreads.

Given that corporate debt is largely nominal, inflation risk could impact credit spreads in two ways. First, higher uncertainty about future price levels increases the ex ante probability that firms will default due to high real liabilities. Second, when inflation and real cash flows are more highly correlated, negative inflation shocks can drive more firms into default and cause them to default on higher real liabilities. Credit spreads increase both because expected losses are higher and because losses are more likely to occur in high marginal utility states.

There has been a close historical relationship between firms' cost of debt finance and inflation uncertainty in the United States, as shown in Figure 1.[1] Both inflation uncertainty and credit spreads were high in the 1970s and 1980s and decreased dramatically during the 1990s. Our empirical results confirm this relationship in a panel of six developed countries, controlling for proxies for business conditions, real uncertainty and time-varying risk aversion.

We formally derive new, testable implications of the impact of time-varying inflation risk on credit spreads in a model with stochastic productivity and optimal but infrequent capital structure choice. In simulated data, inflation risk explains a substantial fraction of the variation in credit spreads, controlling for real uncertainty. Simulated credit spreads increase by around 20 basis points (bps) if the annualized standard deviation of inflation shocks increases by 1 percentage point or if the

[1] Figure 1 shows the Moody's BAA over AAA credit spread and a smoothed dispersion of GDP deflator forecasts from the Survey of Professional Forecasters. Survey dispersion has been shown to be related to subsequent inflation volatility (Zarnowitz and Lambros, 1987, Bomberger, 1996). Patton and Timmerman (2010) show that inflation and growth forecasts are more dispersed when credit spreads are higher and interpret this as evidence that forecasters' beliefs are more dispersed during downturns.

inflation-stock return correlation increases by 100 percentage points.

Three key features in our model generate large, dynamic responses of credit spreads to inflation risk. First, we model both the size of inflation shocks and their correlation with real outcomes as varying over time independently of real activity.

Second, we model nominal corporate bonds with long-term maturities and persistent expected inflation, consistent with U.S. and international evidence (Ball and Cecchetti, 1990, Stock and Watson, 2007).[2] Combined, these two assumptions imply that small permanent shocks to inflation can have large effects on real liabilities. For instance, if log inflation permanently decreases from 3 percent per annum to 1 percent, the real face value of a 10 year nominal bond at maturity increases by 22 percent.

Third, firms in our model refinance infrequently. This assumption is empirically well-founded and helps to generate a realistic level of credit spreads. When firms can adjust leverage, they choose optimally following a textbook tradeoff theory (Gourio, 2011). When inflation risk raises the cost of debt finance, young firms in our overlapping generations model reduce leverage but old firms are unable to respond. Credit spreads of old firms therefore display a substantially stronger initial response to inflation risk than do those of new firms.

We provide new evidence that corporate bond investors price the risk of debt deflation in a panel of corporate bond spread indices from Australia, Canada, Germany, Japan, the United Kingdom, and the United States over four decades. A one standard deviation move in inflation volatility is associated with an economically meaningful increase in credit spreads of 15 bps. A one standard deviation move in the inflation-stock correlation is associated with a similar increase in spreads.[3] These movements are large relative to average credit spreads of 100 bps.

[2] Our model takes as given the fact that most corporate bonds are nominal, implicitly assuming that switching to inflation-indexed debt is too costly in developed country inflation environments. We find an average ratio of floating rate to long-term debt of 28% for U.S. Compustat firms.

[3] For the U.S. we use the Moody's BAA over AAA credit spread. We compute international credit spreads as the difference between a national index of corporate bond yields and a duration-matched government bond yield. We construct proxies for inflation volatility and the correlation of inflation with stock returns from quarterly surprise inflation and stock returns over a rolling backward-looking three year window.

Controlling for other influences on credit spreads, such as business cycle variables, strengthens our results. Our proxies for inflation risk explain as much variation in credit spreads as do equity volatility and the dividend-price ratio, our proxies for real uncertainty and risk aversion. The empirical impact of inflation risk is especially large when real stock returns are low or when inflation shocks are low. Firms also reduce leverage and increase the share of floating rate debt when inflation is more uncertain.

Our empirical findings are consistent with financial markets perceiving an important persistent component in inflation, which makes the long-run price level highly uncertain and generates substantial inflation risk in long-run nominal assets. Our empirical results are all the more striking given that the countries in our sample are developed countries with relatively moderate inflation experiences. The same mechanism should be even more relevant in emerging markets with more volatile inflation.

While high inflation has been a major fear of central bankers and investors in developed economies over the past forty years, a new concern has emerged recently: the danger of a deflationary collapse in aggregate demand. The impact of deflationary fears on firms' borrowing costs becomes especially relevant if investors believe that policymakers will be unable to counteract deflation should there be another recession. Our estimates as of October 2011 suggest that 35 bps of the 126 bps U.S. credit spread can be attributed to the currently high inflation-stock correlation.

The remainder of the paper is organized as follows. After a brief literature review, Section 2 introduces the model. We derive firms' optimal default behavior as a function of leverage, real shocks and inflation shocks. Section 3 argues that inflation risk should be quantitatively important for credit spreads in a calibrated version of the model. Section 4 tests the empirical predictions from the model in an international panel of credit spread indices, and Section 5 concludes.

1.1 Literature Review

This paper argues that time-varying inflation risk has an important impact on the differential pricing between default-free and corporate nominal debt. It builds nat-

urally on Campbell, Sunderam, and Viceira (2011) and Pflueger and Viceira (2011) who show that inflation risk is priced into default free government bonds. Time variation in inflation volatility was first modeled by Engle (1982). There is also substantial evidence from the bond market that the cyclicality of inflation has changed over time (Li, 2002, Baele, Bekaert, and Inghelbrecht, 2009, David and Veronesi, 2009, Viceira, 2010, Wright, 2010, Campbell, Sunderam, and Viceira, 2011). We add to previous structural models of credit risk such as Merton (1974), Shimko, Tejima, and van Deventer (1993), and Longstaff and Schwartz (1995) by allowing the risk of inflation to vary over time.

This paper also speaks to a large literature on the empirical determinants of corporate bond spreads by showing that inflation risk can help explain variation in credit spreads both over time and across countries. Collin-Dufresne, Goldstein, and Martin (2001) and Campbell and Taksler (2003) show that aggregate and idiosyncratic equity volatility are priced into empirical corporate bond spreads.

We also contribute to the wide literature on asset pricing models with optimal leverage and default by arguing that firms should adjust their capital structure in response to time-varying inflation risk (Leland and Toft, 1996, Goldstein, Ju, and Leland, 2001, Hackbarth, Miao, and Morellec, 2006, Chen, Collin-Dufresne, and Goldstein, 2009, Bhamra, Kuehn, and Strebulaev, 2010a, 2010b, Gomes and Schmid, 2010, and Gourio, 2011). Our analysis of inflation risk and firm capital structure has analogies to households' optimal mortgage choice under inflation risk (Campbell and Cocco, 2003, Koijen, Van Hemert, and Van Nieuwerburgh, 2011) but differs in that all assets are priced by the same representative investor in our model.

Fisher (1933) argues that the fall in the price level during the Great Depression increased defaults, thus prolonging and deepening the effects of the Depression. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) model how shocks to firm net worth can feed back into output. This paper finds that the probability of a debt deflation varies over time and is priced into corporate bonds, demonstrating the continuing empirical relevance of these concerns.

Finally, this paper is also related to recent models of monetary policy when firms' liabilities are nominal (Bhamra, Fischer and Kuehn, 2011, De Fiore, Teles,

and Oreste, 2011). Our model highlights inflation volatility and inflation cyclicality as driving credit risk and has directly testable predictions for the dynamic response of credit spreads and leverage to a shock in inflation risk.

2 A Dynamic Model of Inflation Risk in Corporate Bonds

In this section, we motivate and describe the formal model. We assume for simplicity that all corporate bond issuance is long-term and nominal. In reality firms might adjust to changing inflation risk by issuing inflation-indexed corporate debt or by shortening their maturity structure, even though this adjustment is likely to come at a cost. Such costs could include rollover risk (He, and Xiong, 2010, Acharya, Gale, and Yorulmazer, 2010), short-term variability in real payments (Campbell and Cocco, 2003) or liquidity premia, such as those documented for government inflation-indexed bonds (D'Amico, Kim, and Wei, 2008, Fleckenstein, Longstaff, and Lustig, 2011, Pflueger and Viceira, 2011). We implicitly assume that in a developed economy inflation environment these costs are prohibitive and firms choose to issue only nominal long-term debt.

2.1 Intuition: Contingent Claim Payoff Profiles

We illustrate our basic predictions by comparing expected real payoffs on nominal default-free and nominal corporate bonds as a function of a representative firm's underlying real asset value. Black and Scholes (1973) and Merton (1974) show that owning a corporate bond is equivalent to owning a default-free bond and selling a put on the company's underlying assets, so predicted credit spreads are higher when the put option is larger.[4] For nominal corporate bonds the put's real strike price

[4]For simplicity in Figure 2 both the defaultable and default-free bonds are zero coupon with a fixed and equal nominal face value. The firm defaults when the real asset value falls below the real face value of liabilities and in default bond holders become the residual claimants on the firm's assets.

effectively varies with inflation.

Figures 2A and 2B show that when inflation is more uncertain we predict higher credit spreads to reflect the increased payoff gap between corporate and default-free bonds. In the absence of inflation uncertainty, we obtain the well-known contingent claim payoff profile of a corporate bond (Merton, 1974). Figure 2B shows real expected payoffs, averaged over different inflation levels, when inflation is uncertain but uncorrelated with real assets. Real payoffs for two particular inflation levels are shown in dashed lines.

Comparing Figures 2C and 2D shows that when inflation is procyclical, corporate bond spreads should be higher both because expected losses on corporate bonds are higher and because those losses are riskier. In Figure 2C, inflation is high in booms, low in recessions, and perfectly correlated with real assets. The default-free nominal bond pays out especially well during recessions. The firm is more likely to default and it defaults on higher real face values, increasing expected losses on the corporate bond. The gap between default-free and corporate bonds is especially large when real asset values are low, making corporate bond losses even riskier for risk-averse investors. In Figure 2D inflation is perfectly countercyclical and the payoff gap between the corporate bond and the default-free bond is small.

2.2 Timing of Cohort t

We model overlapping generations of firms, where each firm produces for two periods. Leverage is sticky because firms cannot adjust their capital structure in the intermediate period.[5]

Figure 3 illustrates the timing for a firm that enters at the end of period t. A new firm at the end of period t chooses its face value of nominal two-period debt $B_t^{\$}$ and purchases capital K_{t+1}^{y}, which will be available for production at time $t+1$. We observe credit spreads on new corporate bonds with two periods remaining to maturity.

[5]For empirical evidence on sticky leverage see Baker and Wurgler (2002), Welch (2004) and Leary and Roberts (2005).

In period $t+1$, aggregate productivity and inflation shocks are realized. Each firm experiences an idiosyncratic shock to its capital stock and produces. The firm is unable to adjust its capital structure. We observe seasoned credit spreads on corporate bonds with one period remaining to maturity.

In period $t+2$, additional aggregate productivity shocks, inflation shocks and idiosyncratic shocks are realized and firms produce. At the end of period $t+2$, equity holders decide whether to default and equity and debt holders receive payments.

2.3 Production

Firms produce according to a Cobb-Douglas production function with capital and labor inputs. At time t, firm i with capital K_t^i and labor N_t^i produces output Y_t^i

$$Y_t^i = \left(z_t N_t^i\right)^{1-\alpha} \left(K_t^i\right)^{\alpha} \tag{1}$$

We assume that total factor productivity (TFP) z_t is independently and identically distributed around trend growth

$$z_{t+1} = \exp(\mu t) \exp\left(\varepsilon_{t+1}^{TFP} - \frac{1}{2}\sigma^2\right) \tag{2}$$

$$\varepsilon_{t+1}^{TFP} \overset{iid}{\sim} N\left(0, \sigma^2\right) \tag{3}$$

In our calibrated model we consider time periods of 5 years, which are close to business cycle frequency in developed economies, so that independent TFP shocks are a reasonable approximation. TFP trend μ is also the equilibrium trend growth rate for output and consumption in the economy.

Firm i chooses its labor input optimally to maximize single period operating revenue, taking the aggregate wage rate W_t as given.

$$N_t^i = \arg\max_{N_t^i} \left\{ \underbrace{Y_t^i - W_t N_t^i}_{\text{Operating Revenue}} \right\} \tag{4}$$

We assume that the aggregate supply of labor is fixed at 1, abstracting from unemployment. In equilibrium, the aggregate wage adjusts to ensure clearing of the labor market.

We define aggregate output, capital, labor and investment at time t by integrating over all firms

$$Y_t = \int_i Y_t^i di,\ K_t = \int_i K_t^i di,\ N_t = \int_i N_t^i di,\ I_t = \int_i I_t^i di \tag{5}$$

Capital depreciates at a constant rate δ so that next period's capital stock is equal to investment plus depreciated capital: $K_{t+1} = I_t + (1-\delta) K_t$. We impose the resource constraint that total output is equal to the sum of aggregate consumption and investment

$$Y_t = C_t + I_t \tag{6}$$

Solving for the equilibrium hiring policy, we find that total output at time t is given by $Y_t = z_t^{1-\alpha} K_t^{\alpha}$. Young and old firms are heterogenous in their amount of capital. The constant returns to scale production technology implies that the return on capital from time t to time $t+1$ is identical across firms and equal to

$$R_{t+1}^K = \left[\alpha \left(\frac{z_{t+1}}{K_{t+1}}\right)^{1-\alpha} + (1-\delta)\right] \tag{7}$$

Productivity z_{t+1} is random and so from (7) it follows that both the expected level and the volatility of real returns on capital are higher when the capital stock K_{t+1} is low relative to trend.

2.4 Inflation

The economy is subject to persistent nominal shocks, which are exogenously given. Let P_t denote the price level at time t and π_t denote log inflation from time $t-1$ to time t so that

$$\pi_t = \log\left(P_t / P_{t-1}\right) \tag{8}$$

Consistent with U.S. and international empirical evidence (e.g. Stock and Watson, 2007, Ball and Cecchetti, 1990), we model expected log inflation as following a random walk.[6]

$$\pi_{t+1} = \pi_t + \varepsilon^{\pi}_{t+1} \tag{9}$$

$$\varepsilon^{\pi}_{t+1} \big| \, \sigma^{\pi}_{t+1} \sim N\left(0, \left(\sigma^{\pi}_{t+1}\right)^2\right) \tag{10}$$

$$Corr\left(\varepsilon^{\pi}_{t+1}, \varepsilon^{TFP}_{t+1} \big| \, \rho^{\pi}_{t+1}\right) = \rho^{\pi}_{t+1} \tag{11}$$

The dynamics of expected inflation (9) are similar to a reduced form backward-looking Phillips curve, consistent with empirical evidence (Fuhrer, 1997). When σ^{π}_t is higher, the price level is more uncertain. Modeling expected inflation as extremely persistent implies that uncertainty about the price level increases with the time horizon, so that inflation risk should be more relevant for longer maturity nominal bonds.

When ρ^{π}_t is positive, the relationship between inflation and real activity is upward sloping similarly to an upward-sloping Phillips curve. When ρ^{π}_t is negative, the Phillips curve is unstable. Supply shocks or shifting inflation expectations may move inflation and output in opposite directions.

We model time variation in σ^{π}_t and ρ^{π}_t in the simplest possible manner by assuming that they follow two-state Markov switching processes, independent of each other and of all other shocks in the economy.

Inflation uncertainty σ^{π}_t and inflation cyclicality ρ^{π}_t each take a low or a high value

$$\sigma^{\pi}_t \in \left\{\sigma^{\pi,L}, \sigma^{\pi,H}\right\} \tag{12}$$

$$\rho^{\pi}_t \in \left\{\rho^{\pi,L}, \rho^{\pi,H}\right\} \tag{13}$$

[6] It is important for our quantitative results that expected inflation is persistent. The assumption of an exact random walk is primarily for analytical tractability.

We write the probability of going from state $\sigma^{\pi,X}$ to $\sigma^{\pi,Y}$ as

$$p\left(\sigma^{\pi,X} \rightarrow \sigma^{\pi,Y}\right) \tag{14}$$

Similarly the probability of going from state $\rho^{\pi,X}$ to $\rho^{\pi,Y}$ is

$$p\left(\rho^{\pi,X} \rightarrow \rho^{\pi,Y}\right) \tag{15}$$

Equations (12) and (13) make clear that σ_t^π and ρ_t^π are bounded. This assumption is without loss of generality for the correlation ρ_t^π but bounding σ_t^π might reduce the impact of inflation volatility on credit spreads in our model.

2.5 Default Decision

A firm's default decision depends on its initial level of debt, aggregate real shocks, aggregate nominal shocks and idiosyncratic real shocks. We assume that corporate debt promises a fixed nominal payment after two periods, when the firm pays a liquidating dividend. The firm never finds it optimal to default in its intermediate period because no debt payments come due during the intermediate period.

All firms in cohort t are identical ex ante and choose the same initial leverage ratio, defined as the nominal face value of debt discounted by expected inflation relative to initial capital

$$L_t = \frac{B_t^{\$} \exp\left(-2\pi_t\right)}{K_{t+1}^y} \tag{16}$$

Discounting by expected inflation in (16) ensures that the level of inflation does not enter into any subsequent expressions. We denote logs by small letters throughout, so that log leverage equals

$$l_t = b_t^{\$} - 2\pi_t - k_{t+1}^y \tag{17}$$

Log real liabilities of an old firm at time $t+2$ are higher whenever inflation shocks

during the lifetime of the firm are lower

$$b_{t+2}^{\text{real},old} = l_t + k_{t+1}^y - 2\varepsilon_{t+1}^\pi - \varepsilon_{t+2}^\pi \tag{18}$$

The inflation shock in period $t+1$ affects log real liabilities twice because of the persistence of expected inflation.

Firm i in cohort t experiences identical and independent idiosyncratic shocks to log capital at times $t+1$ and $t+2$. We denote by $a_{t+2}^{i,id}$ the sum of time $t+1$ and $t+2$ idiosyncratic shocks to firm i. We assume that the idiosyncratic shock is distributed according to

$$a_{t+2}^{i,id} \sim N\left(-\frac{1}{2}\left(\sigma^{id}\right)^2, \left(\sigma^{id}\right)^2\right) \tag{19}$$

The Jensen's inequality adjustment in (19) ensures that the aggregate level of capital is unaffected by idiosyncratic shocks. Constant returns to scale production technology and firms' inability to make any capital structure decisions in the intermediate period imply that only the combined idiosyncratic shock $a_{t+2}^{i,id}$ affects the real firm value at time $t+2$. Using (7) the log real value of an old firm at the end of period $t+2$ equals

$$v_{t+2}^{i,old} = k_{t+1}^y + r_{t+1}^K + r_{t+2}^K + a_{t+2}^{i,id} \tag{20}$$

Equity holders have the option to default on debt payments and receive a zero liquidating dividend. Otherwise they make promised payments to debt investors and receive the residual firm value. Equity holders optimally default if and only if the real value of the firm (20) is less than its real liabilities (18). Conditional on aggregate shocks the defaulting firms are characterized by

$$a_{t+2}^{i,id} < \underbrace{l_t - 2\varepsilon_{t+1}^\pi - \varepsilon_{t+2}^\pi - r_{t+1}^K - r_{t+2}^K}_{\text{Survival Threshold } a_{t+2}^*} \tag{21}$$

Firms with the most adverse idiosyncratic shocks default and the default rate increases in the survival threshold a_{t+2}^*. Equation (21) formalizes the intuition developed in the introduction. Low inflation shocks ε_{t+1}^π and ε_{t+2}^π increase real liabilities

at time $t+2$ and raise both the survival threshold and the default rate. Low productivity shocks at times $t+1$ and $t+2$ lower real returns on capital and also increase the rate of defaults.

2.6 Stochastic Discount Factor

There exists a representative consumer with expected power utility over consumption, risk aversion γ, and discount rate β

$$U_t = \mathbb{E}_t \sum_{s=t}^{\infty} \exp\left(-\beta\left(s-t\right)\right) \frac{C_s^{1-\gamma}}{1-\gamma} \tag{22}$$

The two-period stochastic discount factor used for pricing two-period real payoffs is

$$M_{t,t+2} = \exp\left(-2\beta\right)\left(C_{t+2}/C_t\right)^{-\gamma} \tag{23}$$

We divide $M_{t,t+2}$ by the change in the price level to obtain the nominal two-period stochastic discount factor, used for pricing nominal two-period payoffs

$$M_{t,t+2}^{\$} = M_{t,t+2}/\exp\left(2\pi_t + 2\varepsilon_{t+1}^{\pi} + \varepsilon_{t+2}^{\pi}\right) \tag{24}$$

2.7 Capital Structure Choice

Firms choose their capital structure by trading off the costs and benefits of debt according to a standard tradeoff view of capital structure. We follow Gourio (2011) in assuming that firms receive $\chi > 1$ in benefits for issuing an additional dollar of debt, creating an incentive to issue debt. Equity holders of cohort t firms choose capital K_{t+1}^{y} and nominal liabilities $B_t^{\$}$ subject to the budget constraint

$$K_{t+1}^{y} = S_t + \chi q_t B_t^{\$} \tag{25}$$

S_t is the value of new equity at time t and q_t is the price of two-period nominal bonds at time t. When the benefits of debt χ are higher, equity holders can purchase

more capital for each dollar of debt financing raised.

Some authors have argued that tax benefits explain only a portion of observed leverage ratios (Graham, 2000), while others have argued that tax benefits are comparable in magnitude to bankruptcy costs (Almeida and Philippon, 2007). We interpret χ as including more general benefits and costs of debt, such as constraining managers from empire-building and reducing informational asymmetries (Jensen and Meckling, 1976, Myers, 1977, Myers and Majluf, 1984, Jensen, 1986).

We follow Leland (1994) in assuming that debt investors only recover a constant fraction $\theta < 1$ of firm value in bankruptcy. An interior optimal leverage ratio exists if bankruptcy costs are sufficiently large relative to debt benefits. We formally assume that $\theta\chi < 1$ (Gourio, 2011).

By imposing the resource constraint (6) we follow Gourio in implicitly assuming that bankruptcy costs and debt benefits are redistributive and do not have a direct effect on output. This is a simplifying assumption and its effect in the model should be small, as long as time variation in default rates and nominal leverage ratios is small.

Let the functions H and Ω give the default probability and average defaulted firm value conditional on the survival threshold a^*_{t+2}

$$H\left(a^*_{t+2}\right) = \mathbb{P}\left(a^{i,id}_{t+2} < a^*_{t+2}\right) \tag{26}$$

$$\Omega\left(a^*_{t+2}\right) = \mathbb{E}\left(\exp\left(a^{i,id}_{t+2}\right)\mathbb{I}\left(a^{i,id}_{t+2} < a^*_{t+2}\right)\right) \tag{27}$$

where $\mathbb{I}$ denotes the indicator function. The price of a nominal long-term corporate bond at time t then equals the expected discounted value of cash flows

$$q_t = \mathbb{E}_t\left[M^{\$}_{t,t+2}\left(1 - \underbrace{H\left(a^*_{t+2}\right)}_{\text{Default Rate}} + \underbrace{\theta\frac{\Omega\left(a^*_{t+2}\right)}{\exp\left(a^*_{t+2}\right)}}_{\text{Recovery}}\right)\right] \tag{28}$$

A lower default probability $H\left(a^*_{t+2}\right)$ and a higher expected recovery $\theta\frac{\Omega\left(a^*_{t+2}\right)}{\exp\left(a^*_{t+2}\right)}$

increase the ex ante price of the bond.

Equity holders' optimal choice of leverage can be expressed as a first-order condition

$$0 = \underbrace{-\chi\left(1-\theta\right)\mathbb{E}_t\left(M^{\$}_{t,t+2}h\left(a^*_{t+2}\right)\right)}_{\text{Marginal Bankruptcy Cost}} + \underbrace{\left(\chi-1\right)\mathbb{E}_t\left(M^{\$}_{t,t+2}\left(1-H\left(a^*_{t+2}\right)\right)\right)}_{\text{Marginal Benefit of Debt}} \tag{29}$$

The marginal default probability h is defined as the derivative of the total default probability with respect to the survival threshold a^*_{t+2}

$$h\left(a^*_{t+2}\right) = H'\left(a^*_{t+2}\right) \tag{30}$$

Equity holders equate the marginal benefit of raising another dollar of debt with the increase in bankruptcy costs.

The optimizing condition for the level of capital gives the first-order condition

$$1 = \mathbb{E}_t\left[M_{t,t+2}R^K_{t+1}R^K_{t+2}F_{t+2}\right] \tag{31}$$

where

$$F_{t+2} = 1 - \underbrace{\left(1-\theta\chi\right)\Omega\left(a^*_{t+2}\right)}_{\text{Bankruptcy Cost}} + \underbrace{\left(\chi-1\right)\exp\left(a^*_{t+2}\right)\left(1-H\left(a^*_{t+2}\right)\right)}_{\text{Benefit of Debt}} \tag{32}$$

The Euler equation (31) determines the optimal level of investment. The expected discounted return on capital, adjusted for bankruptcy costs and benefits of debt by the factor F_{t+2}, equals 1.

Inflation enters into the first-order conditions (29) and (31) through its impact on the survival threshold a^*_{t+2}. When inflation is more volatile or more procyclical the default threshold becomes more volatile, increasing the marginal bankruptcy costs in (29). While equity holders do not incur any bankruptcy costs upon default, debt investors require compensation for bankruptcy costs ex ante, incentivizing firms to reduce leverage ratios.

3 Calibrated Model

3.1 Parameter Values and Model Moments

We solve for the effects of inflation volatility and inflation cyclicality individually in two parameterizations of the model. Model 1 focuses on the effects of stochastic inflation volatility and holds the correlation between inflation shocks and TFP shocks constant at 0. Model 2 holds the volatility of inflation constant but assumes that the inflation-TFP correlation follows a Markov switching process.

Table I summarizes the parameter values. We face a tradeoff in choosing the length of one time period. Lengthening the time horizon increases inflation risk in corporate bonds because inflation is persistent. However, longer time horizons also increase leverage stickiness. We model each period to last five years, so that model seasoned corporate bond durations are slightly shorter than their empirical counterparts. The model implies that firm leverage and investment are constant over ten years, which is towards the long end of the empirical evidence.[7]

We focus on moderate inflation volatility to highlight the relevance of inflation risk even in a stable inflation environment. In Model 1 the standard deviation of annual inflation expectation shocks switches between 0% and 2%. Inflation volatility of 2% corresponds approximately to the inflation volatility experience in the U.S. in the early 1980s and is fifty percent smaller than the inflation volatility experienced in the U.K. during the late 1970s according to our empirical estimates. To focus on the impact of inflation volatility we set the inflation-TFP correlation to zero. Volatility states are persistent, consistent with a five year autoregressive coefficient for U.S. inflation volatility of 0.5. The volatility process spends about two-thirds of its time in the low inflation volatility state.

In Model 2 we assume that the inflation-TFP correlation follows a symmetric process, switching between -0.6 and 0.6, within the range of our empirical esti-

[7] Welch (2004) finds that the mechanistic effects of stock returns can explain about 40% of movements in leverage ratios over a five-year horizon. Baker and Wurgler (2002) find that corporations are likely to raise more equity when their market valuations are relatively higher and that these effects can explain leverage ten years out.

mates for the inflation-stock return correlation in developed countries.[8] We study the impact of inflation cyclicality with moderate inflation uncertainty of 1% p.a. The inflation-TFP correlation spends approximately equal amounts of time in the high and the low states. The average duration for each state is 15 years, consistent with three different regimes over a forty year period.

We choose standard values for the capital share, depreciation and the discount rate (Cooley and Prescott, 1995). We choose a risk aversion of 10, the upper bound of plausible coefficients of risk aversion considered by Mehra and Prescott (1985). As argued in relation to the contingent claim payoff profiles in Figure 2, a high risk aversion is not crucial for our results because inflation risk affects both risk-neutral and risk-adjusted expected payoffs. Trend growth is 2.8% per annum (p.a.), consistent with average U.S. real GDP growth between 1970 and 2009. The recovery rate in bankruptcy equals 40%, consistent with the empirical evidence in Altman (2006).[9] We set the debt benefit parameter to $\chi = 1.4$ to generate empirically plausible default rates. For any dollar of debt financing raised the firm receives 40 cents in benefits. Almeida and Philippon (2007) calculate that tax benefits account for approximately 16% of the debt value, so that our high debt benefits incorporate significant agency benefits of debt.

Table II reports simulated moments from 250 runs of length 100 together with empirical counterparts for the U.S. from 1970 to 2009.[10] The volatility of TFP shocks and idiosyncratic shocks generate plausible levels of aggregate and idiosyncratic equity market volatility. In our model, stock returns are entirely due to dividends in contrast with evidence that equity returns are significantly more volatile than dividends (Shiller, 1971, LeRoy and Porter, 1981). The equity volatility puzzle can be resolved if consumption and dividend growth contain a time-varying long-run component (e.g. Bansal and Yaron, 2004) or if preferences induce persistent fluctuations in risk premia (e.g. Campbell and Cochrane, 1999).

[8] See Table IV.

[9] A recovery rate in the range of 40% to 50% is also consistent with the evidence in Cremers, Driessen, and Maenhout (2008), Glover (2011) and Coval, Jurek and Stafford (2010).

[10] Both model and empirical equity returns are defined as 10 year log nominal equity returns in excess of the continuously compounded ten year nominal interest rate.

We interpret model leverage to include a broad range of liabilities, including pension liabilities and leases, which lead model book leverage to differ from our empirical proxy for book leverage. Pension obligations played a significant role for firms seeking bankruptcy protection during the 2000s, illustrating their relevance for credit risk.[11]

We compare the average Moody's BAA over AAA spread, which is based on secondary market prices rather than prices at issuance, to the model seasoned credit spread. Recent papers have argued that structural models of credit risk can only explain a small portion of empirical credit spreads while matching historically low default rates (Huang and Huang, 2002). We obtain high credit spreads with plausible default rates for a number of reasons. The equity premium is high in our model as a consequence of volatile TFP shocks and high risk aversion, which also helps raise credit spreads. Modeling leverage as persistent and firms as subject to idiosyncratic shocks increases seasoned credit spreads in our model. Leverage ratios of model seasoned firms are heterogeneous across firms, raising average credit spreads, which are convex in leverage ratios. Bhamra, Kuehn, and Strebulaev (2010a, 2010b) stress the importance of modeling a dynamic cross-section of firms for generating a realistic level of credit spreads.

3.2 Model Implications for Credit Spreads

We next study how real risk and inflation risk contribute to time variation in credit spreads in our calibrated model. Throughout this section we focus on seasoned credit spreads, which take into account non-optimal and heterogeneous firm leverage ratios and correspond most closely to empirical secondary market prices of corporate debt.

Figure 4 illustrates the relationship between credit risk, inflation risk, inflation shocks and stock returns implied by the model. We plot average seasoned credit spreads and default rates against stock returns and inflation shocks when inflation volatility is time-varying (Panel A) and when inflation cyclicality is time-varying

[11] See Maynard (2005) for pension negotiations in United Air's bankruptcy. Jin, Merton, and Bodie (2006) argue that firms' equity risk reflects the risk of a firm's pension plan.

(Panel B).[12]

As shown in Figure 4A, default rates and credit spreads increase in periods with high inflation volatility, especially when stock returns are low. The intuition is that the put option in defaultable bonds is significantly larger when inflation is volatile, similarly to the contingent claim payoff in Figure 2B.

In deriving the model, we argued that default rates should be higher after a negative shock to inflation expectations. Figure 4 shows that simulated default rates and credit spreads decrease in the shock to inflation expectations. In the regimes with no inflation volatility the credit spread averages 145 bps. When inflation is volatile, credit spreads are higher on average and decrease from 233 bps to 86 bps as the inflation shock increases from -7.5% p.a. to 7.5% p.a.

Figure 4B shows that when inflation is procyclical, simulated average defaults and credit spreads are higher. Analogously to the contingent claim payoff plots in Figures 2C and 2D, expected defaults are small for a large range of stock returns but increase rapidly for negative stock returns. This increase is more pronounced for the procyclical inflation regime. Credit spreads in the procyclical inflation regime also decrease in the shock to inflation expectations. The intuition for this implication is that corporate bonds are especially exposed to downside inflation risk.

Taken together, we would expect inflation risk to affect corporate bond spreads more strongly during periods when credit risk is already high, whether this is due to adverse real or nominal shocks. We show credit spreads and default rates averaged across all firms in the economy. Credit risk increases even more markedly in inflation risk for firms with above average leverage ratios.

We study the dynamic response of credit spreads to a shock to inflation risk with impulse response functions. Figure 5A shows dynamic responses of new and seasoned credit spreads, new book leverage, and investment to a shock to inflation volatility, averaged over 62,500 simulations of length ten. We simulate impulse responses with a full set of macroeconomic shocks in the background. In period 0, inflation volatility jumps to the high value of 2% p.a. from its steady state distribution, which weights the low inflation volatility state by two thirds and the high inflation volatility state

[12] We simulate 500 runs of length 100.

by one third. Inflation volatility mean reverts to its stochastic steady state in periods 1 through 7.

The inflation volatility shock has a strong effect on the seasoned credit spread, which jumps by 45 bps in the shock period. New firms optimally choose lower leverage when inflation volatility is high, counteracting the effect of inflation volatility on new credit spreads. Leverage decreases by almost one percentage point as inflation volatility increases. New firms in the shock period become seasoned firms in period 1, so that the seasoned credit spread mean reverts almost completely within one period due to the endogenous reduction in leverage. We find that the investment to capital ratio does not react to an increase in inflation risk because the increase in bankruptcy costs in the Euler equation (31) is small.

Figure 5B shows that seasoned credit spreads also increase substantially in response to a shock to the inflation-TFP correlation. In period 0, the inflation-TFP correlation jumps to 0.6 from its stochastic steady state, which puts equal weights on -0.6 and 0.6. The seasoned credit spread increases by 30 bps in the shock period, overshoots below its steady state value and mean reverts. Book leverage decreases in the shock period but less markedly so than in response to the inflation volatility shock in Figure 5A. This is partly due to the fact that nominal long-term interest rates decrease as inflation becomes more procyclical,[13] so liabilities are discounted at a lower rate. The new credit spread is unaffected by the shock to the inflation-TFP correlation. The overshoot in the seasoned credit spread occurs because new firms in the shock period choose lower leverage. When the inflation-TFP correlation mean reverts in period 1 the seasoned credit spread decreases below its steady state level. The investment to capital ratio is again unaffected by inflation risk.

We now formally decompose the variation in seasoned model credit spreads by running regressions of model credit spreads onto inflation risk, real risk, inflation shocks, and real shocks, shown in Table III. Empirical observations may be correlated over time and across countries, making it hard to map the length of a simulated regression into an empirical number of observations. We report regressions on simu-

[13] Real returns on nominal default-free bonds are safer when inflation is procyclical as illustrated in Figures 2C and 2D.

lated data of length 100, the simulation size corresponding approximately to 40 years of bi-annual data from five countries.[14]

Table IIIA shows that time-varying inflation volatility contributes to time variation in model credit spreads. Lagged real and nominal shocks jointly account for three fourths of all variation in seasoned credit spreads, with similar amounts of variation explained by stock returns and the inflation shock. We would expect to be able to explain almost all variation in seasoned credit spreads because the simulation generates model credit spreads as a function of the shocks on the right-hand side of the regression. At the same time we would not expect this result to carry over to our empirical analysis, especially if empirical nominal and real shocks are imperfectly measured.

The slope of the inflation shock is larger in magnitude than the slope on stock returns because of inflation persistence. However, two thirds of the time the inflation shock is zero, so that in a short simulation the coefficient on the inflation shock may be noisily estimated.

Equity volatility and the dividend-price ratio[15] both enter positively into the regression and increase the R^2 by seven percentage points to 83%. Risk-aversion is constant in the model, but the risk of real investments and the risk of equity returns vary over the business cycle. When a larger share of real returns on capital is due to depreciated capital and not subject to productivity shocks, real returns on capital are safer and both equity and debt investors require a lower risk premium.

When adding inflation volatility to the model regression in Table IIIA, the R^2 increases by an additional three percentage points to 86%. The slope with respect to inflation volatility is positive and large. A one percentage point increase in the standard deviation of annual inflation shocks on average leads to an economically significant increase in credit spreads of 26 bps.

Adding the inflation-stock return correlation as an additional explanatory variable in Table IIIB shows that inflation cyclicality also has a substantial effect on

[14] To ensure that regressors are never perfectly collinear we add small measurement errors to the inflation shock and inflation risk variables. The standard deviations of the model measurement errors are approximately 2% of the standard deviations of the underlying parameters.

[15] The dividend-price ratio is computed as expected seasoned stock returns.

credit spreads. The credit spread increases by 20 bps as the inflation-stock return correlation increases by 100 percentage points. The R^2 increases by one additional percentage point.

Taken together, our model credit spreads are highly sensitive to inflation risk even for moderate levels of inflation volatility. Increases in either inflation volatility or inflation cyclicality induce substantial increases in seasoned credit spreads and lead firms to reduce their leverage ratios. Endogenous adjustment in leverage implies that credit spreads mean revert after a shock to inflation risk. The impact of inflation risk on credit spreads is especially large in periods of low stock returns or in periods of negative shocks to inflation expectations.

4 Empirical Tests

We now test the predictions from our model in an international panel of credit spread indices. Time-series and cross-sectional variation in inflation risk are substantial and allow us to test our predictions in an international context. We construct empirical credit spreads, inflation volatility and inflation-stock correlations for a panel of six developed economies: Australia, Canada, Germany, Japan, the U.K., and the U.S.

4.1 Data Description

We obtain corporate bond yield indices, government bond yield indices, GDP growth, stock returns and CPI inflation from Global Financial Data (GFD).[16] Corporate bond spread indices with approximate durations between 5 and 15 years are computed as

[16] According to GFD, the original sources for government bond yields are the Reserve Bank of Australia, Bank of Canada, Deutsche Bundesbank, Bank of Japan, Bank of England, and Federal Reserve Bank. The original inflation sources are the Australian Bureau of Statistics, Statistics Canada, German Statistisches Bundesamt, Japanese Statistics Bureau, UK Central Statistical Office, and US Bureau of Labor Statistics. Stock returns correspond to the following equity indices: Australia ASX Accumulation Index, Canada S&P/TSX-300 Total Return Index, Germany CDAX Total Return Index, Japan Topix Total Return Index, United Kingdom FTSE All-Share Return Index, and United States S&P 500 Total Return Index. We are extremely grateful to Yoichi Matsubayashi for providing us with Japanese corporate bond yield data.

the difference between corporate bond yields and comparable duration government bond yields, both continuously compounded.[17]

In addition to time-varying credit risk captured in our model corporate bond spreads are also plausibly exposed to time-varying liquidity relative to government bonds. We use the Moody's BAA over AAA corporate bond spread for the U.S. to control for time-varying liquidity. Comparable data are not available internationally, so our international credit spreads may contain additional noise due to corporate bond illiquidity.[18] Corporate bond spreads during the financial crisis plausibly also indicated heightened credit risk, as evidenced by the fact that in 2009 5.4% of all Moody's rated corporate bond issuers defaulted (Moody's, 2011).

The structure of corporate bond markets varies significantly across countries.[19] We take into account the possibility of structurally different levels of credit spreads across countries by controlling for country fixed effects in all our tests.

We obtain empirical proxies for each country's equity volatility, inflation volatility, and inflation-stock correlation using rolling backward-looking three year windows of quarterly real stock returns and inflation innovations. Unexpected inflation is

[17] Durations are estimated from bond maturities assuming that bonds sell at par following Campbell, Lo, and MacKinlay (1997), p. 408. The U.S. credit spread is computed as the Moody's BAA over AAA credit spread to adjust for liquidity and tax effects. For a description of the Moody's credit spreads, see http://credittrends.moodys.com/chartroom.asp?r=3. Table B.1 in the online appendix (Kang and Pflueger, 2011) lists further details on the corporate bond data sources and durations.

[18] Chen, Collin-Dufresne, and Goldstein (2009) study the BAA over AAA spread for the same reason. Elton, Gruber, Agrawal, and Mann (2001) attribute 23 bps of the 10-year BBB spread to state and local taxes. They also note that the number of dealer quoted AAA bonds is very small and therefore noisy. Longstaff, Mithal, and Neis (2005) present evidence from Corporate Default Swaps that default risk accounts for the majority of the corporate bond spread across all rating categories, while Bao, Pan, and Wang (2011) argue that the illiquidity premium in highly-rated U.S. bonds increased substantially during the recent financial crisis. For a decomposition of interest rate swap spreads into liquidity and credit factors see Duffie and Singleton (1997).

[19] Corporate bond markets in the countries covered have previously been described and studied by central bank economists. For an analysis of the Japanese corporate bonds market, see Hattori, Koyama, and Yonetani (2001), who argue that default risk of the individual issuer is the most important determinant of corporate bond spreads in Japan after 1997. The Reserve Bank of Australia Bulletin (2001) provides an overview of the Australian corporate bond market. Galati and Tsatsaronis (2001) and De Bondt and Lichtenberger (2003) study the transition of the Euro corporate bond market during the introduction of the Euro.

the residual from a regression of quarterly log inflation onto its own four lags and seasonal dummies. Quarterly real stock return shocks are obtained as the residual from regressing quarterly real stock returns onto their own first lag.

We interpret the time variation in our ability to forecast inflation as a measure of inflation volatility. Stock and Watson (2008) argue that the performance of autoregressions for predicting inflation is inferior to other models and has varied over time. Since we require an estimate of the time variation in inflation predictability but not of the best inflation forecast, a simple and transparent model for inflation seems advantageous. Our main results are very similar when we instead predict inflation using survey forecasts or a model of the type suggested by Atkeson and Ohanian (2001). Firms might default when the nominal prices they can charge for their products and services are low relative to their nominal debt payments. We therefore use consumer prices to measure inflation risk, but our main results are robust to using different inflation indices.

Stock and Watson (2007) and Campbell, Sunderam, and Viceira (2011) have argued that inflation is well described as the sum of a persistent component and cyclical fluctuations. Ideally, our model calls for an empirical measure of long-run inflation risk that updates quickly. Our empirical measures represent a compromise between capturing shorter lags, smaller measurement error and a smaller cyclical component of inflation risk. We might partly reflect the risk of cyclical inflation fluctuations, acting similarly to measurement error and biasing our coefficient estimates downward.

In the previous section we found that if firms refinance infrequently, leverage and hence credit spreads should vary with stock returns and changing inflation expectations. We therefore control for lagged stock returns, GDP growth, unemployment and lagged inflation surprises. We explicitly control for equal-weighted market leverage ratios of non-financial Compustat firms over a shorter time period.[20]

[20]Data for the U.S. and Canada are from Compustat North America and CRSP. Data for all other countries are from Compustat Global. We divide annual book debt values from the previous year end by the sum of the same book debt and quarterly market equity. Following Baker and Wurgler (2002), we define book debt as the sum of total liabilities and preferred stock minus deferred taxes and convertible debt. When preferred stock is missing, we use the redemption value

Real asset growth might be subject to time-varying aggregate and idiosyncratic uncertainty. We control for the volatility of a stock market index and for idiosyncratic stock return volatility, when available. We follow Campbell, Lettau, Malkiel and Xu (2001) in decomposing individual daily stock returns into a market component, an industry component, and a firm component. Idiosyncratic volatility is calculated as the volatility of the firm component over the past quarter, averaged over all individual stocks.[21]

Fama and French (1989) suggest that corporate bond spreads and the stock market dividend yield represent closely related components of expected asset returns. In our model the dividend-price ratio helps to capture the time-varying risk of equity returns, while in a model of time-varying risk aversion, such as in Campbell and Cochrane (1999), it serves as a proxy for aggregate risk aversion. We therefore control for the dividend-price ratio from Datastream.[22]

Campbell, Sunderam, and Viceira (2011) have previously argued that the comovement between nominal government bond returns and stock returns reflects time-varying inflation risk. If nominal long-term bond yields reflect long-term inflation expectations, the negative of the bond-stock return correlation may give another, quickly updating, measure of inflation cyclicality that focuses on the long-run component of inflation and that may be less subject to measurement error than inflation-derived measures. However, the volatility of nominal government bond returns and the bond-stock correlation may also reflect real interest rate risk and, therefore also serve as important controls. We construct high frequency measures of bond return volatility and the bond-stock correlation from daily or weekly government bond and stock returns over the past quarter, using the highest frequency available.

In addition to the leverage choice explicitly modeled, real firms may be able to

of preferred stock. Corporate bond yield indices, such as the Moody's long-term yield indices, weight observations equally and therefore we control for equal-weighted market leverage.

[21] We obtain U.S. stock returns from CRSP, Canadian stock returns from Datastream, and all other country stock returns from Compustat Global. Industries are defined according to GIC classification codes.

[22] For a given MSCI index, the dividend yield is computed as the market-value weighted average dividend yield of all of its constituents. The dividend yield for an individual stock is based on its most recent annualized dividend rate (i.e., dividends per share) divided by the current share price.

adjust their capital structure along numerous margins. To understand how firms adjust their capital structure in response to inflation risk, we construct measures of aggregate book leverage and the share of floating rate debt from Compustat and Compustat Global and use the equity share in new financing from Baker and Wurgler (2000). We set missing floating rate observations to zero to obtain aggregate floating rate shares consistent with the literature (Chernenko and Faulkender, 2011). The time-series behavior of the floating rate share is similar when instead excluding missing observations. When firms refinance infrequently, book leverage is less subject to market fluctuations than market leverage and we therefore use book leverage to capture firms' target leverage ratio. We compute aggregate book leverage ratios by summing book debt across all non-financial firms and dividing by the sum of aggregated total assets.

While our model predicts no adjustment in investment to inflation risk, investment is important for macroeconomic outcomes and we therefore explore the empirical relationship between investment and inflation risk. We compute aggregate investment to capital ratios by summing capital expenditures across all non-financial firms and divide by aggregated PP&E at the end of the previous year, taking into account the reporting lag.[23]

4.2 Summary Statistics

In the introduction we argued that inflation uncertainty in the U.S. has varied substantially over time and has covaried with credit spreads. Summary statistics in Table IV reveal that both the volatility and the cyclicality of inflation have varied substantially over time in each country.

Average annualized inflation volatility ranges from 100 bps for Germany to 161 bps for the U.K. Inflation volatility displays significant time variation within each country with standard deviations ranging from 42 bps to 70 bps. The highest inflation volatility in our sample of 412 bps occurs in the U.K. during the 1970s.

The inflation-stock correlation, our measure of the slope of the Phillips curve, is

[23] Philippon (2009) and Polk and Sapienza (2009) construct similar investment variables.

negative or zero on average in every country. Its time variation within each country is substantial, with within country standard deviations of around 0.30.

Bond volatility and the bond-stock correlation report the annualized standard deviation of changes in long-term nominal government bond yields and the correlation between changes in nominal government bond yields and stock returns, respectively. These measures are also equal to the volatility of government bond returns scaled by the bond duration and the negative of the correlation between government bond returns and stock returns, where bond returns are approximated using changes in yields. Our choice of units ensures that the inflation risk component in the bond volatility and the bond-stock correlation are comparable to the inflation-derived measures of inflation risk.

Figure B.1 in the online appendix (Kang and Pflueger, 2011) explores the significance of inflation risk for the bond-stock correlation for the U.S. and the U.K. by comparing it to the breakeven-stock return correlation. For these two countries inflation-indexed bonds have been available for a significant subsample, allowing us to use breakeven inflation, or the difference between nominal and inflation-indexed government bond yields, as a market-based proxy for long-term inflation expectations.[24] Inflation risk, as captured by the breakeven inflation-stock return correlation, moves very closely with the bond-stock return correlation, supporting our interpretation of the bond-stock correlation as an additional measure of inflation risk.

Credit spreads average around 100 bps and have within country standard deviations between 36 bps to 91 bps. Rare negative values in Japanese and German credit spreads are most likely due to measurement error. The correlations of international credit spreads with U.S. credit spreads range from -0.21 for Japan to 0.55 for the U.K. As shown in Table B.2 in the online appendix, international time series of credit spreads and inflation risk are not perfectly correlated with U.S. time series, effectively increasing our number of observations relative to an analysis of the U.S. time series.

Figure 6 plots time series of credit spreads and inflation volatility. The co-

[24] Breakeven inflation also contains an inflation risk premium and a liquidity premium (Pflueger and Viceira, 2011).

movement between international credit spreads and inflation volatility over time is apparent for many of the countries in our sample. Figure 6 also suggests a cross-sectional relationship between inflation volatility and credit spreads. As noted in the introduction, U.S. inflation volatility and credit spreads were both high in the 1970s and 1980s. We now see that both inflation volatility and credit spreads were even more elevated in the U.K. during the same period.

Figure 7 documents visually the relationship between credit spreads and the inflation-stock correlation in our international data. For ease of comparison the inflation-stock correlation is scaled to have the same mean and standard deviation as credit spreads in each country. The U.S. inflation-stock return correlation was mostly negative during the 1970s and 1980s, indicating that supply shocks and shifting inflation expectations moved inflation and real outcomes in opposite directions. In contrast, the inflation-stock correlation was positive during much of the 1990s and 2000s, potentially as a result of smaller macroeconomic shocks or more stable monetary policy. In particular, two periods of high inflation-stock return correlations during the early 2000s and during the financial crisis coincided with high credit spreads. The co-movement between the inflation-stock return correlation and credit spreads is also visually apparent for other countries, even if our estimate of the inflation-stock return correlation contains measurement error. For instance, in Germany the inflation-stock correlation and credit spreads show very similar low-frequency movements with decreases during the 1970s and 1980s and steep increases during the 1990s and 2000s.[25]

4.3 Testing for Inflation Risk in Credit Spreads

We now test the model's key predictions that corporate bond spreads should be higher on average when inflation is more volatile or more procyclical, using the international panel of credit spreads.

Our benchmark regressions in Table VA provide evidence for the model predic-

[25] Using bond-market derived measures Wright (2010) argues that the cyclicality of inflation has increased since 1990 in most developed countries.

tion that inflation risk should have a substantial impact on credit spreads. Both inflation volatility and the inflation-stock correlation enter with large, positive, and significant coefficients, while controlling for proxies for real uncertainty, time-varying risk aversion, and the business cycle. Equity volatility and the dividend-price ratio, our proxies for real uncertainty and time-varying risk aversion, both enter with the expected signs and jointly explain 12% of the variation in credit spreads after controlling for country fixed effects. We find that inflation volatility and the inflation-stock correlation jointly can explain as much variation in credit spreads as can our proxies for real uncertainty and time-varying risk aversion, raising the residual R^2 to 27% (after taking out fixed effects).

Since inflation uncertainty might move over the business cycle and with changes in inflation, it is important to control for proxies for real economic activity and shocks to inflation expectations. In the model, positive real returns and inflation surprises reduce real leverage ratios and therefore reduce credit spreads. Column (4) shows our benchmark estimate, which controls for lagged inflation shocks, stock returns, GDP growth and change in unemployment. Adding controls to our regression increases the residual R^2 by another ten percentage points and improves the precision of the estimated slope on the inflation-stock correlation.

The empirical estimates in Table V indicate a large effect of inflation volatility and the inflation-stock correlation on credit spreads, comparable to the theoretical magnitudes in the calibrated model in Table III. A 50 bps move in inflation volatility, corresponding approximately to one standard deviation in the U.S., is associated with a 16 bps increase in empirical credit spreads. A one standard deviation move in the inflation-stock correlation (30 percentage points) is associated with a 13 bps increase in credits spreads. The magnitudes are economically meaningful relative to average credit spreads of around 100 bps.

The reported standard errors take into account potential cross-country correlation, heteroskedasticity, and serial autocorrelation. We compute standard errors according to Driscoll and Kraay's (1998) extension of Newey and West (1987) with 16 lags.[26]

[26] Hoechle (2007) provides a Stata routine.

Our benchmark estimates might reflect both time-series and cross-country variation in inflation risk. Adding time fixed effects to the benchmark regression confirms our previous visual impression that cross-country variation helps in estimating the empirical relationship between credit spreads and inflation risk. The slope coefficients onto inflation volatility and the inflation-stock return correlation remain similar in magnitude and significant.[27] This finding also helps to alleviate concerns that the results might be driven by any global omitted variable, such as global real interest rate risk or global growth risk.

Excluding the financial crisis, the coefficients on inflation volatility and the inflation-stock correlation decrease in magnitude, but inflation risk remains economically and statistically significant in the pre-crisis subsample. From our theoretical analysis, we would expect that inflation risk should have especially large effects on credit spreads during crises, but it appears that the empirical relationship between credit spreads and inflation risk is not solely driven by the most recent financial crisis.

We also report estimates for the U.S. time series, which might be especially familiar to readers and for which we can subtract a AAA credit spread as a way of adjusting for time-varying liquidity and tax treatment, common across all corporate bonds.[28] Table VB shows that credit spreads are clearly related to inflation risk in the U.S., although the smaller sample size decreases the statistical power of the tests. The regression R^2 increases from 22% to 48% as we add inflation volatility and the inflation-stock correlation as explanatory variables to our proxies for real risk and time-varying risk aversion. The slope on inflation volatility is large, significant, and comparable to the slope in the international regression. The inflation-stock correlation enters positively but is only significant for the pre-crisis subsample. While both U.S. credit spreads and the U.S. inflation-stock correlation were high during the financial crisis, the inflation-stock correlation remained high after the financial crisis. It therefore did not capture the significant decline in U.S. credit spreads in 2010.

[27] We estimate the time fixed effects regression by first time demeaning all left-hand side and right-hand side variables. We again report Driscoll and Kraay (1998) standard errors with 16 lags.

[28] Table A.V in the appendix shows that all results in Table V are robust to computing the U.S. credit spread with respect to a duration-matched government bond yield.

As shown in Table VI, the benchmark empirical results are remarkably consistent across countries, especially considering that institutional features differ widely across international credit markets. Inflation volatility and the inflation-stock return correlation enter positively and significantly in most countries. Inflation volatility appears to have been less important in Germany and Japan than in other countries, potentially owing to stable and low inflation uncertainty in these countries during much of the sample period.

The sensitivities of credit risk with respect to real growth shocks and inflation shocks play crucial roles in our proposed mechanism. Table VII spells out the coefficient estimates on the proxies for real and nominal shocks, that are included as controls in Table V. Quarterly inflation shocks consistently enter negatively, providing support for the model mechanism. Magnitudes are comparable to the slope of credit spreads onto inflation shocks in the model. Three year inflation shocks enter negatively in the U.S. but not internationally, potentially due to the comovement between the level of inflation and long-run inflation uncertainty (Ball and Cecchetti, 1990). As shown in Figure B.2 in the online appendix, the relationship between U.S. inflation shocks and credit spreads is clearest during the recent financial crisis, when a rapid fall in consumer prices coincided with high credit spreads. However, column (4) in Table VII indicates that U.S. credit spreads also have an inverse relationship with quarterly inflation shocks during the pre-crisis period. The coefficients on real growth variables need to be interpreted with caution because of collinearity between different real activity variables, but quarterly GDP growth enters consistently with a negative sign.

Our proposed mechanism implies that the impact of inflation risk on credit spreads should be especially strong when either real stock returns or inflation surprises are low. The put option in corporate bonds should matter only on the downside, but not on the upside, and therefore we would expect the relationship between credit spreads, stock returns and inflation shocks to be highly nonlinear. Figure 8 explores these predictions using a non-parametric approach and provides an empirical analogue to the theoretical relationships in Figure 4.

We construct the left panel in Figure 8A by splitting observations in each country

into quintiles of real stock returns and into equal-sized subsamples for high and low inflation volatility. We sort by three year real stock returns for consistency with the construction of the inflation risk variables. Normalizing credit spreads in the middle real stock return quintile to zero focuses on the comparison between credit spread slopes across inflation risk regimes. The panel averages credit spreads across all countries within each inflation risk regime and quintile. The other panels are constructed similarly, instead sorting by the inflation-stock correlation and the three year inflation shock.

The empirical relationship between credit spreads, stock returns and inflation shocks in Figure 8 bears striking resemblance to the theoretical relationships in Figure 4. The left panel in Figure 8A shows that credit spreads disproportionately increase with inflation volatility when real stock returns are low. The slope of credit spreads is identical across high and low inflation volatility regimes for the top four quintiles of stock returns. However, the gap between credit spreads in the high and low inflation volatility regimes widens to 20 bps in the lowest stock return quintile, indicating a larger put option in defaultable bonds when inflation uncertainty is greater.

The right panel of Figure 8A similarly suggests that the impact of inflation volatility on credit spreads is larger when inflation is surprisingly low, even if the largest difference in credit spreads obtains in the second-lowest quintile of inflation shocks rather than the lowest.

Figure 8B shows that inflation cyclicality also impacts credit spreads most strongly when real stock returns and inflation shocks are low. The gap between credit spreads in high and low inflation-stock correlation regimes widens to 40 bps in the lowest stock return quintile. Finally, credit spreads in the high inflation-stock correlation regime are higher in the lowest inflation shock quintile than in the middle inflation shock quintile by 30 bps, even if the volatility of the average credit spreads across quintiles suggest that these averages may be estimated noisily.

The empirical magnitudes in Figure 8 are large compared to our benchmark empirical results, which suggest that a one standard deviation move in the inflation volatility or the inflation-stock correlation goes along with a credit spread increase of about 15 bps. However, they are smaller than the theoretical magnitudes shown

in Figure 4. Besides measurement error, one potential reason is that in Figure 8 we discretize a continuum of inflation risk regimes into two equal-sized parts. Averaging over different inflation risk regimes implies that the difference between the high inflation volatility and the low inflation volatility regimes in Figure 8 is only 73 bps as compared to 200 bps in Figure 4. The difference between the high and low inflation-stock correlations in Figure 8 is 44 bps and is smaller by a factor of three than the difference between the theoretical inflation-TFP correlations in Figure 4.

4.4 Robustness of Benchmark Results

Table VIII shows that our benchmark results are robust to including idiosyncratic equity volatility, market leverage, the return volatility of nominal government bonds, and the bond-stock correlation, available over a shorter sample period starting in 1989.

We interpret bond return volatility and the bond-stock correlation as reflecting both inflation risk and real interest rate risk. The bond-stock correlation enters positively and significantly with a large regression coefficient, offering additional evidence for the strong relevance of inflation risk for corporate bond spreads. The bond volatility enters positively but is only marginally significant. The residual R^2 increases by fourteen percentage points to 54% when adding these two explanatory variables. At the same time the coefficients on inflation volatility remain significant and show small decreases in magnitude, indicating that inflation risk is priced into corporate bonds above and beyond real interest rate risk.

Controlling for time fixed effects helps us to isolate further the inflation risk component from a global real interest rate risk component in the bond market derived variables. If financial markets are highly integrated across the six developed countries in our sample, real interest rate risk should be equated across countries.[29] Any country-specific components of bond volatility and the bond-stock correlation should then reflect inflation risk. When controlling for country fixed effects, the

[29] For instance, Wright (2010) uses an assumption along these lines in his analysis of international interest rate risk premia.

coefficient on the bond-stock correlation remains large and significant, suggesting that the bond-stock correlation contains a significant country-specific inflation risk component, which is priced into corporate bond spreads across countries. Adding time fixed effects renders the inflation volatility and the inflation-stock correlation insignificant, reflecting the limited cross-country variation in these variables over the shorter time period.

Further robustness checks using different inflation indices and empirical proxies for inflation shocks, HP filtered explanatory variables, and different measures for real uncertainty are reported in the online appendix.

4.5 Testing Dynamic Implications

We now proceed to test the dynamic model predictions for credit spreads in Table IX. Model impulse responses show that credit spreads increase simultaneously with inflation risk increases and then mean revert, due to endogenous adjustment in leverage and the changing composition of the credit spread index, as shown in Figure 5.

Table IXA regresses changes in credit spreads onto changes in inflation risk and finds a strong relationship, consistent with our level regressions in Table V. The slope with respect to inflation volatility is constant across horizons, while the slope with respect to the inflation-stock correlation increases as we lengthen the horizon of credit spread changes. Our inflation risk measures use long lags, so changes in inflation risk are plausibly more accurately measured over longer time horizons.

Table IXB tests whether changes in credit spreads are predictable from inflation risk. Table IXB shows that empirical changes in credit spreads are negatively related to the lagged level of inflation risk. The magnitudes of regression coefficients of five year changes in credit spreads are comparable to those obtained in the benchmark regressions in Table V, suggesting that credit spreads mean revert fully over a horizon of five years.

To better understand the contribution of the changing composition of the credit spread index, we would ideally like to run similar regressions using credit returns. In

Tables B.XI and B.XII in the online appendix we find that while inflation volatility predicts changes in U.S. credit spreads it does not predict returns on U.S. corporate bonds in excess of government bond returns, indicating that the changing composition of credit spread indices might indeed be the main source of credit spread predictability.

4.6 Implications for Capital Structure

If investors demand compensation for bearing credit risk associated with inflation, firms should adjust their capital structure accordingly. The financing choice of firms in our model is highly simplified, but in reality firms can reduce their exposure to fluctuations in real liabilities along multiple dimensions.

Issuing equity instead of debt reduces leverage and the inflation exposure of firms' liabilities. Indeed, we see in Figure 9B that the share of equity issuance was especially high during periods of volatile inflation in the 1970s and 1980s.

The issuance of floating-rate debt offers firms the possibility of indexing interest payments to nominal interest rates, even if face values are still fixed in nominal terms, and therefore also helps to reduce inflation risk of firms' liabilities. The floating-rate share of long-term debt among U.S. Compustat firms, shown in Figure 9A, appears related to inflation uncertainty. It peaked during the 1970s, came down during the 1980s and 1990s and increased subsequently.[30]

Formally testing the relationship between aggregate book leverage and inflation risk yields evidence consistent with firms adjusting their book leverage downwards when inflation is more volatile. In contrast to market leverage, book leverage should be less exposed to mechanical effects of stock returns and therefore give a more reliable measure of firms' intended leverage ratio. Leverage data are annual, with the U.S. time series available starting in 1970 and international data available starting in 1994.

Table XA shows a significant negative relationship between leverage and inflation

[30] Only 60% of Compustat firms report floating-rate debt, so the floating rate debt share may be subject to time-varying reporting bias.

volatility. The results look similar for the longer U.S. time series and for the international panel. We control for three year stock returns, inflation surprises, GDP growth and change in unemployment, as before. A one standard deviation move in inflation volatility is associated with a 1.5 percentage point decrease in leverage. The slope of leverage onto inflation volatility is significantly larger than in the model but imprecisely estimated. We find no relationship between leverage and the inflation-stock correlation, which is consistent with the relative magnitudes in the model.

Finally, we test the relationship between investment and inflation risk. In the calibrated version of our model, frictions arising from bankruptcy costs are too small to affect firms' investment decisions. Because of the relevance of investment for macroeconomic outcomes and growth, it appears important to understand whether inflation risk can impact aggregated investment to capital ratios.[31] Fischer and Modigliani (1978) suggested that inflation uncertainty might lead to shortening of financial contracts and consequently might reduce investment. We find no robust relationship between inflation risk and investment in Table XB.

5 Conclusion

This paper argues both theoretically and empirically that uncertainty about the long-run price level and the relationship of inflation with the business cycle are major macroeconomic determinants of corporate bond spreads. Using data on international corporate bond spreads, we provide new evidence that corporate bond investors price the risk of debt deflation.

In a real business cycle model with time-varying inflation risk, inflation persistence generates large effects of inflation risk on credit spreads. Firms reduce their leverage ratios when inflation risk increases, so credit spreads mean revert after a shock to inflation risk.

We test the model using a panel of corporate bond spreads from six major developed economies. We find that inflation volatility and the inflation-stock return

[31] Philippon (2009) argues that corporate bond spreads, controlling for idiosyncratic volatility, give a measure of firms' investment opportunities.

correlation explain substantial variation in credit spreads, both in the time series and in the cross-section. A one standard deviation move in the volatility of inflation is associated with an increase in credit spreads of 15 bps. A one standard deviation move in the inflation-stock return correlation is associated with an increase in credit spreads of 13 bps. Inflation risk can explain a meaningful portion of variation in international credit spreads. Equity volatility and the dividend-price ratio jointly explain 12% of the variation in international credit spreads, but adding our proxies for inflation risk increases the residual R^2 to 27%. Leverage decreases during periods of higher inflation volatility while equity issuance and the share of floating rate debt increase, consistent with firms partially insulating their capital structure from inflation risk during periods of higher inflation uncertainty.

As of October 2011, the BAA minus AAA U.S. credit spread was 126 bps, or 25 basis points spread above our sample average, suggesting that investors were reluctant to hold corporate bonds. The corporate bond spread seems especially high given that equity valuations were high relative to their historical average.[32] If one believes that policymakers will be unable to counteract deflation should another recession arrive, we can rationalize this discrepancy. Indeed, our measures of inflation cyclicality were close to all-time highs, and our benchmark estimates attribute about 35 of the 126 bps credit spread to the inflation-stock correlation.

Our results suggest fruitful avenues for further research. The risk of debt deflation should be especially relevant for firms with high leverage ratios. French, Ruback, and Schwert (1983) previously found no evidence that stocks of firms with higher nominal liabilities benefit more from positive inflation surprises. Given the strong aggregate empirical results in this paper it seems promising to study the sensitivity of credit spreads to inflation risk across firms. Slow adjustment in firms' financing policies could be used to obtain significant and plausibly exogenous variation in firms' leverage ratios.

This paper suggests that investors attach an economically meaningful price to financial distress associated with deflation, highlighting the importance of better

[32] The S&P500 index dividend-price ratio was about three-fourths of a standard deviation below its sample average.

understanding the macroeconomic and monetary policy determinants. A decomposition of time-varying inflation risk into macroeconomic shocks, such as cost push shocks and shocks to aggregate demand, and time-varying monetary policy, could be of particular interest to central banks around the world.

Finally, our analysis suggests that corporate bond spreads may be useful measures of investors' deflationary concerns and for gauging central banks' credibility in counteracting deflation. This is particularly relevant given recent renewed concerns about a deflationary drop in aggregate demand and about ineffectiveness of traditional monetary policy at the zero lower bound.

A Model Appendix

A.1 Optimal Choice of Labor

From (4) we obtain the first-order condition with respect to labor

$$(1-\alpha)\, z_t^{1-\alpha} \left(\frac{K_t^i}{N_t^i}\right)^{\alpha} = W_t \tag{33}$$

The capital to labor ratio is constant across firms and equal to K_t. Substituting back into operating revenue gives firm $i's$ one-period equilibrium revenue as $\alpha K_t^i \left(\frac{z_t}{K_t}\right)^{1-\alpha}$. The expression for the equilibrium return on capital (7) follows.

A.2 First-Order Conditions

The time $t+2$ real cash flow of a corporate bond issued by firm i at time t is

$$\frac{\left(1-\mathbb{I}\left\{a_{t+2}^{i,id} < a_{t+2}^{*}\right\}\right)}{\exp\left(2\pi_t + 2\varepsilon_{t+1}^{\pi} + \varepsilon_{t+2}^{\pi}\right)} + \theta \frac{K_{t+1}^{y}}{B_t^{\$}} R_{t+1}^{K} R_{t+2}^{K} \exp\left(a_{t+2}^{i,id}\right) \mathbb{I}\left\{a_{t+2}^{i,id} < a_{t+2}^{*}\right\} \tag{34}$$

The time t price of the bond is given by the expected stochastic discounted value of real cash flows

$$\begin{aligned} q_t &= \mathbb{E}_t\left[M_{t,t+2}^{\$}\left(1-H\left(a_{t+2}^{*}\right)\right)\right] \\ &\quad + \theta \mathbb{E}_t\left[M_{t,t+2} \frac{K_{t+1}^{y}}{B_t^{\$}} R_{t+1}^{K} R_{t+2}^{K} \Omega\left(a_{t+2}^{*}\right)\right] \end{aligned} \tag{35}$$

The expression (21) for the survival threshold then implies (28). Equity holders maximize

$$\mathbb{E}_t\left[M_{t,t+2} \max\left(V_{t+2}^{i,old} - B_t^{\$} \exp\left(-2\pi_t - 2\varepsilon_{t+1}^{\pi} - \varepsilon_{t+2}^{\pi}\right), 0\right)\right] - S_t \tag{36}$$

subject to (20) and (25). Given constant returns to scale and no equity issuance costs, the net equity value (36) will equal zero in equilibrium, reflecting free entry.

Substituting (20), (25), and (28) into (36) we can rewrite the firm's problem as maximizing

$$\exp\left(2\pi_t\right) K_{t+1}^{y} L_t \mathbb{E}_t \left[M_{t,t+2}^{\$} \left(\begin{array}{c} \exp\left(-a_{t+2}^{*}\right) + (\chi - 1)\left(1 - H\left(a_{t+2}^{*}\right)\right) \\ + (\chi\theta - 1)\,\Omega\left(a_{t+2}^{*}\right)\exp\left(-a_{t+2}^{*}\right) \end{array} \right) \right] - K_{t+1}^{y} \tag{37}$$

Differentiating (37) with respect to K_{t+1}^{y} while holding constant the initial leverage ratio L_t gives:

$$0 = \exp\left(2\pi_t\right) L_t \mathbb{E}_t \left[M_{t,t+2}^{\$} \left(\begin{array}{c} \exp\left(-a_{t+2}^{*}\right) + (\chi - 1)\left(1 - H\left(a_{t+2}^{*}\right)\right) \\ + (\chi\theta - 1)\,\Omega\left(a_{t+2}^{*}\right)\exp\left(-a_{t+2}^{*}\right) \end{array} \right) \right] - 1 \tag{38}$$

Using the expression (21) for the survival threshold gives the first-order condition (31). Differentiating (37) with respect to L_t while holding constant the level of capital K_{t+1}^{y} gives:

$$0 = \left(1 + \frac{\partial}{\partial a_{t+2}^{*}}\right) \mathbb{E}_t \left[\left(M_{t,t+2}^{\$} \left(\begin{array}{c} \exp\left(-a_{t+2}^{*}\right) + (\chi - 1)\left(1 - H\left(a_{t+2}^{*}\right)\right) \\ + (\chi\theta - 1)\,\Omega\left(a_{t+2}^{*}\right)\exp\left(-a_{t+2}^{*}\right) \end{array} \right) \right) \right] \tag{39}$$

Using $\frac{\partial}{\partial a_{t+2}^{*}}\Omega\left(a_{t+2}^{*}\right) = \exp\left(a_{t+2}^{*}\right) h\left(a_{t+2}^{*}\right)$ gives (29).

A.3 Solution Method

Define rescaled variables relative to trend productivity $\exp\left(\mu t\right)$

$$\tilde{K}_t = \frac{K_t}{\exp\left(\mu t\right)}, \tilde{C}_t = \frac{C_t}{\exp\left(\mu t\right)}, \tilde{Y}_t = \frac{Y_t}{\exp\left(\mu t\right)}, \tilde{z}_t = \frac{z_t}{\exp\left(\mu t\right)}$$

We denote logs by lower case letters. Since $\tilde{z}_t$ is identically and independently distributed, our only state variable is end of period total wealth $\tilde{W} = \tilde{Y} + (1 - \delta)\,\tilde{K}$. We use projection methods to solve for the two policy functions for leverage and consumption (Aruoba, Fernandez-Villaverde, and Rubio-Ramirez, 2006). A recursive equilibrium has to satisfy the two first-order conditions (29) and (31) with the ad-

ditional dynamics $\tilde{K}_{t+1} = \left(\tilde{W}_t - \tilde{C}_t\right) \exp(-\mu)$. We define $ER(\tilde{w})$ as the expected two-period return on capital in a model with zero inflation volatility. Intuitively, scaling leverage by ER makes the survival threshold well-behaved. We then solve for both log detrended consumption $\tilde{c}$ and scaled leverage L/ER as polynomials of degree two in log detrended wealth $\tilde{w}$.

We minimize the errors of the first-order conditions along a grid of 19 nodes using MATLAB's fminsearch function.We solve for the optimal policy function over a wide range. In simulations, the de-trended end of period wealth $\tilde{w}_t$ falls within this range at least 99% of the time. We choose a grid that is denser towards the center of the range as a way of putting higher weight on more likely values of $\tilde{w}$. We discretize the normal distribution using the Gauss-Hermite methodology with 7 nodes.[33]

[33] Wouter den Haan provides software for Gaussian quadrature (http://www.wouterdenhaan.com/software.htm).

References

Acharya, Viral V., D. Gale, and T. Yorulmazer, 2010, "Rollover Risk and Market Freezes", NBER Working Paper w15674

Almeida, Heitor, and T. Philippon, 2007, "The Risk-Adjusted Cost of Financial Distress", *Journal of Finance* 62(6):2557-2586

Altman, Edward, 2006, "Default Recovery rates and LGD in Credit Risk Modeling and Practice: An Updated Review of the Literature and Empirical Evidence", NYU, mimeo

Aruoba, S. Boragan, J. Fernandez-Villaverde, and J. F. Rubio-Ramirez, 2006, "Comparing Solution Methods for Dynamic Equilibrium Economies", *Journal of Economic Dynamics and Control* 30:2477–2508

Atkeson, Andrew, and L.E. Ohanian, 2001, "Are Phillips Curves Useful for Forecasting Inflation?", *Federal Reserve Bank of Minneapolis Quarterly Review* 25(1):2-11

Baele, Lieven, G. Bekaert, and K. Inghelbrecht, 2009, "The Determinants of Stock and Bond Return Comovements", NBER Working Paper w15260

Baker, Malcolm, and J. Wurgler, 2002, "Market Timing and Capital Structure", *Journal of Finance* 57(1):1-32

Ball, Laurence, and S. Cecchetti, 1990, "Inflation and Uncertainty at Long and Short Horizons", *Brookings Papers on Economic Activity* 1:215-245

Bansal, Ravi, and A. Yaron, 2004, "Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles", *Journal of Finance* 59(4):1481-1509

Bernanke, Ben, and M. Gertler, 1989, "Agency Costs, Net Worth, and Business Fluctuations", *American Economic Review* 79(1):14-31

Bhamra, Harjoat S., A. J. Fisher, and L. Kuehn, 2011, "Monetary Policy and Corporate Default", University of British Columbia, mimeo

Bhamra, Harjoat S., L. Kuehn, and I. A. Strebulaev, 2010a, "The Levered Equity Risk Premium and Credit Spreads: A Unified Framework", *Review of Financial Studies* 23 (2):645-703.

Bhamra, Harjoat S., L. Kuehn, and I. A. Strebulaev, 2010b, "Long Run Risks, Credit Markets, and Financial Structure", *American Economic Review: Papers & Proceedings* 100:547–551

Black, Fischer, and M. Scholes, 1973, "The Pricing of Options and Corporate Liabilities", *Journal of Political Economy* 81:637-654

Bomberger, William A., 1996, "Disagreement as a Measure of Uncertainty", *Journal of Money, Credit, and Banking* 28(3):381-392

Campbell, John Y., and J. Cocco, 2003, "Household Risk Management and Optimal Mortgage Choice", *Quarterly Journal of Economics* 118(4):1449-1494

Campbell, John Y., and J. H. Cochrane, 1999, "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behavior", *Journal of Political Economy* 107(2):205-251

Campbell, John Y., M. Lettau, B. G. Malkiel, and Y. Xu, 2001, "Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk", *Journal of Finance* 56(1):1-43

Campbell, John Y., A. W. Lo, and A. C. MacKinlay, 1997, *The Econometrics of Financial Markets*, Princeton University Press

Campbell, John Y., A. Sunderam, and L. M. Viceira, 2011, "Inflation Bets or Deflation Hedges? The Changing Risks of Nominal Bonds", Harvard University, mimeo

Campbell, John Y., and G. B. Taksler, 2003, "Equity Volatility and Corporate Bond Yields", *Journal of Finance* 58(6):2321-2349

Chen, Long, P. Collin-Dufresne, and R. S. Goldstein, 2009, "On the Relationship Between the Credit Spread Puzzle and the Equity Premium Puzzle", *Review of Financial Studies* 22(9):3367-3409

Chernenko, Sergey, and M. Faulkender, 2011, "The Two Sides of Derivatives Usage: Hedging and Speculating with Interest Rate Swaps", *Journal of Financial and Quantitative Analysis,* forthcoming

Collin-Dufresne, Pierre, R. S. Goldstein, and J. S. Martin, 2001, "The Determinants of Credit Spread Changes", *Journal of Finance* 56(6):2177-2207

Cooley, Thomas F., and E.C. Prescott, 1995, *Frontiers of Business Cycle Research,* Princeton University Press

Coval, Joshua D., J. Jurek, and E. Stafford, 2009, "Economic Catastrophe Bonds", *American Economic Review* 99(3):628-666

Cremers, Martijn, J. Driessen, and P. Maenhout, 2008, "Explaining the Level of Credit Spreads: Option-Implied Jump Risk Premia in a Firm Value Model", *Review of Financial Studies* 21(5):2209-2242

D'Amico, Stefania, D. H. Kim, and M. Wei, 2008, "Tips from TIPS: The Informational Content of Treasury Inflation-Protected Security Prices", *BIS Working Papers*, No 248

David, Alexander, and P. Veronesi, 2009, "What Ties Return Volatilities to Price Valuations and Fundamentals?", NBER Working Paper w15563

De Bondt, Gabe, and J. Lichtenberger, 2003, "The Euro Area Corporate Bond Market: Where Do We Stand Since the Introduction of the Euro?", *European Business Organization Law Review* 4:517-539

De Fiore, Fiorella, P. Teles, and O. Tristani, 2011, "Monetary Policy and the Financing of Firms", *American Economic Journal: Macroeconomics* 3: 112–142

Duffie, Darrell, and K. J. Singleton, 1997, "An Econometric Model of the Term Structure of Interest-Rate Swap Yields", *Journal of Finance* 52:1287-1321

Driscoll, John C., and A. C. Kraay, 1998, "Consistent Covariance Matrix Estimation With Spatially Dependent Panel Data", *Review of Economics and Statistics* 80(4):549-560

Elton, Edwin J., M.J. Gruber, D. Agrawal, and C. Mann, 2001, "Explaining the Rate Spread on Corporate Bonds", *Journal of Finance* 56(1):247-278

Engle, Robert F., 1982, "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation", *Econometrica* 50(4):987-1007

Fama, Eugene F., and K. R. French, 1989, "Business Conditions and Expected Returns on Stocks and Bonds", *Journal of Financial Economics* 25:23-49

Fischer, Stanley, and F. Modigliani, 1978, "Towards an Understanding of the Real Effects and Costs of Inflation", *Review of World Economics* 114(4):810-833

Fisher, Irving, 1933, "The Debt-Deflation Theory of Great Depressions", *Econometrica* 1(4):337-357

Fleckenstein, Matthias, F. A. Longstaff, and H. Lustig, 2010, "Why Does the Treasury Issue TIPS? The Tips–Treasury Bond Puzzle", NBER working paper w16358

Fuhrer, Jeffrey C., 1997, "The (Un)Importance of Forward-Looking Behavior in Price Specifications", *Journal of Money, Credit, and Banking* 29(3):338-350

Galati, Gabriele, and K. Tsatsaronis, 2001, "The Impact of the Euro on Europe's Financial Markets", BIS Working Paper No 100

Glover, Brent, 2011, "The Expected Cost of Default", University of Pennsylvania, mimeo

Goldstein, Robert, N. Ju, and H. Leland, 2001, "An EBIT-Based Model of Dynamic Capital Structure", *Journal of Business* 74(4):483-512

Gomes, Joao, and M. Schmid, 2010, "Levered Returns", *Journal of Finance* 65(2):467-494

Gourio, Francois, 2011, "Credit Risk and Disaster Risk", Boston University, mimeo

Graham, John R., 2000, "How Big Are the Tax Benefits of Debt?", *Journal of Finance* 60(5):1901:1941

Hackbarth, Dirk, J. Miao, and E. Morellec, 2006, "Capital Structure, Credit Risk, and Macroeconomic Conditions", *Journal of Financial Economics* 82:519–550

Hattori, Masazumi, K. Koyama, and T. Yonetani, 2001, "Analysis of Credit Spread in Japan's Corporate Bond Market", BIS Papers No. 5, The Changing Shape of Fixed Income Markets: A Collection of Studies by Central Bank Economists.

He, Zhiguo, and W. Xiong, 2010, "Rollover Risk and Credit Risk", NBER Working Paper w15653

Hoechle, Daniel, 2007, "Robust Standard Errors for Panel Regressions with Cross-Sectional Dependence", *Stata Journal* 7(ii):1-31

Huang, Jing-zhi, and M. Huang, 2002, "How Much of the Corporate-Treasury Yield Spread is Due to Credit Risk?", Stanford University, mimeo

Jensen, Michael C., 1986, "Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers", *American Economic Review* 76(2):323-329

Jensen, Michael C., and W. H. Meckling, 1976, "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure", *Journal of Financial Economics* 3(4):305-360

Jin, Li, R. C. Merton, and Z. Bodie, "Do a firm's equity returns reflect the risk of its pension plan?", *Journal of Financial Economics* 81:1–26

Kang, Johnny, and C. E. Pflueger, 2011, "Appendix to Inflation Risk in Corporate Bonds", available at http://www.people.fas.harvard.edu/~pflueger/papers.html

Kiyotaki, Nobuhiro, and J. Moore, 1997, "Credit Cycles", *Journal of Political Economy* 105(2):211-248

Koijen, Ralph S.J., O. Van Hemert, and S. Van Nieuwerburgh, 2009, "Mortgage Timing", *Journal of Financial Economics* 3:292–324

Leary, Mark T., and M. R. Roberts, 2005, "Do Firms Rebalance Their Capital Structures?", *Journal of Finance* 60(6):2575–2619

Leland, Mark T., 1994, "Corporate Debt Value, Bond Covenants and Optimal Capital Structure", *Journal of Finance* 49(4):1213-1252

Leland, Hayne E., and K. B. Toft, 1996, "Optimal Capital Structure, Endogenous Bankruptcy, and the Term Structure of Credit Spreads", *Journal of Finance* 51(3):987-1019

LeRoy, Stephen F., and R. Porter, 1981, "The Present Value Relation: Tests Based on Variance Bounds", *Econometrica* 49:555-577

Li, Lingfeng, 2002, "Macroeconomic Factors and the Correlation of Stock and Bond Returns", Yale ICF Working Paper No. 02-46

Longstaff, Francis A., and E. S. Schwartz, 1995, "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt", *Journal of Finance* 50(3):789-819

Newey, Whitney K., and K. D. West, 1987, "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica* 55: 703–708

Maynard, Micheline, "United Air Wins Right to Default on Its Employee Pension Plans", The New York Times, May 11, 2005

Mehra, Rajnish, and E. C. Prescott, 1985, "The Equity Premium: A Puzzle", *Journal of Monetary Economics* 15:145-161

Merton, Robert C., 1974, "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates", *Journal of Finance* 29(1):449-470

Moody's, 2011, Corporate Default and Recovery Rates, 1920-2010. Moody's Investor Service, Global Credit Research.

Myers, Stewart C., 1977, "Determinants of Corporate Borrowing", *Journal of Financial Economics* 5(2):147-175

Myers, Stewart C., and N. S. Majluf, 1984, "Corporate Financing and Investment Decisions when Firms Have Information that Investors Do Not Have", *Journal of Financial Economics* 13(2):187-221

Patton, Andrew J., and A. Timmermann, 2010, "Why Do Forecasters Disagree? Lessons from the Term structure of Cross-Sectional Dispersion", *Journal of Monetary Economics* 57(7):803-820

Philippon, Thomas, 2009, "The Bond Market's q", *Quarterly Journal of Economics* 124(3):1011-1056

Pflueger, Carolin E., and L. M. Viceira, 2011, "An Empirical Decomposition of Risk and Liquidity in Nominal and Inflation-Indexed Government Bonds", NBER Working Paper w16892

Polk, Christopher, and P. Sapienza, 2009, "The Stock Market and Corporate Investment: A Test of Catering Theory", *Review of Financial Studies* 22(1):187-217

Reserve Bank of Australia Bulletin, June 2001, "Corporate Bond Yields in Australia"

Shiller, Robert J., 1971, "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?", *American Economic Review* 71:421-436

Shimko, David C., N. Tejima, and D. R. van Deventer, 1993 "The Pricing of Risky Debt when Interest Rates are Stochastic", *Journal of Fixed Income* 3(2):58-65

Stock, James H., and M. Watson, 2007, "Why has US Inflation Become Harder to Forecast?", *Journal of Money Credit and Banking* 39(1):3-33

Stock, James H., and M. Watson, 2008, "Phillips Curve Inflation Forecasts", NBER Working Paper w14322

Viceira, Luis M., 2010, "Bond Risk, Bond Return Volatility, and the Term Structure of Interest Rates", *International Journal of Forecasting*, forthcoming

Welch, Ivo, 2004, "Capital Structure and Stock Returns", *Journal of Political Economy* 112(1):106-130

Wright, Jonathan H., 2010, "Term Premia and Inflation Uncertainty: Empirical Evidence from an International Panel Dataset", *American Economic Review* 101:1514-1534

Zarnowitz, Victor, and L.A. Lambros, 1987, "Consensus and Uncertainty in Economic Prediction", *Journal of Political Economy* 95(3):591-621

Figure 1: Credit Spreads and Inflation Uncertainty in the U.S.

Quarterly BAA minus AAA corporate bond spread from Moody's. Inflation uncertainty is the smoothed difference between the 75th percentile and the 25th percentile of one quarter ahead GDP Price Index inflation forecasts from the Survey of Professional Forecasters.

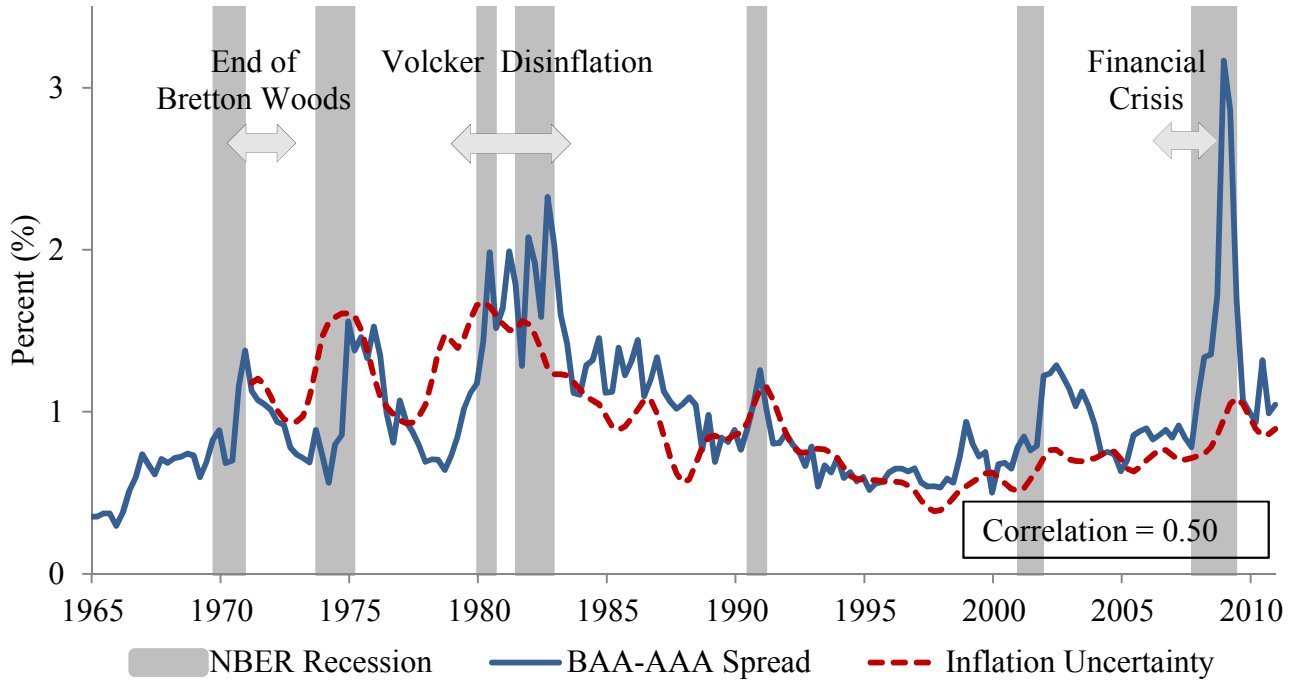


Figure 2: Contingent Claim Payoff Profiles

Expected real payoffs of nominal default-free and nominal corporate bonds. Expected real payoffs are conditional on the underlying real asset value and averaged over inflation realizations. Inflation volatility is set to zero in Panel A. Inflation is uncorrelated with real asset values in Panel B. Inflation shocks are perfectly positively correlated with asset values in Panel C and perfectly negatively correlated with asset values in Panel D.

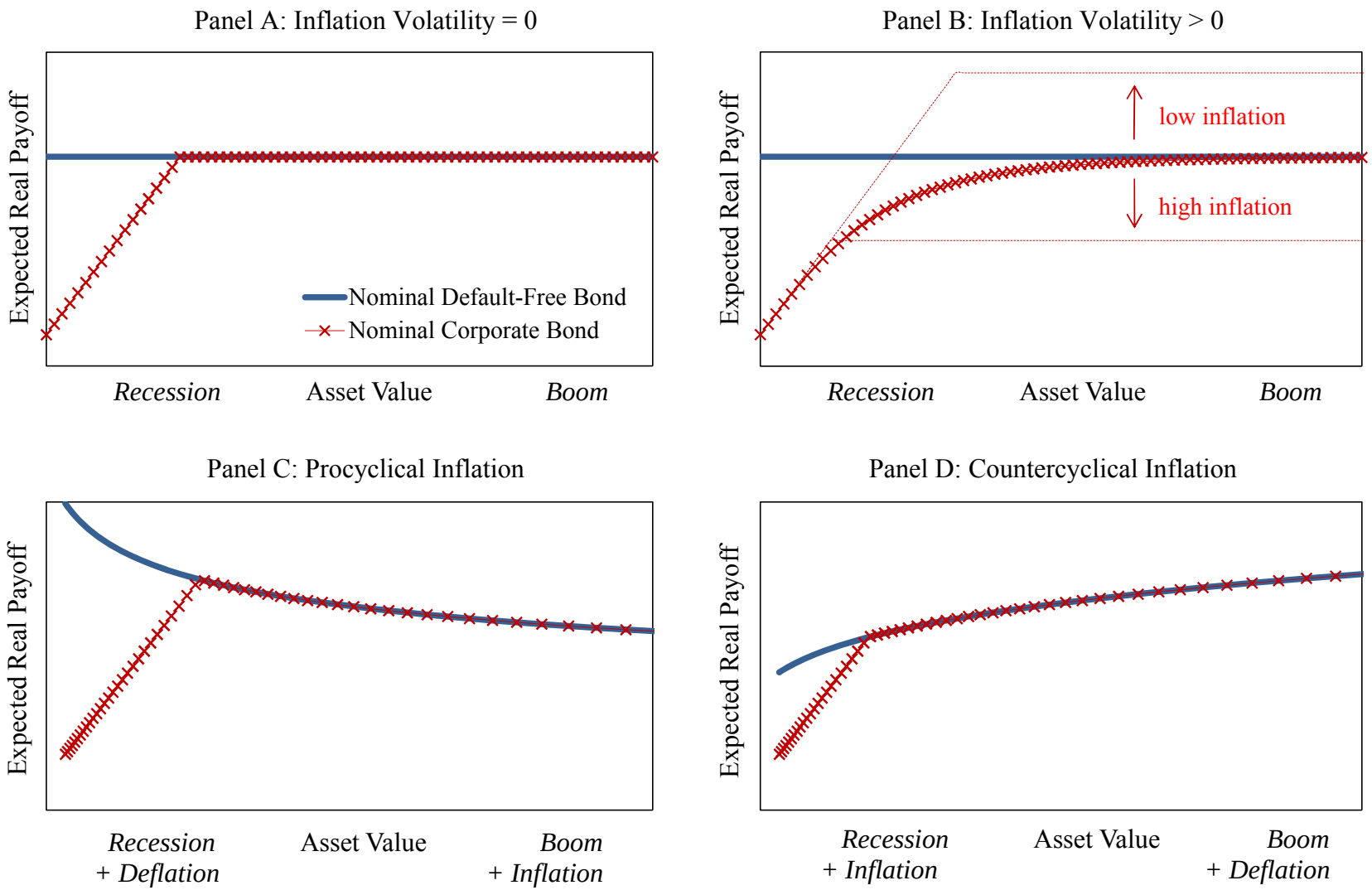


Figure 3: Timeline of Firm Cohort t

t	t + 1	t + 2
· Choose nominal debt $B^{\$}_{t}$ · Purchase capital K^{y}_{t+1} · New credit spreads	· Real aggregate TFP shock ε^{TFP}_{t+1} · Nominal aggregate shock ε^{π}_{t+1} · Seasoned credit spreads	· Real and nominal aggregate shocks ε^{TFP}_{t+2}, ε^{π}_{t+2} · Real idiosyncratic shocks $a^{i,id}_{t+2}$ · Default decision

Figure 4: Model Credit Spreads, Stock Returns and Inflation Shocks

Simulated average credit spreads and default rates versus stock returns and inflation shocks. In Panel A, inflation volatility switches between 0% p.a. and 2% p.a., and inflation is uncorrelated with TFP shocks. In Panel B, inflation volatility is constant at 1% p.a., and the inflation-TFP correlation switches between -0.6 and 0.6.

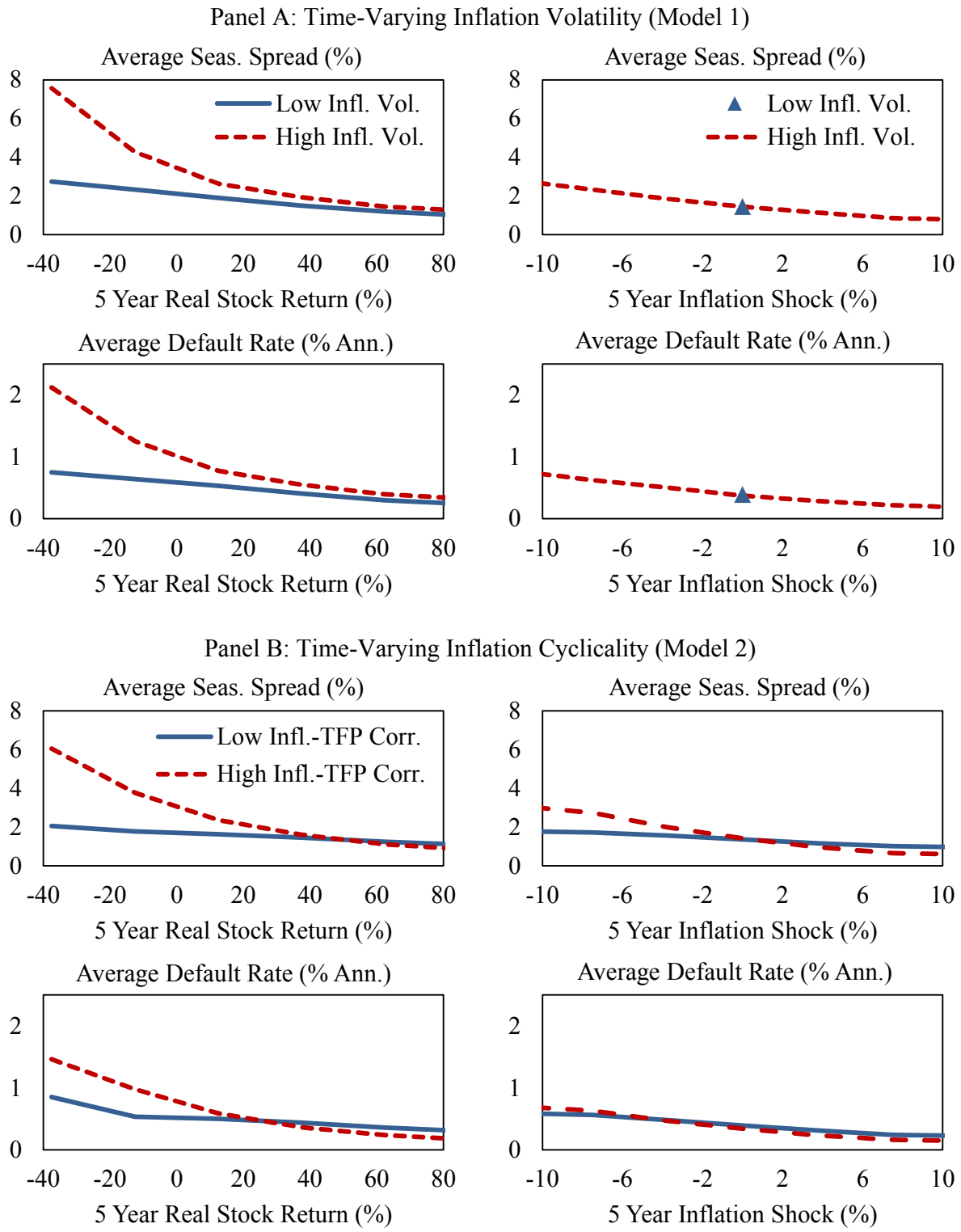
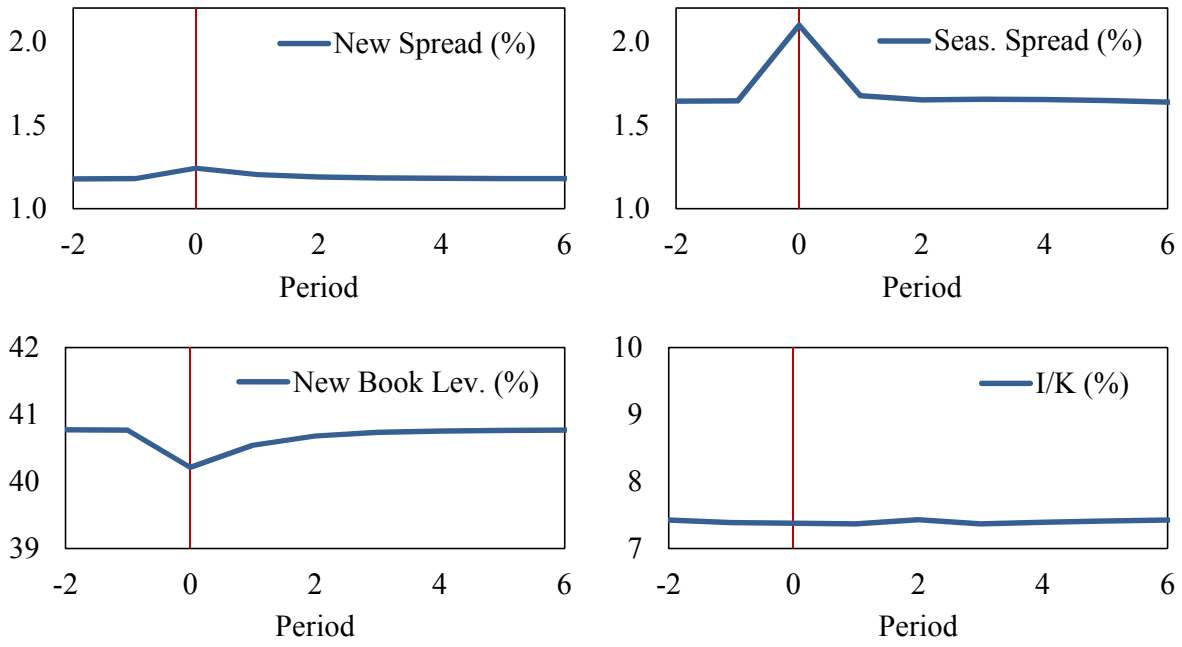


Figure 5: Model Impulse Responses

In period 0 of Panel A, the inflation volatility jumps from its stochastic steady state to 2% p.a. and mean reverts in subsequent periods. In Panel A, the inflation-TFP correlation is constant at zero. In period 0 of Panel B, the inflation-TFP correlation jumps from its stochastic steady state to 0.6. In Panel B, inflation volatility is constant at 1% p.a. Impulse responses are averaged over 62,500 simulations.

Panel A: Inflation Volatility Shock (Model 1)



Panel B: Inflation-TFP Correlation Shock (Model 2)

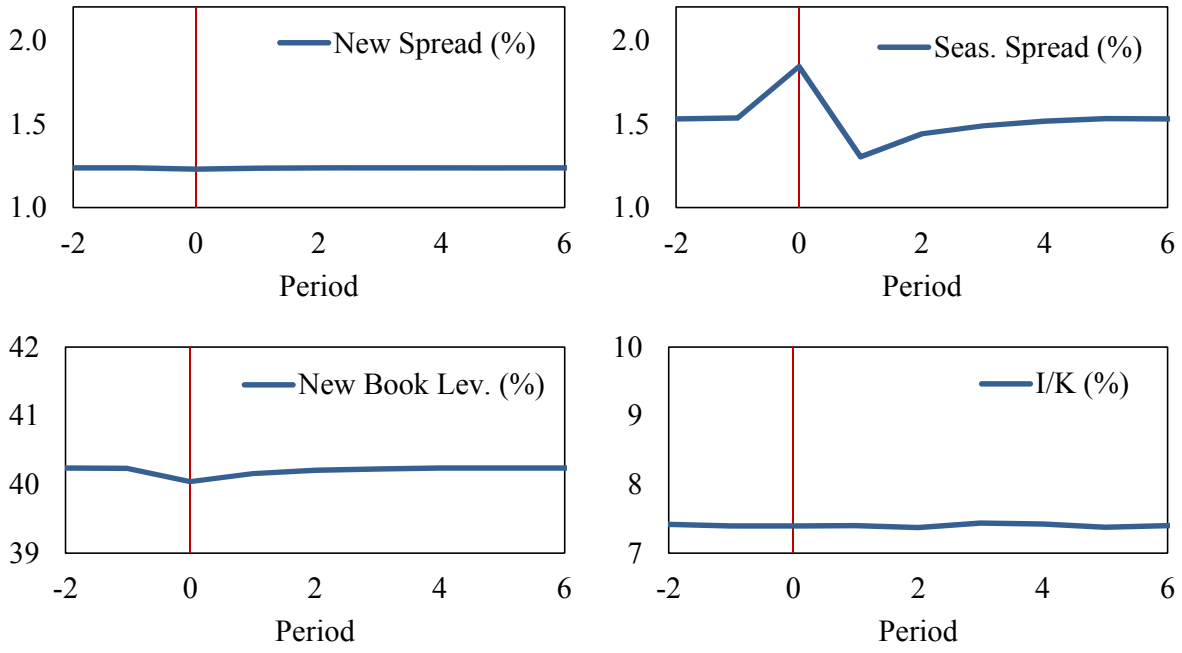


Figure 6: International Credit Spreads and Inflation Volatility

Quarterly credit spreads (bold) and inflation volatility (dashed) for Australia, Canada, Germany, Japan, the U.K., and the U.S. Credit spreads are investment grade corporate bond index yields in excess of duration-matched nominal government bond yields, except for the U.S. which is the Moody's BAA minus AAA spread. All yields are continuously compounded. Inflation volatility is computed using a 3 year backward-looking window of quarterly inflation surprises. Both variables are shown in percentage units.

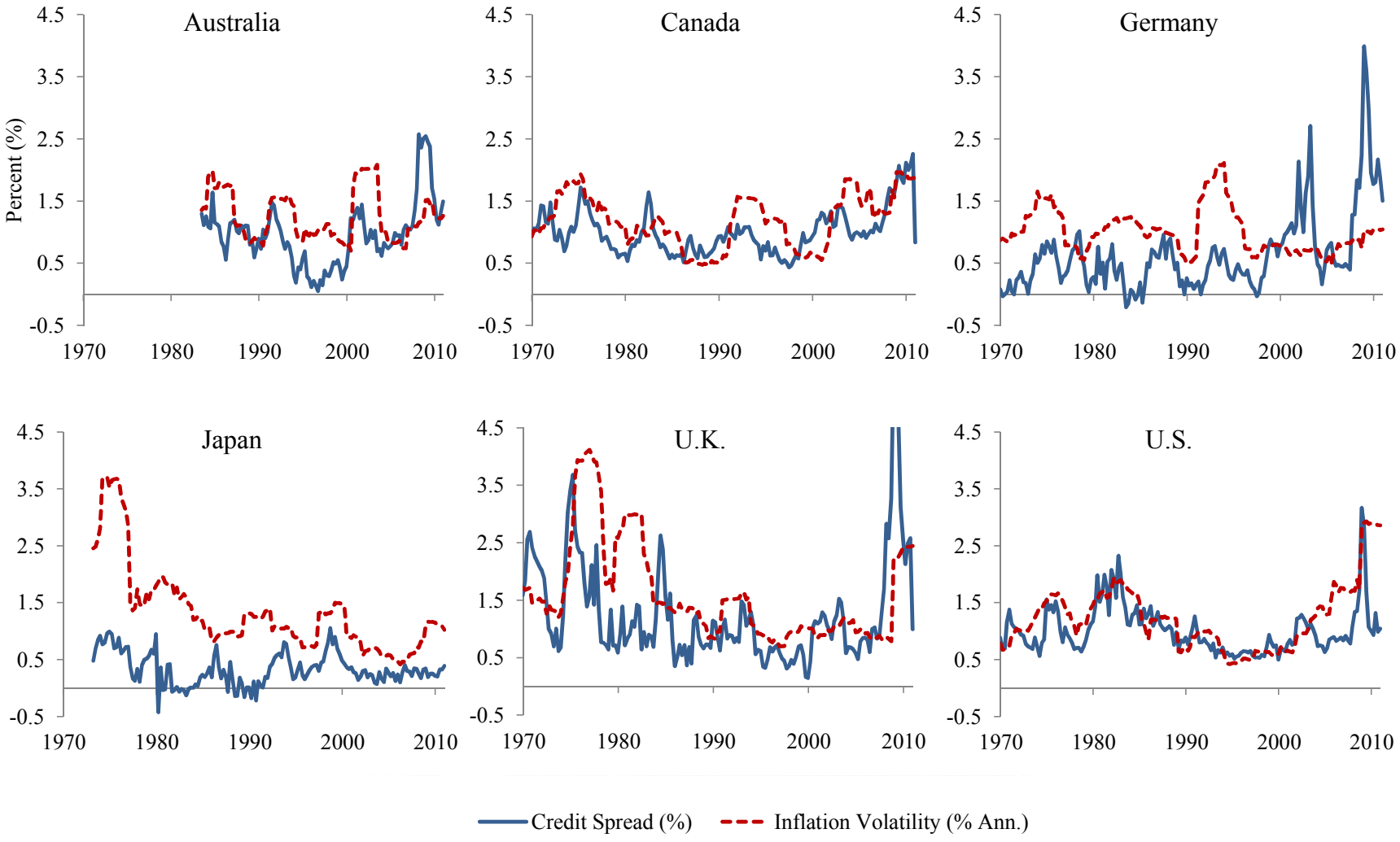


Figure 7: International Credit Spreads and Inflation-Stock Correlation

Quarterly credit spreads (bold) and inflation-stock correlation (dashed) for Australia, Canada, Germany, Japan, the U.K., and the U.S. Credit spreads are investment grade corporate bond index yields in excess of duration-matched nominal government bond yields, except for the U.S. which is the Moody's BAA minus AAA spread. All yields are continuously compounded. The inflation-stock correlation is computed using a 3-year backward-looking window of quarterly inflation surprises and stock returns as described in Table IV.

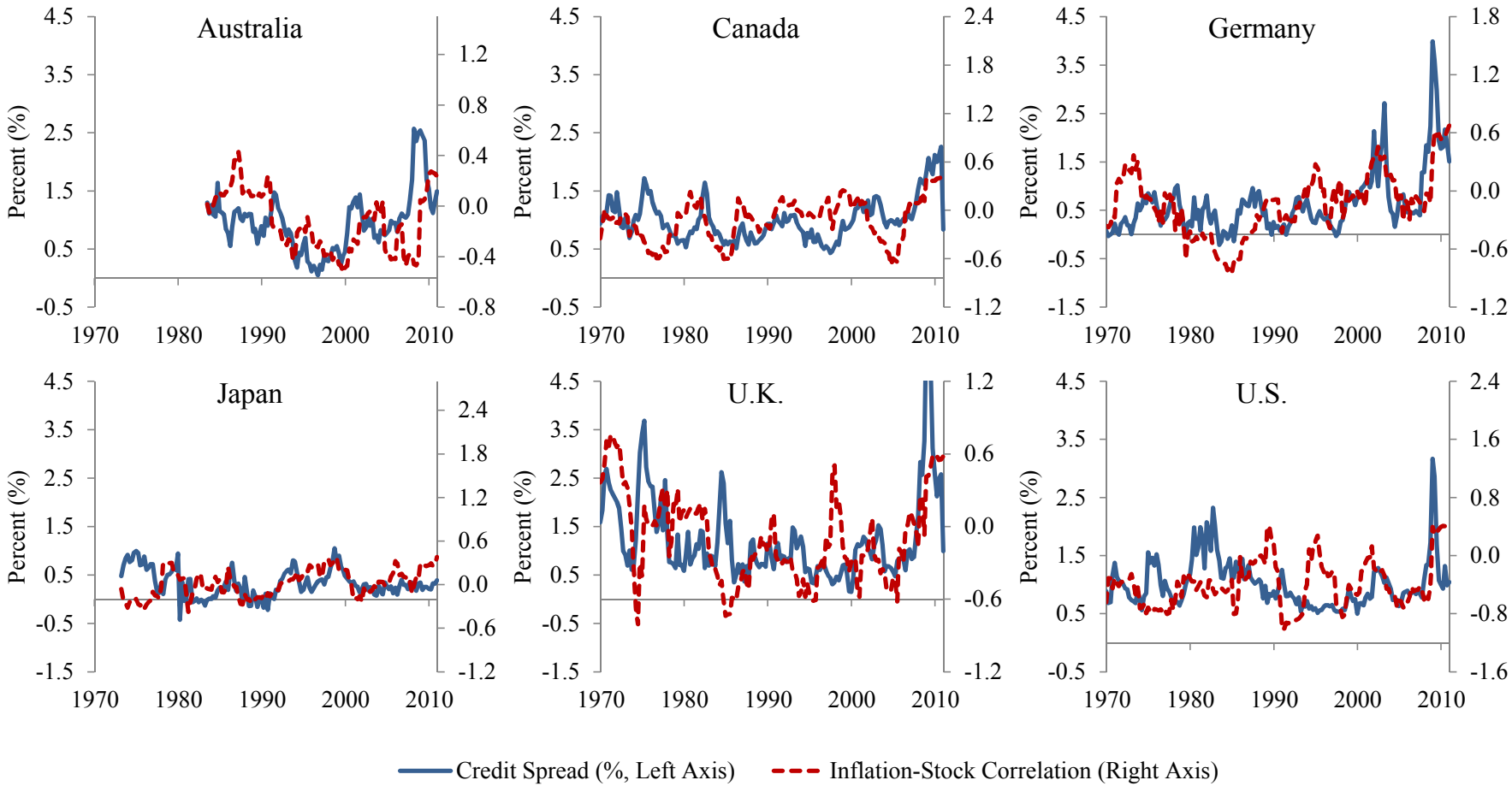


Figure 8: Empirical Credit Spreads, Stock Returns and Inflation Shocks

Empirical credit spreads versus real stock returns and inflation shocks averaged across Australia, Canada, Germany, Japan, the U.K., and the U.S. for different inflation risk regimes. In Panel A, credit spreads across countries are averaged for both low and high inflation volatility regimes within quintiles of 3 year real stock returns and 3 year inflation shocks. In Panel B, credit spreads across countries are averaged for both low and high inflation-stock correlation regimes within quintiles of 3 year real stock returns and 3 year inflation shocks. Low and high inflation risk regimes are defined relative to median values within each country. Credit spreads are normalized to zero in the middle quintile for both inflation risk regimes. A horizontal line is shown at 0 bps.

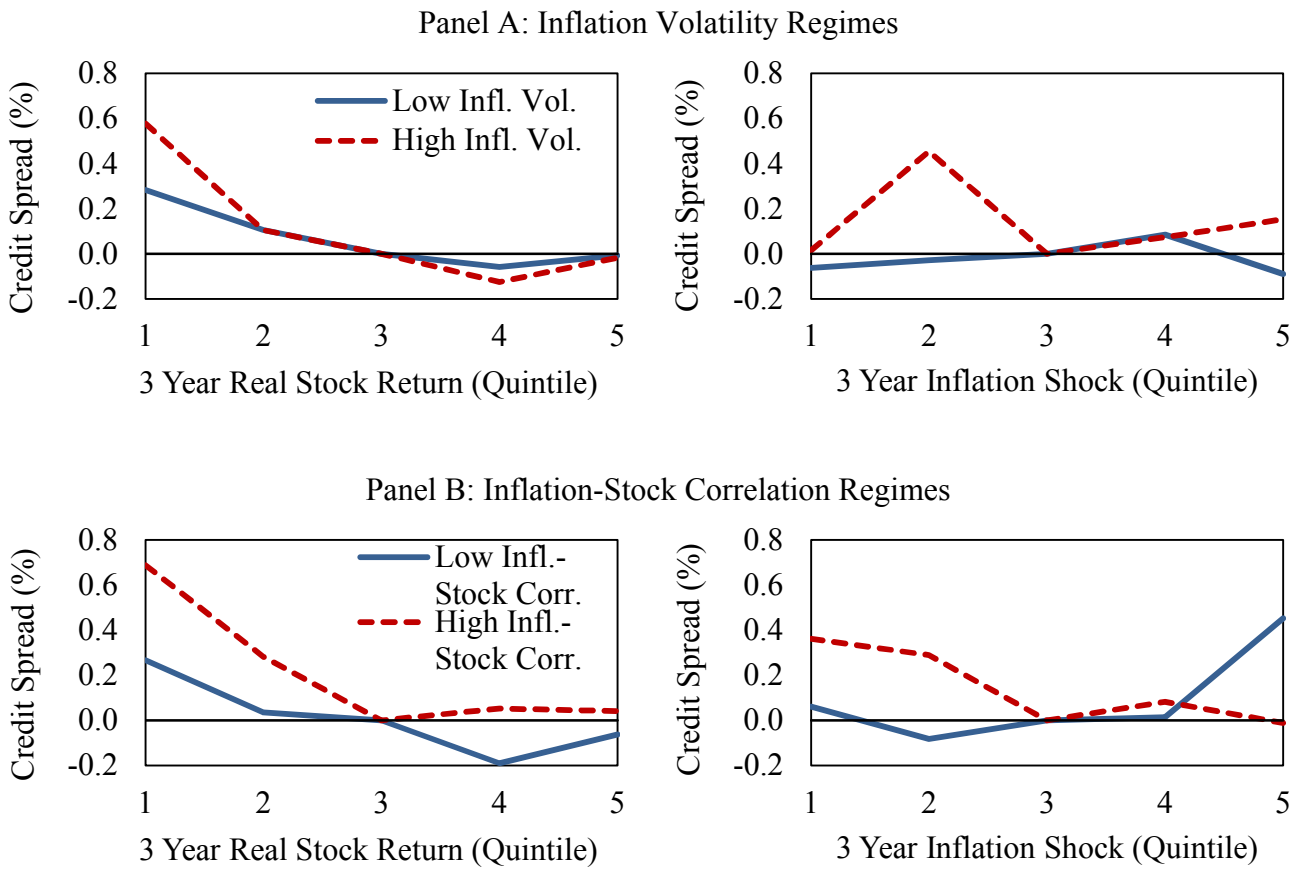
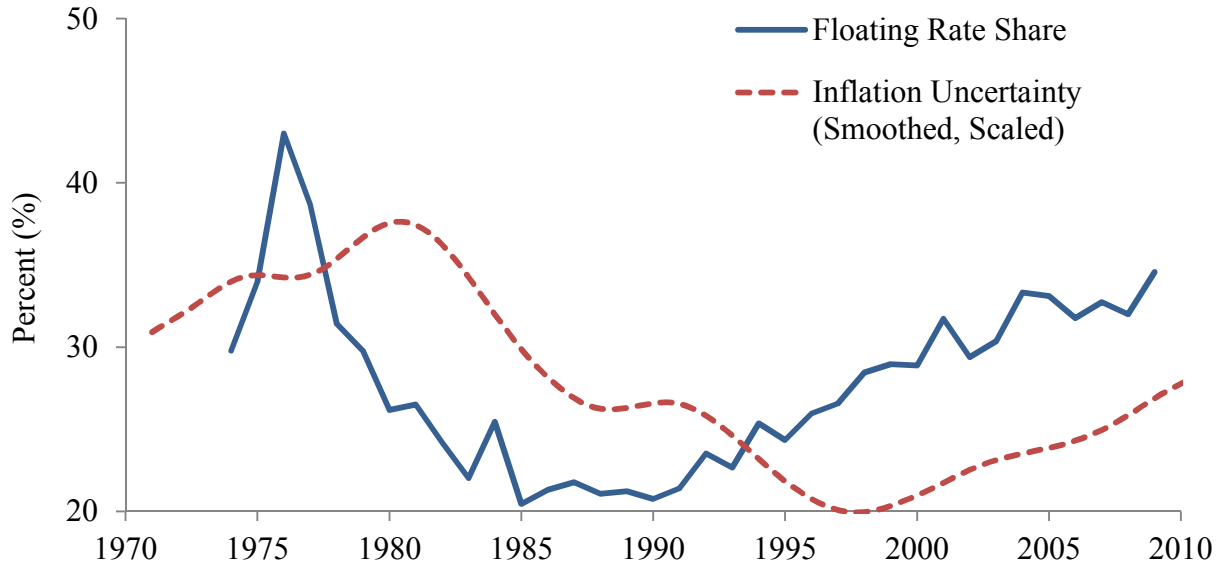


Figure 9: Capital Structure and Inflation Uncertainty in the U.S.

Floating rate debt as a share of long-term debt aggregated over all non-financial firms from Compustat (1974-2009). Missing floating rate values are set to zero. Equity share (1971-2007) in new issues is from Baker and Wurgler (2000). Inflation uncertainty is the difference between the 75th percentile and the 25th percentile of one quarter ahead GDP Price Index inflation forecasts from the Survey of Professional Forecasters. Inflation uncertainty is Hodrick Prescott filtered with smoothing parameter 1,600 and scaled to have the same mean and standard deviation as the floating rate share (or equity share).



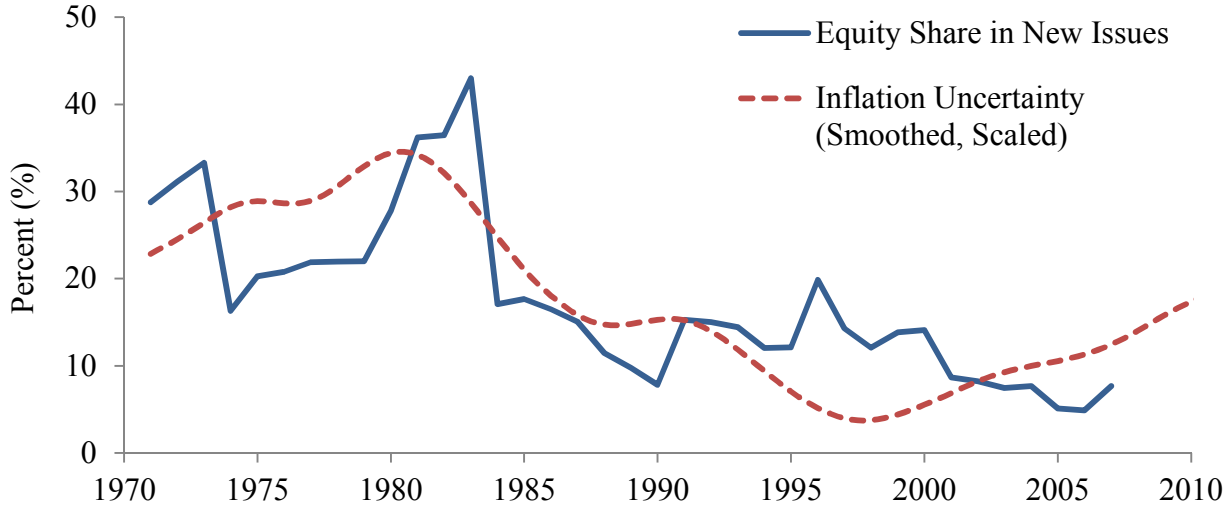


Table I: Model Parameters

* denotes parameters reported in per annum units. Annualized inflation volatility is the standard deviation of a one year inflation shock. Given that the state at time t is X, p(X→X) denotes the probability that the state at time t+1 is also X.

General Parameters		
Period Length		5 years
Discount Rate	β	3%*
Risk Aversion	γ	10
Capital Share	α	0.33
Depreciation	δ	8%*
Trend Growth	μ	2.8%*
Volatility of TFP Shock	σ	26%*
Recovery Rate	θ	0.40
Tax Benefit of Debt	χ	1.40
Idiosyncratic Volatility	σ^{id}	17%*

Model 1: Time-Varying Inflation Volatility		
Inflation-TFP Correlation	ρ^{π}	0.00
High Inflation Volatility	$\sigma^{\pi,H}$	2%*
Low Inflation Volatility	$\sigma^{\pi,L}$	0%*
Persistence of $\sigma^{\pi,H}$	$p(\sigma^{\pi,H}\rightarrow\sigma^{\pi,H})$	0.60
Persistence of $\sigma^{\pi,L}$	$p(\sigma^{\pi,L}\rightarrow\sigma^{\pi,L})$	0.80

Model 2: Time-Varying Inflation TFP Correlation		
Inflation Volatility	σ^{π}	1%*
High Inflation-TFP Correlation	$\rho^{\pi,H}$	0.60
Low Inflation-TFP Correlation	$\rho^{\pi,L}$	-0.60
Persistence of $\rho^{\pi,H}$	$p(\rho^{\pi,H}\rightarrow\rho^{\pi,H})$	0.70
Persistence of $\rho^{\pi,L}$	$p(\rho^{\pi,L}\rightarrow\rho^{\pi,L})$	0.70

Table II: Empirical and Model Moments

Empirical moments correspond to U.S. data from 1970 to 2009. Equity volatility is the standard deviation of 10 year log nominal equity returns minus the 10 year log nominal government yield. Firm volatility is the standard deviation of idiosyncratic 10 year log nominal stock returns of non-defaulted firms. The equity premium is the average 10 year log nominal equity return minus the 10 year log nominal government yield (adjusted for Jensen's Inequality). Seasoned credit spreads are computed as the Moody's BAA minus AAA corporate bond index yield. The historical default probability for 10 year investment grade bonds is from Almeida and Philippon (2007) for the U.S. between 1970 and 2001. Leverage is the aggregate book leverage ratio computed as long-term debt plus short-term debt divided by total assets from Compustat.

	Empirical U.S. 1970-2009	Model 1 Time-Varying σ^{π}	Model 2 Time-Varying ρ^{π}
Equity Volatility (% Ann.)	18.4%	18.5%	18.0%
Firm Volatility (% Ann.)	47.2%	29.3%	29.0%
Equity Premium (% Ann.)	2.90%	7.82%	7.83%
$y_t^{gov,10} - \pi_t$	2.50%	2.80%	2.72%
$y_t^{gov,10} - y_t^{gov,5}$	0.25%	1.16%	1.08%
New Credit Spread		1.18%	1.23%
Seasoned Credit Spread	1.01%	1.64%	1.53%
Default Probability	0.52%	0.45%	0.40%
Leverage	25%	41%	40%

Table III: Model Credit Spread Regressions

Equity returns are one-period log seasoned equity returns. Inflation shocks are one-period changes in log inflation expectations. Equity return volatility is the standard deviation of log real returns on seasoned equity. The inflation-stock correlation is the correlation between log seasoned equity returns and shocks to log inflation expectations. The dividend-price ratio is the expected return on seasoned equity. In Panel A, inflation volatility switches between 0% p.a. and 2% p.a., and the inflation-TFP correlation is zero. In Panel B, inflation volatility is constant at 1% p.a., and the inflation-TFP correlation switches between -0.6 and 0.6.

Panel A: Time-Varying Inflation Volatility (Model 1)

Seas. Credit Spread (%)	(1)	(2)	(3)	(4)
Equity Return (% Ann.)	-0.02	-0.01	-0.02	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)
Inflation Shock (% Ann.)		-0.11	-0.10	-0.11
		(0.03)	(0.03)	(0.03)
Equity Volatility (% Ann.)			0.08	0.02
			(0.07)	(0.07)
Dividend-Price Ratio (% Ann.)			0.17	0.29
			(0.15)	(0.14)
Inflation Volatility (% Ann.)				0.26
				(0.11)
Constant	2.39	2.26	1.06	1.29
	(0.29)	(0.14)	(0.49)	(0.50)
R^2	0.27	0.76	0.83	0.86

Panel B: Time-Varying Inflation-TFP Correlation (Model 2)

Seas. Credit Spread (%)	(1)	(2)	(3)	(4)
Equity Return (% Ann.)	-0.02	-0.01	-0.02	-0.02
	(0.00)	(0.00)	(0.00)	(0.00)
Inflation Shock (% Ann.)		-0.09	-0.09	-0.09
		0.01	(0.01)	(0.01)
Equity Volatility (% Ann.)			0.11	0.05
			(0.04)	(0.06)
Dividend-Price Ratio (% Ann.)			0.12	0.24
			(0.11)	(0.14)
Inflation-Stock Correlation				0.20
				(0.13)
Constant	2.25	2.18	0.83	1.22
	(0.18)	(0.12)	(0.31)	(0.41)
R^2	0.31	0.72	0.80	0.81

Table IV: Summary Statistics

Credit spreads are computed as yields on investment grade corporate bond indices in excess of duration-matched nominal government bond yields, both continuously compounded. For the U.S. we show the Moody's BAA over AAA spread. Inflation volatility is the annualized standard deviation of three years of quarterly inflation innovations. The inflation-stock correlation is computed using three years of quarterly inflation and stock return innovations. Inflation innovations are residuals from regressing quarterly inflation onto its own four lags and seasonal dummies. Stock return innovations are residuals from regressing the quarterly real stock return onto its own first lag. Equity volatility is the annualized standard deviation of quarterly real stock return innovations. Dividend-price ratios are from MSCI. Idiosyncratic volatility is computed using one quarter of daily individual stock returns and GIC sector classifications and follows the methodology of Campbell et. al. (2001). Compustat equal-weighted market leverage is computed as total debt divided by total debt plus market value of equity. We approximate daily or weekly government bond log returns using changes in continuously compounded yields. Government bond volatility is the annualized standard deviation of daily or weekly nominal government bond returns over the past quarter divided by bond duration. The bond-stock correlation is the negative of the correlation between daily or weekly government bond returns and stock returns over the past quarter. All volatilities are standard deviations.

Panel A: Long Sample Period Variables

		Australia	Canada	Germany	Japan	U.K.	U.S.
Start Date		1989.Q1	1969.Q4	1969.Q4	1973.Q1	1969.Q4	1969.Q4
End Date		2010.Q2	2010.Q4	2010.Q4	2010.Q2	2010.Q4	2010.Q4
Credit Spread (%)	mean	0.93	1.01	0.63	0.33	1.26	1.01
	std	0.57	0.36	0.65	0.28	0.91	0.42
	min	0.05	0.44	-0.21	-0.42	0.15	0.50
	max	2.57	2.26	3.99	1.06	5.87	3.17
Inflation Vol. (%, Ann.)	mean	1.21	1.19	1.00	1.33	1.61	1.22
	std	0.39	0.43	0.36	0.77	0.87	0.58
	min	0.70	0.45	0.48	0.42	0.70	0.42
	max	2.09	1.97	2.11	3.72	4.12	2.93
Inflation-Stock Correl.	mean	-0.18	-0.04	-0.15	0.00	-0.11	-0.27
	std	0.28	0.34	0.31	0.27	0.31	0.34
	min	-0.61	-0.77	-0.83	-0.56	-0.70	-0.90
	max	0.43	0.66	0.63	0.51	0.59	0.55
Equity Vol. (%, Ann.)	mean	14.93	16.16	19.42	19.61	18.52	15.99
	std	7.53	5.50	7.58	6.32	8.03	5.32
	min	6.72	7.87	7.80	5.51	5.85	5.66
	max	37.15	27.40	40.20	36.04	44.41	27.99
Div.-Price Ratio (%, Ann.)	mean	3.85	2.96	3.39	1.30	4.26	3.12
	std	0.87	1.00	1.12	0.66	1.24	1.32
	min	2.82	0.99	1.67	0.43	2.11	1.14
	max	6.95	5.67	6.20	2.86	10.46	6.14

Panel B: Short Sample Period Variables

		Australia	Canada	Germany	Japan	U.K.	U.S.
Start Date		1989.Q1	1989.Q1	1990.Q1	1989.Q1	1989.Q1	1989.Q1
End Date		2010.Q2	2010.Q2	2010.Q2	2010.Q2	2010.Q2	2010.Q2
Bond Vol. (%, Ann.)	mean	0.80	0.66	0.54	0.49	0.66	0.72
	std	0.22	0.18	0.17	0.20	0.21	0.22
	min	0.42	0.28	0.28	0.19	0.30	0.40
	max	1.62	1.32	0.97	1.18	1.42	1.54
Bond-Stock Correl.	mean	-0.04	0.00	-0.09	0.11	-0.03	-0.04
	std	0.35	0.32	0.39	0.31	0.41	0.42
	min	-0.65	-0.62	-0.84	-0.69	-0.80	-0.77
	max	0.78	0.68	0.72	0.64	0.72	0.77
Idiosync. Vol. (%, Ann.)	mean	22.23	26.80	26.24	31.28	18.28	25.95
	std	12.03	5.20	9.02	7.46	12.36	7.61
	min	5.02	19.69	15.91	19.08	4.04	16.26
	max	57.68	54.67	54.95	58.00	52.75	50.39
Leverage (%)	mean	17.89	22.58	41.23	34.28	21.45	23.11
	std	6.25	6.11	13.51	6.69	3.94	3.91
	min	8.69	12.70	21.72	19.59	13.84	16.84
	max	40.76	35.53	63.12	47.40	31.67	33.67

Table V: Credit Spreads and Inflation Risk (1969.Q4-2010.Q4)

Panel A includes the following countries: Canada, Germany, Japan, the U.K., and the U.S. Panel B includes the U.S. only. Panel A reports Driscoll and Kraay (1998) standard errors accounting for cross-country correlation and 16 lags. We estimate time fixed effects by time demeaning all left-hand side and right-hand side variables and again report Driscoll and Kraay (1998) standard errors with 16 lags. The residual R^2 reflects explanatory power in excess of fixed effects. Panel B reports Newey-West standard errors with 16 lags in parentheses. Controls include quarterly and three year inflation innovations, stock returns, GDP growth, and three year change in unemployment. Japan data starts in 1973.Q1. Variables are constructed as described in Table IV. * and ** denote significance at the 1% and 5% levels, respectively.

Panel A: International

Credit Spread (%)	(1)	(2)	(3)	(4)	(5)	(6)
Equity Volatility (% Ann.)	0.02**	0.02*	0.02*	0.02*	0.02*	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Dividend-Price Ratio (% Ann.)	0.11**	0.07*	0.10*	0.17**	0.16*	0.12**
	(0.03)	(0.03)	(0.04)	(0.04)	(0.08)	(0.04)
Inflation Volatility (% Ann.)		0.22**	0.19**	0.32**	0.18**	0.24**
		(0.07)	(0.06)	(0.08)	(0.06)	(0.06)
Inflation-Stock Correlation			0.60**	0.41**	0.42**	0.30*
			(0.20)	(0.11)	(0.11)	(0.12)
Residual R^2	0.12	0.17	0.27	0.37	0.19	0.35
Controls	No	No	No	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	Yes	No
Excluding 2008-2010	No	No	No	No	No	Yes

Panel B: U.S.

Credit Spread (%)	(1)	(2)	(3)	(4)	(5)
Equity Volatility (% Ann.)	0.01	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Dividend-Price Ratio (% Ann.)	0.14**	0.10*	0.11**	0.06	0.08*
	(0.05)	(0.04)	(0.04)	(0.03)	(0.04)
Inflation Volatility (% Ann.)		0.39**	0.38**	0.32**	0.38**
		(0.08)	(0.08)	(0.05)	(0.08)
Inflation-Stock Correlation			0.11	0.14	0.30*
			(0.10)	(0.08)	(0.13)
R^2	0.22	0.47	0.48	0.66	0.69
Controls	No	No	No	Yes	Yes
Excluding 2008-2010	No	No	No	No	Yes

Table VI: Individual Country Credit Spreads and Inflation Risk (1969.Q4-2010.Q4)

Newey-West standard errors with 16 lags in parentheses. Controls include quarterly and three year inflation innovations, stock returns, GDP growth, and three year change in unemployment. Japan data starts in 1973.Q1. Variables are constructed as described in Table IV. * and ** denote significance at the 1% and 5% levels, respectively.

Credit Spread (%)	Canada	Germany	Japan	U.K.	U.S.
Equity Volatility (% Ann.)	0.02**	0.00	-0.01	0.04	0.00
	(0.00)	(0.01)	(0.01)	(0.02)	(0.01)
Dividend-Price Ratio (% Ann.)	-0.03	0.18**	-0.15**	0.37**	0.06
	(0.04)	(0.06)	(0.05)	(0.14)	(0.03)
Inflation Volatility (% Ann.)	0.45**	0.58**	-0.02	-0.01	0.32**
	(0.09)	(0.14)	(0.17)	(0.22)	(0.05)
Inflation-Stock Correlation	0.49**	0.72**	0.37**	1.19**	0.14
	(0.09)	(0.20)	(0.10)	(0.37)	(0.08)
R^2	0.65	0.73	0.48	0.54	0.66
Controls	Yes	Yes	Yes	Yes	Yes

Table VII: Inflation and Growth Controls (1969.Q4-2010.Q4)

This table reports the coefficient estimates on control variables in Table VA, columns (4) and (6), and Table VB, columns (4) and (5). * and ** denote significance at the 1% and 5% levels, respectively. All variables are as described in Table V.

	International	International	U.S.	U.S.
Credit Spread (%)	(1)	(2)	(3)	(4)
Quarterly Inflation Shock	-0.06*	-0.02	-0.14**	-0.08*
	(0.03)	(0.02)	(0.04)	(0.04)
3 Year Inflation Shock	0.01	0.02	-0.02	-0.00
	(0.01)	(0.01)	(0.02)	(0.02)
Quarterly Real Stock Return	-0.00	0.00	-0.00	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
3 Year Real Stock Return	-0.00	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Quarterly GDP Growth	-0.34	-0.11	-0.59*	-0.34*
	(0.18)	(0.12)	(0.23)	(0.13)
3 Year GDP Growth	-0.06**	-0.05**	0.10*	0.04
	(0.02)	(0.02)	(0.04)	(0.05)
3 Year Change Unemployment	-0.04	-0.01	0.03	0.06*
	(0.03)	(0.02)	(0.02)	(0.03)
Country Fixed Effects	Yes	Yes		
Excluding 2008-2010	No	Yes	No	Yes

Table VIII: Credit Spread Regressions with Additional Controls (1989.Q1-2010.Q4)

Panel A includes the following countries: Australia, Canada, Germany, Japan, the U.K., and the U.S. Panel B includes the U.S. only. Panel A reports Driscoll and Kraay (1998) standard errors accounting for cross-country correlation and 16 lags. We estimate time fixed effects by time-demeaning all left-hand side and right-hand side variables and again report Driscoll and Kraay (1998) standard errors with 16 lags. The residual R^2 reflects explanatory power in excess of fixed effects. Panel B reports Newey-West standard errors with 16 lags in parentheses. Controls include quarterly and three year inflation innovations, stock returns, GDP growth, and three year change in unemployment. Germany data starts in 1990.Q1. Variables are constructed as described in Table IV. * and ** denote significance at the 1% and 5% levels, respectively.

Panel A: International

Credit Spread (%)	(1)	(2)	(3)	(4)	(5)	(6)
Idiosyncratic Volatility (% Ann.)	0.02**	0.02**	0.01*	0.01	0.00	0.01
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Dividend-Price Ratio (% Ann.)	0.36*	0.28*	0.31**	0.28**	0.29**	0.09**
	(0.17)	(0.13)	(0.10)	(0.10)	(0.10)	(0.02)
Leverage (%)	-0.02*	-0.02*	-0.01*	-0.01*	-0.01**	-0.01**
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Inflation Volatility (% Ann.)		0.41**	0.31**	0.31**	0.10	0.13**
		(0.11)	(0.07)	(0.07)	(0.07)	(0.04)
Inflation-Stock Correlation		0.47**	0.30**	0.25**	0.14	0.14**
		(0.08)	(0.04)	(0.05)	(0.07)	(0.04)
Bond Volatility (% Ann.)			0.30	0.25	0.35	-0.03
			(0.16)	(0.16)	(0.21)	(0.04)
Bond-Stock Correlation			0.74**	0.70**	0.43*	0.36**
			(0.16)	(0.19)	(0.19)	(0.06)
Residual R^2	0.27	0.39	0.52	0.54	0.21	0.40
Controls	No	No	No	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No	Yes	No
Excluding 2008-2010	No	No	No	No	No	Yes

Panel B: U.S.

Credit Spread (%)	(1)	(2)	(3)	(4)	(5)
Idiosyncratic Volatility (% Ann.)	0.03	0.02	0.01	0.01	-0.00
	(0.03)	(0.02)	(0.01)	(0.00)	(0.00)
Dividend-Price Ratio (% Ann.)	0.20	0.08	0.10	0.05	-0.07**
	(0.30)	(0.15)	(0.10)	(0.03)	(0.02)
Leverage (%)	-0.01	0.02	0.02	0.02**	0.03**
	(0.05)	(0.02)	(0.02)	(0.01)	(0.01)
Inflation Volatility (% Ann.)		0.51**	0.40**	0.48**	0.30**
		(0.05)	(0.07)	(0.05)	(0.04)
Inflation-Stock Correlation		0.07	-0.03	-0.17	-0.03
		(0.10)	(0.09)	(0.09)	(0.04)
Bond Volatility (% Ann.)			0.53**	0.39**	0.18*
			(0.16)	(0.10)	(0.08)
Bond-Stock Correlation			0.12	0.02	0.03
			(0.06)	(0.06)	(0.02)
R^2	0.17	0.73	0.80	0.90	0.74
Controls	No	No	No	Yes	Yes
Excluding 2008-2010	No	No	No	No	Yes

Table IX: Credit Spread Changes (1969.Q4-2010.Q4)

In Panel A, changes in credit spreads from time t to time t+n are regressed onto changes in explanatory variables from time t to time t+n. In Panel B, changes in credit spreads from time t to time t+n are regressed onto time t explanatory variables. Control variables are the same as in Table V and countries included are: Canada, Germany, Japan, the U.K., and the U.S. In Panel A, for a lag horizon of n quarters control variables include contemporaneous n quarter inflation innovations, n quarter stock returns, n quarter GDP growth and n quarter change in unemployment. For a horizon of n quarters Driscoll and Kraay (1998) standard errors are used with 16+n lags in parentheses. Japan data starts 1973.Q1. The residual R^2 reflects explanatory power in excess of fixed effects. Variables are constructed as described in Table IV. * and ** denote significance at the 5% and 1% levels, respectively.

Panel A: Credit Spread Changes onto Contemporaneous Changes

Δ Credit Spread (%)	(1)	(2)	(3)	(4)
Horizon (Quarters)	1	4	12	20
Δ Equity Volatility (% Ann.)	0.01	0.02*	0.02**	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)
Δ Dividend-Price Ratio (% Ann.)	0.27**	0.38**	0.33**	0.33**
	(0.09)	(0.11)	(0.11)	(0.08)
Δ Inflation Volatility (% Ann.)	0.36*	0.25**	0.23*	0.24**
	(0.15)	(0.08)	(0.09)	(0.06)
Δ Inflation-Stock Correlation	0.17	0.18**	0.28**	0.32**
	(0.09)	(0.07)	(0.11)	(0.05)
Residual R^2	0.17	0.34	0.39	0.42
Controls	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
Time Fixed Effects	No	No	No	No

Panel B: Credit Spread Changes onto Lagged Variables

Δ Credit Spread (%)	(1)	(2)	(3)	(4)
Horizon (Quarters)	1	4	12	20
Lag Equity Volatility (% Ann.)	-0.00*	-0.02**	-0.02**	-0.01
	(0.00)	(0.01)	(0.01)	(0.01)
Lag Dividend-Price Ratio (% Ann.)	-0.02	-0.13**	-0.22**	-0.31**
	(0.02)	(0.04)	(0.06)	(0.05)
Lag Inflation Volatility (% Ann.)	-0.06*	-0.15**	-0.25*	-0.30**
	(0.02)	(0.06)	(0.11)	(0.08)
Lag Inflation-Stock Correlation	-0.08	-0.17	-0.16	-0.39*
	(0.05)	(0.12)	(0.17)	(0.17)
Residual R^2	0.12	0.20	0.25	0.23
Controls	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes

Table X: Leverage and Investment Regressions

Aggregate book leverage from Compustat and Compustat Global is computed by summing book debt across all non-financial firms and dividing by the sum of aggregated total assets. Aggregate investment to capital is computed by summing capital expenditures across all non-financial firms and dividing by aggregated PP&E at the end of the previous year. International regressions include the following countries: Canada, Germany, Japan, the U.K., and the U.S. International data is annual 1994-2009. U.S. data is annual 1970-2009. Driscoll and Kraay (1998) standard errors adjusted for cross-country correlation with 4 lags in parentheses. U.S. regressions report Newey-West standard errors with 4 lags. The residual R^2 reflects explanatory power in excess of fixed effects. Variables are constructed as described in Table IV. * and ** denote significance at the 5% and 1% levels, respectively.

Panel A: Leverage

	(1)	(2)	(3)	(4)
Book Leverage (%)	International 1994-2009		U.S. 1970-2009	
Lag Inflation Volatility (% Ann.)	-2.26**	-2.54**	-3.86**	-3.04**
	(0.65)	(0.35)	(0.76)	(0.82)
Lag Inflation-Stock Correlation	2.83*	2.26	0.83	1.02
	(1.01)	(1.57)	(1.60)	(1.87)
Lag Change T-bill (%)		-0.27		-0.22
		(0.27)		(0.39)
Residual R^2	0.12	0.18	0.39	0.53
Controls	No	Yes	No	Yes
Country Fixed Effects	Yes	Yes		

Panel B: Investment

	(1)	(2)	(3)	(4)
Investment / Capital (%)	International 1994-2009		U.S. 1970-2009	
Lag Inflation Volatility (% Ann.)	-2.66**	-0.40	-0.43	1.28
	(0.83)	(0.67)	(1.03)	(0.82)
Lag Inflation-Stock Correlation	-1.98**	-1.17	-1.99	-0.11
	(0.59)	(0.65)	(1.64)	(0.87)
Lag Stock Market Q		0.03		6.82**
		(0.61)		(1.13)
Residual R^2	0.28	0.64	0.05	0.76
Controls	No	Yes	No	Yes
Country Fixed Effects	Yes	Yes		