Before the Storm: Firm Policies and Varying Recession Risk*

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March 2024

Abstract

We develop a model with *varying* recession risk and find that the precautionary actions of *large* firms "before the storm" are more sensitive to these changes. Smaller firms take precautionary steps when recession risk is low to protect their attractive investment program. Otherwise, investment decreases cash holdings and increases liquidation risk in a recession. By contrast, large firms postpone precautionary actions since they invest at lower rates, allowing cash to accumulate. However, when a recession becomes more likely, large firms have less time to accumulate cash, so they cannot delay precautionary measures. We provide empirical evidence to support these predictions.

JEL classification: E22, E44, G30.

Keywords: Recession, business cycles, risk management, financial crises, liquidity.

*First draft February 2023. We are grateful to Kerry Back, Aaron Burt, Hui Chen, Juliane Begenau, Alan Crane, João Gomes, Gustavo Grullon, David Hodgson, Amir Kermani, Juliana Salomao, James Weston, Neng Wang, Toni Whited, Hao Xing, Qianqian Yu and seminar and conference participants at the NBER Summer Institute, SFS Cavalcade, the AFA Annual Meeting, 2023 FMA, 36th Australasian Finance and Banking Conference, and 4th Annual Boca Corporate Finance and Governance Conference for their very helpful comments. Ali Kakhbod and Dmitry Livdan are with the Haas School of Business at UC Berkeley. Livdan is also a Research Fellow of the CEPR. A. Max Reppen is with the Questrom School of Business at Boston University. Tarik Umar is with the Jesse H. Jones School of Business at Rice University. Emails: Ali Kakhbod (akakhbod@berkeley.edu), Dmitry Livdan (livdan@haas.berkeley.edu), A. Max Reppen (amreppen@bu.edu), Tarik Umar (tarik.umar@rice.edu).

1 Introduction

A stylized fact is that the risk of the economy transitioning into a recession varies greatly over time. The estimated probability of the U.S. entering a recession within the next year based on the Treasury term spread exhibits a monthly standard deviation of around 11 percentage points. In contrast to this, traditional business cycle models often assume that the risk of transitioning into a recession is constant (e.g., Chen, Xu and Yang, 2021). The major twist of our paper is to incorporate this stylized fact and to *vary* the risk of transitioning into a recession over time. This departure from the literature opens up an entirely new class of theoretical predictions and related empirical tests. Specifically, to mitigate the variable risk of a *future* recession, firms can adjust cash holdings, issuances, investments, and payout policies, among others, during an expansion *before the storm*. Although increases in recession risk predictably lead to more precautionary savings by firms in general, it is unclear which types of firms take certain preemptive actions when the recession risk is low and which types *endogenously delay* certain preemptive actions until the risk of a recession is high. For policymakers, understanding how the risk of recession differentially affects companies is crucial to any evaluation of the costs and benefits of interventions, such as banking regulations, economic stimulus programs, and monetary policy adjustments. Our analysis is especially pertinent, as we find that *large* firms adjust their cash management policies more significantly when the risk of recession increases.

We solve and estimate (using the simulated method of moments) a rich dynamic model of a firm facing time-varying recession risk. To do so, we allow the firm to transition between two expansion regimes in addition to a recession regime. One expansion regime has a low probability of transitioning directly to a recession regime, while the other has a high probability of transitioning to a recession regime. We initially assume that the two expansion regimes are otherwise identical, apart from their different transition rates to the recession regime. In other words, we take advantage of our model to run an experiment where only the recession risk varies, to isolate the sensitivity of a firm's policies to changes in recession risk. We move beyond this initial assumption in our robustness analysis section by allowing other parameters (e.g., the risk-free rate and issuance costs) to vary between the two expansion regimes. In contrast, in the recession regime, firms' cash flows decrease, cash-flow volatility increases, liquidation becomes costlier, and external financing becomes unavailable.

To illustrate the distinct responses of firms to changes in recession risk based on their size—small versus large—we solve a model that is not homothetic in firm size. That is, we model the productive capital stock k and the cash holdings c as separate state variables. When a firm is small, it has better investment opportunities than it does when the same firm is large, because companies operate capital equipment with diminishing returns to scale (e.g., Caballero, 1991). Furthermore, when a firm is small, it faces higher financing costs relative to its size than it does when the firm is large because we model a fixed component of issuance costs that does not scale with the firm's size (e.g., Altınkılıç and Hansen, 2000).

Most interestingly, the model shows that the policies of large firms for issuance, investment, and payouts change more when the risk of recession increases. The rationale is that small firms preemptively respond more to recession risk in the low-risk expansion regime and, therefore, need less adjustment in their policies when entering the high-risk expansion regime. The early response of small firms to recession risk in the low-risk expansion regime is attributed to their attractive investment opportunities and, therefore, more aggressive investment. This higher investment rate reduces their cash holdings and increases their exposure to liquidation risks during a future recession regime. In contrast, larger firms invest at lower rates, increasing their cash over time and reducing their exposure to liquidation risks. However, when a recession becomes imminent as the firm enters the high-risk expansion regime, the larger firms cannot afford to wait to increase their cash holdings to the optimal level and thus lose the option to delay precautionary actions. Consequently, larger firms focus more on managing recession risk by adjusting their issuances, investments, and payouts with changes in regime between low- and high-risk expansions. Therefore, the model predicts a more significant covariance between the policies of larger firms and the risk of recession.

There exists anecdotal support for this interesting finding. The quote below by Jordan Kaplan (CEO of Douglas Emmett, Inc) from the Q1 2023 earnings call highlights that the firm's larger customers exhibit a higher response to the increase in recessionary concerns than the firm's smaller customers. (Additional examples in Table C.1).

> "We continue to have ***strong demand from tenants under 10,000 square feet*** who dominate our markets, but because ***larger tenants*** have become ***more conservative in response to recessionary concerns***, we leased less total square footage."

We also provide empirical evidence that qualitatively validates the significance of the finding. To proxy for recession risk in the data, we use a measure of the probability of a recession *one year in the future* derived from the term spread of U.S. Treasury rates. When comparing a variety of possible predictors of a recession, Estrella and Mishkin (1998) shows that the term spread emerges as the clear individual choice and usually performs better by itself out of sample than in conjunction with other variables. Furthermore, anecdotal evidence suggests that firms are aware of this measure. For example, Jason Serrano (CEO of New York Mortgage Trust, Inc.) mentioned in the Q1 2023 earnings call, "We highlighted the obvious fact that the entire yield curve is inverted, but the not so obvious fact is that the months of inversion are now beyond or very close to when recessions were previously triggered." To focus on how firms respond during expansions to changes in the risk of a future recession, we exclude the National Bureau of Economic Research (NBER) designated recessions.

We find that a firm's preemptive issuances, investments, payouts, and value respond more to changes in recession risk when the firm is larger. In the model, firms issue equity more preemptively when they issue at higher cash levels. In the data, cash holdings immediately prior to issuance are significantly more positively related to recession risk when a firm is larger. Additionally, within a firm, the sensitivity of investment and payouts to recession risk is significantly more negative when the firm is larger. Lastly, within a firm, stock returns are significantly more negatively related to changes in recession risk when the firm is larger.

We perform a series of robustness analyses that relax the assumption that the low- and high-risk expansion regimes are otherwise identical and show that the model predictions are qualitatively the same. Specifically, we model a scenario in which the risk-free rate falls during the recession and the high-risk expansion regime (i.e., when the recession becomes imminent). This captures possible monetary policy responses to the risk of recession. We also allow the issuance costs to increase in the high-risk expansion regime. One may imagine a scenario in which financial institutions and investors, aware of the higher risk of recession, increase the cost of raising capital with the risk of recession. Although the main predictions are the same, we find that lowering the risk-free rate or increasing issuance costs in the high-risk expansion regime decreases the sensitivity of preemptive issuances to recession risk, especially when a firm is larger. Lowering the risk-free rate also reduces the sensitivity of investment to recession risk, especially when a firm is larger.

Lastly, a methodological contribution of our paper useful for other researchers is to present an algorithm to solve the model based on the policy iteration method. We also show that the firm value function is the unique solution of this dynamic programming equation and obtain numerical convergence to the value function by proving a comparison theorem for viscosity solutions to the Hamilton–Jacobi–Bellman (HJB) equation.

Our paper contributes to several major themes in the literature. The key twist in our model, and a point of departure from the existing literature, is the feature of time-varying recession risk. This innovation allows us to examine both theoretically and empirically the sensitivity of firm policies to changes in recession risk and to characterize this sensitivity across the cross-section of firm sizes. A new insight is that the policies of a firm are more sensitive to changes in recession risk when the firm is larger. Thus, our paper advances the theoretical literature on recession risk and firm policies. Chen, Xu and Yang (2021) solves a dynamic capital structure model with static recession risk to link firms' maturity choices to their systematic risk exposure and macroeconomic conditions. In their conclusion, they call for future work like ours that examines how firms adjust cash holdings, real investments, and payouts to prepare for a future recession. Bolton, Chen and Wang (2013) models static stochastic financing risk and liquidity management, predicting that low-cash firms preemptively issue when issuance costs are low.

More broadly, our study contributes to the literature on risk management (e.g., Holmström and Tirole, 2000; Caballero and Krishnamurthy, 2008; Rampini and Viswanathan, 2010; Jermann and Quadrini, 2012). Several studies advocate for the adjustment of corporate policies in accordance with the prevailing economic conditions (e.g., Hackbarth, Miao and Morellec, 2006; Bhamra, Kuehn and Strebulaev, 2010; Begenau and Salomao, 2018). Within this domain, Froot, Scharfstein and Stein (1993) establishes a comprehensive framework to examine corporate risk management strategies. Crouzet and Mehrotra (2020) investigates the correlation between investment fluctuations and firm size throughout economic cycles, attributing observed variations to disparities in financial robustness.

Our paper also adds to the literature on dynamic liquidity management outside of business cycle models: examples include Décamps et al. (2011) who model equity issuance; Anderson and Carverhill (2012) and Abel and Panageas (2023) who illustrate the importance of modeling persistence in cash flows; Dou et al. (2021) who model cash management under the threat of losing key talent; and Dai et al. (2020) who find that diversification potentially diminishes firm value in scenarios of low liquidity. Several papers such as Bolton, Chen and Wang (2011) and Bolton, Wang and Yang (2019) incorporate models of both cash accumulation and investment strategies.

Our work, which explores how companies prepare for potential recessions "before the storm" hits, adds valuable insights to the extensive body of work focused on how firm policies adapt during the turbulence of a recession itself. Garvey (1992) and Haushalter, Klasa and Maxwell (2007) find that, in a crisis, cash allowed firms to maintain or make new investments and emerge stronger from the recession. Duchin, Ozbas and Sensoy (2010) finds that investment declines more in a crisis for firms more dependent on external financing. Kahle and Stulz (2013) document a decrease in cash holdings during the most recent financial crisis followed by an increase in cash holdings to pre-crisis levels. Bliss, Cheng and Denis (2015) finds that firms in recessions cut dividends. Bachmann, Elstner and Sims (2013) conducts an empirical analysis to test the hypotheses presented by Bloom (2009), specifically the notion that significant increases in uncertainty following major economic upheavals lead to immediate declines in industrial output.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 presents the model solution. Section 4 describes the data and presents additional empirical results that qualitatively support the findings of the estimated model. Section 5 considers when the risk-free rate and issuance costs vary with the risk of recession. Finally, Section 6 concludes. The Appendix includes omitted proofs and provides additional empirical work.

2 Model

The model incorporates multiple risks. One source of risk is that the economic regime s varies stochastically between expansions (l), recessions (h), and an intermediate regime (m) in which the economy has expansive properties, but the risk of entering a recession is high. Specifically, we assume that the firm is in only one of these three (observable) regimes of the world. The financing and investment opportunities of a firm may differ between the regimes h, m, and l. This is modeled by a Markov chain s taking the value $s_t \in \{h, m, l\}$ at time t. The transition rate from regime s to s' is denoted $q_{s,s'}$, i.e., $\sum_{s' \neq s} q_{s,s'}$ is the transition rate away from s. Figure 1 illustrates the three regimes and the probability of transitioning between regimes. The thickness of the edges reflects higher transition rates. We discuss how we pick these transition rates in more detail in Section 3.

The second risk in the model is that a firm's cash flows are stochastic and are a function of the size of its productive capital stock and a cash-flow shock. We assume that

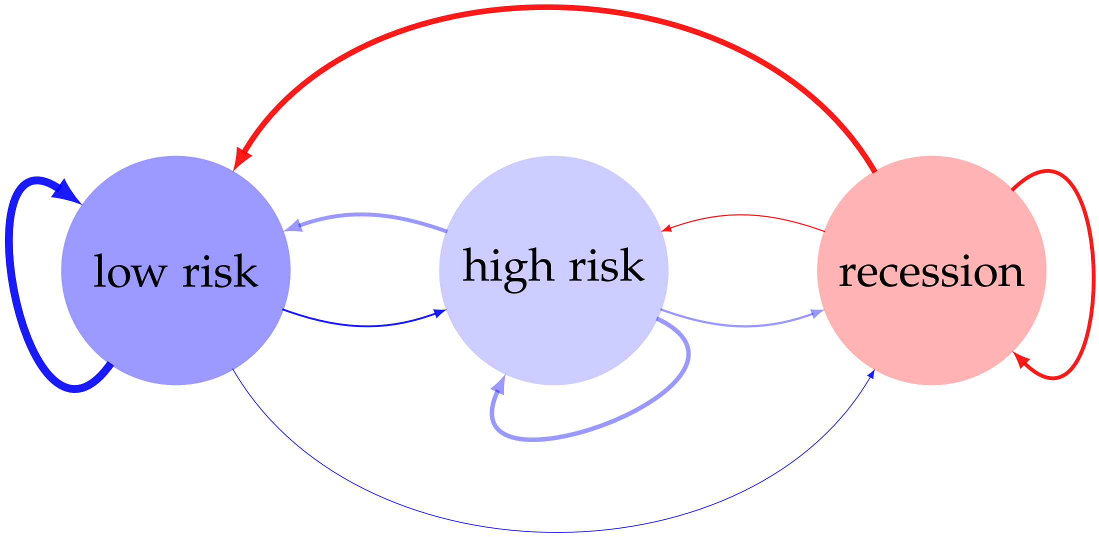


Figure 1: **Transition probabilities diagram**

This figure illustrates the transition probabilities between the low-risk expansion regime (l), high-risk expansion regime (m), and recession regime (h). Edge thickness is adjusted by the corresponding transition probabilities (see Table 1).

the firm's cash flow shock Z_{st} evolves according to

$$dZ_{st} = \mu_s dt + \sigma_s dW_t, \tag{1}$$

where W_t is a one-dimensional Brownian motion and μ_s and σ_s are positive constants that depend on the business cycle, denoted by s. Thus, shocks dZ_{st} are assumed to be i.i.d. with mean $\mu_s dt$ and variance $\sigma_s^2 dt$. The firm's cumulative cash flows Y_{st} follow the dynamics

$$dY_{st} = k_t^{\alpha} dZ_{st}, \tag{2}$$

where k is the size of the firm's capital stock and $\alpha \in (0, 1)$ is a scale parameter following Bertola and Caballero (1994).[1] Therefore, production exhibits decreasing returns to scale.

The productive capital stock depreciates over time at a rate $\delta \geq 0$, and the firm can invest in productive capital. As is standard in capital accumulation models, for an

[1]We estimate $\alpha = 0.84$. Our model can accommodate $\alpha = 1$ or $\alpha > 1$. Evidence of diminishing returns to scale is quite common in the literature. See Caballero (1991), Basu and Fernald (1997), Gomes (2001), and Grullon and Ikenberry (2021).

investment process i, the dynamics of the productive capital stock follows

$$dk_t = \Big(i_t - \delta k_t\Big)dt. \tag{3}$$

We assume that investment is irreversible, i.e., $i \geq 0$, and that the depreciation rate does not depend on the business cycle.

As is also standard in capital accumulation models, the investment is subject to convex adjustment costs:

$$g(k,i) = \frac{\theta}{2}\left(\frac{i}{k}\right)^2 k, \tag{4}$$

where θ is a positive constant that measures the degree to which convexity in adjustment costs matters. These investment costs decrease in firm size at a rate of $1/k_t$, which is another reason why small and large firms differ in the model. Intuitively, it is cheaper for a firm of size $k = 2.0$ to grow by 0.25 units (a 12.5% growth) than for a firm of size $k = 1.25$ (a 20% growth).

The firm determines its investment and cash management strategies, which include when to raise equity and when to pay a dividend as well as the amount of equity to raise and the dividend to pay. The value of the cash reserve follows the dynamics

$$dc_t = (r - \lambda_c)c_t dt + dY_{st} - i_t dt - g(k_t, i_t)dt - dD_t + dI_t. \tag{5}$$

Here, r is the interest rate assumed to be regime and time independent, λ_c is the cash holding cost (liquidity premium) also assumed to be regime and time independent, D_t is the cumulative dividend payout, and I_t is the cumulative equity issuance. Both D_t and I_t are nondecreasing processes. Cash earns a return equal to the risk-free rate (r) net of the carry cost of holding cash (λ_c).[2] Even though cash earns a lower rate of return, the firm holds cash for precautionary reasons to lower expected issuance or liquidation costs if it runs out of liquid funds. The firm manages an optimal cash policy to trade off the risk management benefits of maintaining a cash reserve against the delay in dividend payouts.

[2]If $\lambda_c = 0$, then the firm finds it optimal to hold as much cash as it can (indefinitely postponing the dividend) to prevent costly equity issuance. Equity is still valuable because equity holders could always choose to extract cash via a dividend. The more realistic case is where $\lambda_c > 0$. Cash may earn low returns because interest earned on a firm's cash holdings is taxed at the corporate tax rate, which generally exceeds the personal tax rate (Graham, 2000; Faulkender and Wang, 2006). Agency problems may lower cash returns (Jensen, 1986; Harford, 1999; Dittmar and Shivdasani, 2003; Pinkowitz, Stulz and Williamson, 2006; Dittmar and Mahrt-Smith, 2007; Harford, Mansi and Maxwell, 2008; Caprio, Faccio and McConnell, 2011; Gao, Harford and Li, 2013).

Equity issuance is costly. The issuance spread is the compensation paid to the underwriter for selling a firm's security issue, calculated as a percent of capital raised. We characterize the nominal cost of issuing a lump sum of size I as:

$$\lambda(I, s) = \lambda_{f,s} + \lambda_p \times I. \tag{6}$$

The first term, λ_p, is the fixed spread or the flat percentage fee. Thus, a \$1 billion issue will have higher costs than a \$1 million issue. The second term, $\lambda_{f,s}$, is the fixed component of the issuance costs, which results in the issuance costs scaled by size decreasing in size (Altınkılıç and Hansen, 2000; Benzoni et al., 2022). Together, $\lambda_{f,s}$ and λ_p can be thought of as summarizing the information, incentive, and transaction costs that a firm incurs whenever it chooses to issue external equity. These costs imply that the firm will optimally tap equity markets only intermittently, and, when doing so, it raises funds in lumps, consistent with observed firm behavior. The cost $\lambda_{f,s}$ may be regime-dependent to replicate the fact that issuances are procyclical and largely dry up in recessions (Covas and Den Haan, 2011).

Even if a firm neither pays out cash nor invests, its cash reserve can run out due to negative productivity shocks. When this happens, the firm compares the benefit of equity issuance to continue operations (continuation value) with the value for equity holders after liquidation (liquidation value). If the latter outweighs the former, the firm liquidates. Therefore, $\tau = \inf\{t \geq 0 : c_t < 0\}$ is the firm's liquidation time. When the firm liquidates, its capital stock k_τ is fire sold. The recovery rate ℓ_s depends on the regime of the business cycle and is constant across sizes of productive capital. However, even when the firm's cash reserve is still positive, the firm can still liquidate strategically and pay out its remaining cash.

2.1 The firm's problem

The firm chooses policies for investment i_t, dividend payout D_t, equity issuance I_t, and when to liquidate to maximize the present value of dividend payouts net of equity issuance costs:

$$\sup_{i \geq 0, D, \{\sigma_j, I_j\}} \mathbb{E}_0 \left[\int_0^\tau e^{-rt} dD_t - \sum_j e^{-r\sigma_j} \Big(I_j + \lambda(I_j, s_{\sigma_j}) \Big) + 1_{\{\tau < \infty\}} e^{-r\tau} \ell_{s_\tau} k_\tau \right], \tag{7}$$

where $\{\sigma_j\}$ is a sequence of stopping times when the lump sum of equity of size I_j is issued at each σ_j.[3]

The size of the capital stock k, the value of the cash reserve c, and the regime of the economy s are the three state variables of the problem of the firm. The firm's value function is

$$V(k_t, c_t, s_t) = \sup_{i \geq 0, D, \{\sigma_j, I_j\}} \mathbb{E}_t \Bigg[\int_t^\tau e^{-r(\rho - t)} dD_\rho - \sum_{\sigma_j \geq t} e^{-r(\sigma_j - t)} \Big(I_j + \lambda(I_j, s_{\sigma_j}) \Big) \\ + 1_{\{\tau < \infty\}} e^{-r(\tau - t)} \ell_{s_\tau} k_\tau \Bigg]. \tag{8}$$

The firms have a number of options—control variables—to choose from. Each control variable corresponds to a component of the Hamilton–Jacobi–Bellman (HJB) equation that the value function satisfies (see (12) below).

The option of paying a lump sum of $\Delta D \leq c$ as dividends implies that

$$\underbrace{V(k, c, s)}_{\text{before payout}} \geq \Delta D + \underbrace{V(k, c - \Delta D, s)}_{\text{value after payout}}.$$

satisfied with equality if a lump sum dividend of (at least) size ΔD is optimal, otherwise the value is greater when not paying the lump sum dividend. This inequality has two implications. First, subtract the right hand side, divide by ΔD, and let $\Delta D \to 0$ to obtain

$$\partial_c V - 1 \geq 0. \tag{9}$$

Again, equality holds whenever dividend payouts are optimal. Second, it is possible for a firm to strategically pay all its liquid assets as a dividend, that is, $\Delta D = c$, and immediately liquidate afterward:

$$V(k, c, s) \geq V(k, 0, s) + c \geq \ell_s k + c.$$

In particular, this is a special case of the condition $\partial_c V - 1 \geq 0$, as $\partial_c V - 1 \geq 0$ implies $V(k, c, s) - V(k, 0, s) - c = \int_0^c \partial_c (V(k, c', s) - c') dc' \geq 0$.

Next, the firm may issue equity. The issuance of I increases the cash by as much, at the shareholder expense of $I + \lambda(I, s)$ and, therefore, the net value to shareholders is

[3] Note that because there is no information asymmetry between existing and new investors, one can simply think of the problem through the lens of a representative investor.

equal to

$$V(k, c+I, s) - I - \lambda(I, s),$$

and if it is optimal to issue equity then the value of the firm should be no less than the largest post-issuance value:

$$V(k,c,s) \geq \sup_{I \geq 0} \Big[V(k, c+I, s) - I - \lambda(I, s) \Big]. \tag{10}$$

Finally, the firm may decide not to pay a dividend or issue equity, in which case it only needs to pick its optimal instantaneous investment. By standard control arguments, V must satisfy the following inequality

$$\begin{aligned} rV - \sup_{i \geq 0} \bigg\{ \Big[i - \delta k \Big] \partial_k V + \Big[(r - \lambda_c) c + k^{\alpha} \mu_s - i - g(k,i) \Big] \partial_c V \\ + \frac{1}{2} k^{2\alpha} \sigma_s^2 \partial_{cc}^2 V + \sum_{s'} q_{s,s'} V(k,c,s') \bigg\} \geq 0, \end{aligned} \tag{11}$$

holding with equality when investment is optimal. Here, rV represents the required rate of return on equity, which is equal to the risk-free rate demanded by risk-neutral investors. The term $\partial_k V$ is a firm's marginal benefit of capital; hence, $[i - \delta k]\partial_k V$ captures the marginal effect of net investment on the value of the equity. The term $\partial_c V$ is the firm's marginal cost of cash; hence the term

$$[(r - \lambda_c)c + k^{\alpha}\mu_s - i - g(k,i)]\partial_c V,$$

is the effect of a firm's expected savings on the value of the equity. The term $\frac{1}{2}k^{2\alpha}\sigma_s^2\partial_{cc}^2 V$ captures the effect of the volatility of cash holdings due to the volatility of production on the value of the equity. The last term in the first expression, $\sum_{s'} q_{s,s'} V(k,c,s')$, captures the gain or loss of value due to a potential regime transition from s to s'.

The three inequalities (9), (10), and (11), when stated together, give us the HJB equation. As each is satisfied with equality when the corresponding action is optimal and at least one action is optimal, it is clear that at least one holds with equality. This observation is effectively summarized by the min in the following HJB equation for the value function

$V(k, c, s)$:

$$0 = \min \Bigg\{ rV - \sup_{i \geq 0} \Bigg\{ \Big[i - \delta k \Big] \partial_k V + \Big[(r - \lambda_c) c + k^{\alpha} \mu_s - i - g(k, i) \Big] \partial_c V + \frac{1}{2} k^{2\alpha} \sigma_s^2 \partial_{cc}^2 V + \sum_{s'} q_{s,s'} V(k, c, s') \Bigg\}, \partial_c V - 1, V(k, c, s) - \sup_{I \geq 0} \Big[V(k, c + I, s) - I - \lambda(I, s) \Big] \Bigg\}. \tag{12}$$

The equation highlights that the firm chooses among three alternatives: investment (the group of terms on the first line of the right-hand side of the equation), dividend payout (the first group of terms on the second line), and equity issuance (the second group on the second line).

The boundary condition at $c = 0$ is determined by comparing the liquidation and issuance values:

$$0 = \min \Bigg\{ V(k, 0, s) - \ell_s k, \; V(k, 0, s) - \sup_{I \geq 0} \Big[V(k, I, s) - I - \lambda(I) \Big] \Bigg\}. \tag{13}$$

In the above equation, the boundary value $V(k, 0, s)$ dominates the liquidation value $\ell_s k$ and the best issuance value $\sup_{I \geq 0}[V(k, I, s) - I - \lambda(I, s)]$, and for each value of k is equal to one of the terms, depending on which is largest. If $V(k, 0, s)$ is equal to the former value, it is optimal for the firm to liquidate; otherwise, issuance is optimal with an optimal size.

3 The Model Solution

In this section, we present and discuss the model solution with a series of figures illustrating how recession risk affects a firm's investments, payouts, issuances, and value. We also examine how the effects of recession risk vary with a firm's size and financial flexibility, captured by cash holdings.

To solve the model numerically, we need to determine several parameters, including the transition probabilities between regimes s. We estimate the transition probabilities empirically. Specifically, we use the monthly probability of a future recession in 12 months from 1985 to 2022, derived from the term spread. (See Section 4.1 for additional discussion of the recession risk measure.) Because our firm-level data are at the quarterly frequency, we calculate the average recession probability for each quarter. Ignoring quarters containing NBER recessions, we identify the 75th percentile cutoff recession probability (15.2%) and use this threshold to separate quarters into the "expansion, low risk" and "expansion, high risk" regimes. Quarters with an NBER recession are labeled "recession."

Next, we examine the transition intensity from one regime to each of the others. In Table 1, we report the transition probabilities. The "expansion, low-risk" regime is the most stable. When a firm is in that regime, there is a 77% chance of staying in that regime for the next period. By contrast, in the "expansion, high-risk" regime, there is only a 46% chance of being in that regime next period. In a "recession," there is a 29% probability of remaining in a recession and a 52% probability of transitioning to the low-risk expansion regime. Figure 1 in Section 2 illustrates Table 1.

[Insert Table 1 Here]

We present the complete set of parameter values for the model in Table 2, together with the rationale. To determine the values of our parameters, we separate them into two subgroups.

[Insert Table 2 Here]

The first group consists of the curvature of the production function α, a cash flow scaling parameter Ξ for expected cash flows μ_s and the volatility of cash flows σ_s, and the adjustment cost parameter θ. These parameters are influential but difficult to observe. Therefore, we estimate them using the simulated method of moments to bring the model closer to the data. Table 2 reports the estimated values, and Table 3 panel A also includes the standard errors for α and Ξ. Panel B of Table 3 reports the calibrated moments and shows that they are close to the sample moments. More details of the calibration are presented in Section B.1.

[Insert Table 3 Here]

In the second group of parameters, we select plausible numbers based on existing empirical evidence to the extent that it is available. The last column of Table 2 contains a discussion of the choice of model parameters.

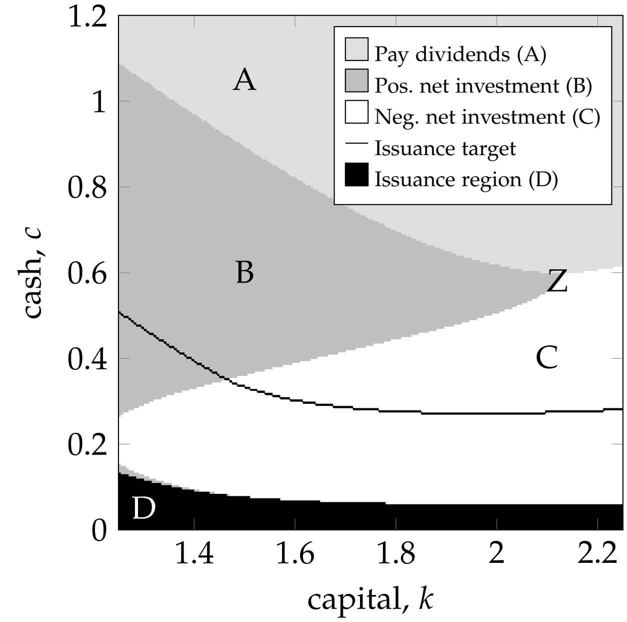
In our baseline parameterization, expected cash flows, the size of cash flow shocks, the fixed component of issuance costs, and the recovery rate in the liquidation of capital change between expansion and recession regimes. Following Hackbarth, Miao and Morellec (2006), the interest rate is not cyclical in our baseline parameterization. However, in Section 5, we relax this assumption by allowing the discount rate to change to consider the implications of monetary policy for firms' responses to recession risk. Also in Section 5, we allow the fixed component of issuance costs λ_f to increase between the two expansion regimes to account for the awareness of investors and intermediaries of the increased risk of recession.

3.1 Firm policies in the expansion regimes

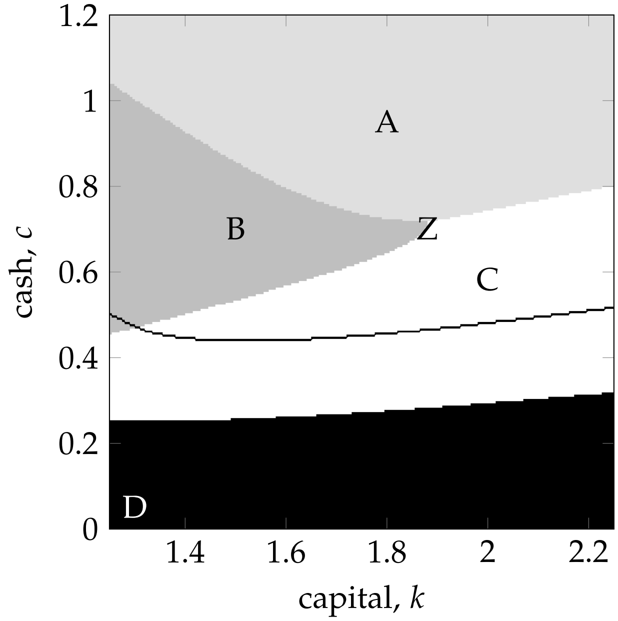
Subplots (a) and (b) of Figure 2 depict the optimal policies of a firm in an expansion regime with low and high recession risk, respectively. The vertical axis captures the size of a firm's cash reserve, c, and the horizontal axis captures the size of a firm's capital stock, k. The legend notates which regions of k and c correspond to which firm behaviors. Simulations reveal that the firm spends almost all its time around point Z, with a reasonable range of k between 1.25 and 2.25. (See Figure B1 for the full state space.)

The payout region, labeled A, characterizes when a firm pays a dividend in (k, c) space. The model firm only pays a dividend when the marginal cost of reducing its cash reserve matches the marginal benefit of the dividend payout. For lower levels of cash c, the firm retains cash to economize on issuance costs, but the value of these precautionary savings decreases as the cash balance increases. Eventually, as the cash c increases, holding additional cash is not economical due to the liquidity premium λ_c, and the firm begins making payouts. If c is initially higher than the payout boundary, which is where the payout region (A) touches the two investment regions (B and C), a lump-sum dividend is paid so that the state process (k, c) lands exactly on the boundary after the dividend payout. When the state process (k, c) reaches the payout boundary from below, a minimal dividend is paid to reflect the state process below so that the state process remains lower than the payout boundary.

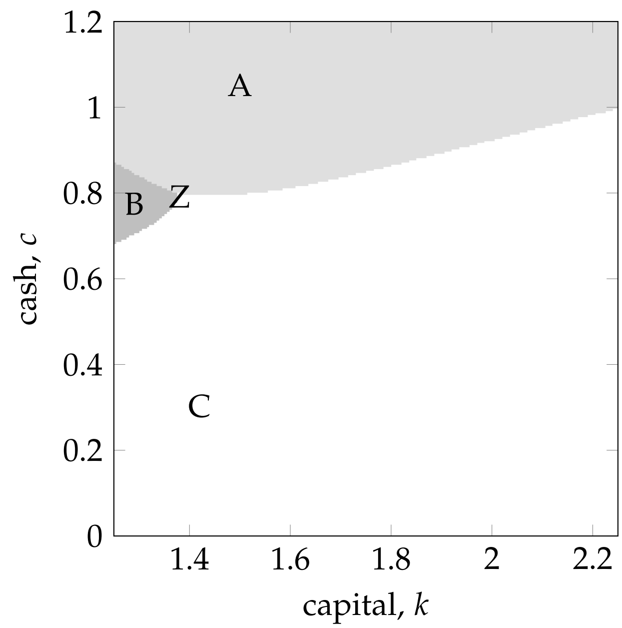
The two investment regions (B and C) exist because of diminishing returns to scale. Let i^* be the optimal investment policy of the firm. In the positive net investment region, labeled B, it is optimal for the firm to grow its capital stock, and therefore the investment i^* is higher than the depreciation δk. In the negative net investment region, labeled C, it is optimal for the firm to invest below the depreciation δk, resulting in net disinvestment. Due to diminishing returns to scale, the firm generally is in the positive net investment region (B) when it is smaller, and it is in the negative net investment region (C) when it is



(a) **Expansion, Low Risk (*l*)**



(b) **Expansion, High Risk (*m*)**



(c) **Recession (*h*)**

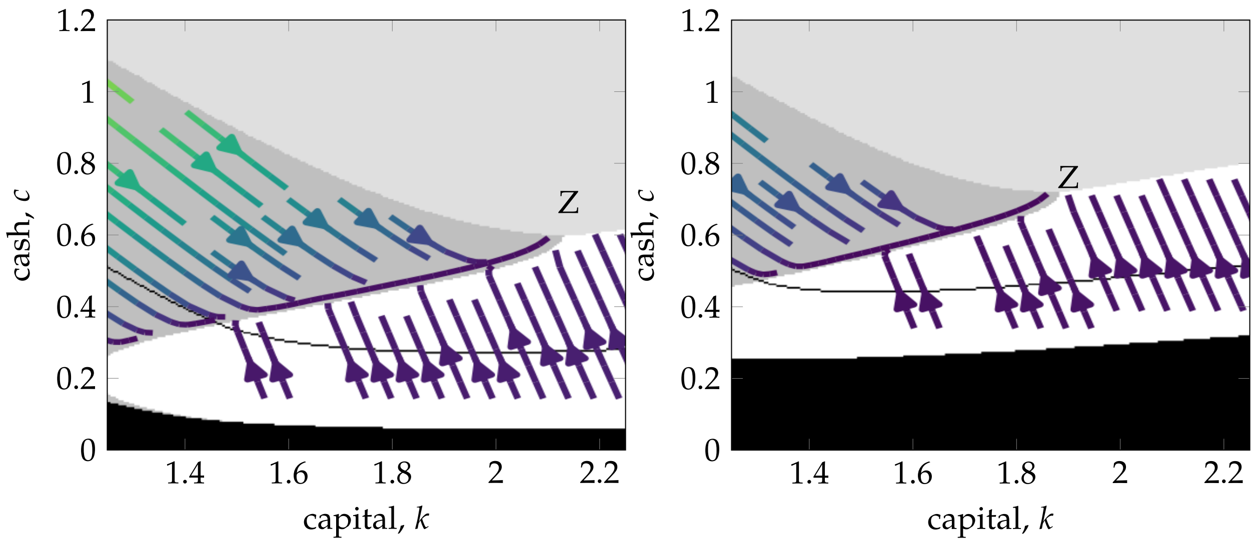
Figure 2: **Optimal policies with time-varying recession risks**
This figure shows the firm's optimal policies in the (k, c) state space for low-risk expansion (panel a), high-risk expansion (panel b), and recession (panel c) regimes. Parameters used are summarized in Table 2.

larger. The interface between the positive (B) and negative (C) net-investment regions is where the investment exactly equals the depreciation.

The issuance target, shown in Figure 2 as a solid black line, denotes a firm's optimal cash holdings after raising external financing and paying the financing costs. The issuance boundary (∂D) is the upper boundary of the black region labeled D. Issuance activity is lumpy (the difference between the issuance boundary and the issuance target) to economize on the fixed component of the issuance costs. When facing recession risk, the firm finds it optimal to issue at positive cash levels even when there is no immediate use of the funds for investment. Cost-benefit analysis helps rationalize why low-cash firms respond to recession risk by issuing equity preemptively. In terms of costs, firms anticipate the unavailability of external financing during a future recession, and thus have incentives to preemptively issue during the expansion phase to reduce the possibility of liquidation when the recovery rate on productive capital is low. Why do higher cash firms not also issue equity preemptively? Higher cash firms are further away from possible liquidation in a recession and thus require less additional external financing to prepare for the recession risk. However, issuing less equity is less cost-effective because of the fixed component of issuance costs.

3.2 Illustrating firm dynamics

To illustrate the firm's dynamics, Figure 3 shows the expected trajectories in (k, c) space for each expansion regime conditional on the regime not transitioning. Interestingly, when the productive capital stock k is smaller (e.g., $k = 1.4$) the firm sees a faster downward trajectory of cash in capital because net investment rates are higher and cash flows are lower than when k is larger (e.g., $k = 2.0$). That is because small firms invest more aggressively, using cash to grow the firm. As the firm grows, investment incentives decline, and the firm starts to accumulate cash to manage larger-scale cash flow shocks. Therefore, there is a negative covariance between size and cash when a firm is small and investing. By contrast, when a firm is large (e.g., $k = 2.0$), the trajectory is towards the northwest. That is, the firm invests less than depreciation due to the diminishing returns to scale assumption, which shrinks the firm and also builds cash holdings. The trajectories suggest that firms spend more time around the dividend boundary (lower boundary of the region A) and around the point Z.



(a) **Expansion, Low Risk (l)** (b) **Expansion, High Risk (m)**

Figure 3: **Expected optimal state trajectories**

Illustration of the *expected* instantaneous expansion state trajectories of a firm while not paying dividends or issuing equity. The actual trajectory depends on the Brownian productivity path, regime changes, and possible excursions into the issuance or dividend region. The arrow shade indicates the instantaneous speed, from slow/dark to fast/light. Small firms have a high incentive to invest and grow. However, the investment cost is high, so they do not move much faster in k. According to the simulations, the firm's density is concentrated around the point Z.

3.3 Firm policies in the recession regime

Firms can temporarily enter a recession regime. In a recession regime, the firm faces the chance of leaving the recession regime for an expansion regime with either a low risk or high risk of a subsequent recession. Panel (c) of Figure 2 shows the policies of a firm when the firm is in a recession regime.

One notable difference between the recession regime and the two expansion regimes is that in a recession regime, the issuance boundary region (D) and issuance target are absent because there is no opportunity for external financing. If a firm runs out of cash, it must liquidate. Indeed, there is no empirical study to measure issuance costs in a financial crisis for the obvious reason that there are virtually no initial public offerings or secondary equity offerings in a crisis (Bolton, Chen and Wang, 2013).

Another difference is that a firm is less willing to invest during the recession regime. The positive net investment region B shrinks. The rationale is that the value of cash increases, which competes with the value of using cash to invest. Additionally, investment productivity falls in a recession, whereas investment riskiness increases in terms of larger cash flow shocks.

3.4 Comparing how small and large firms' policies respond differently to recession risk

The next subsections examine the effects of varying recession risk on firm policies (comparing Panels (a) and (b) of Figure 2). Higher recession risk increases a firm's probability of liquidation. The likelihood of liquidation increases in a recession because external financing is unavailable, cash flows become more volatile, and expected cash flows decline. Firms can manage recession risk by issuing equity preemptively and curbing uses of cash, such as investments and payouts. The extent to which firms use each of these levers to manage recession risk depends on a firm's cash holdings and size.

3.4.1 Issuances and recession risk

Figure 4 plots the percentage change in the issuance boundary (upper boundary of the region D) across the low-risk and high-risk expansion regimes for different firm sizes. The model evidently predicts a higher sensitivity of preemptive issuance behavior to recession risk when a firm is larger. A firm of size $k = 1.25$ ($k = 2.25$) increases the minimum cash tolerated before preemptive issuance by about 100% (400%) when recession risk increases. Thus, the model predicts a higher positive sensitivity of cash levels immediately prior to issuance to changes in recession risk for larger firms.

The rationale is that smaller firms respond more completely to the risk of recession already in the low-risk expansion regime than larger firms. Note that even in the low-risk expansion regime, there is a 5% chance of transitioning directly into a recession regime. A small firm has incentives to respond more completely, even when recession risk is low because small firms have better investment opportunities and are investing more aggressively, which lowers cash holdings and raises the possibility of liquidation when a recession occurs.

To support this reasoning, note that the issuance region D exists due to the potential for external financing to become unavailable in a recession. Thus, the boundary of the issuance region ∂D reflects the minimum cash holdings firms of various sizes tolerate because of recession risk before preemptively issuing new equity. Figure 5(a) shows the issuance boundary and shows that small firms require more cash in the low-risk regime, that is, they respond more completely to the risk of recession in the low-risk regime. As a

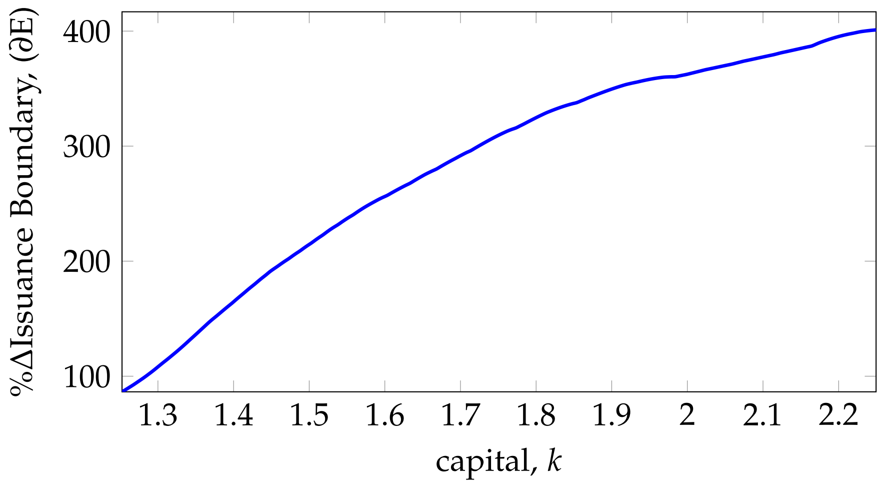


Figure 4: **How does the impact of recession risk on the cash level at which a firm decides to issue equity vary with the size of the firm?**
This figure shows by the size of the firm k, the percentage change in the issuance boundary (∂E) when recession risk is low (l) versus high (m) in Figure 2. In other words, firms facing recession risk optimally issue when cash holdings are positive and without an immediate need for the issuance proceeds to preempt the rise in issuance costs in a recession. This figure examines the change in cash holdings immediately prior to issuance when recession risk increases. Parameters used are summarized in Table 2.

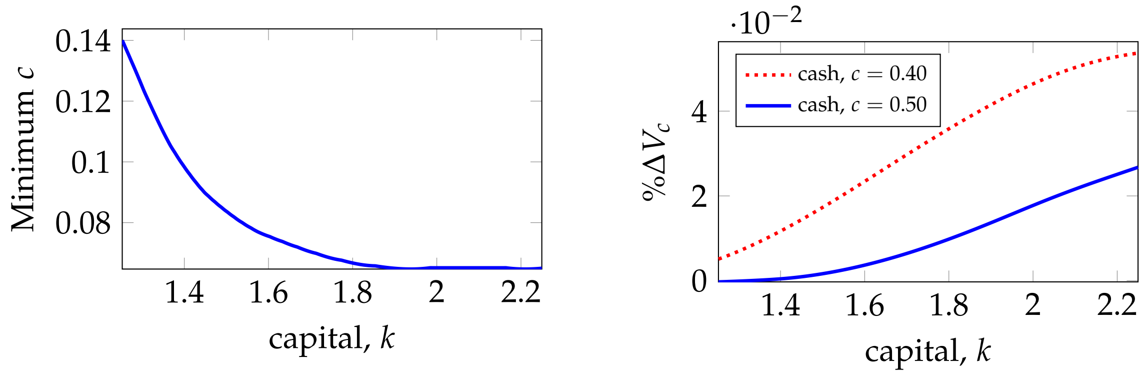
result, the small firm's policies adjust less when recession risk does increase in the event of a transition to the high-risk regime.

Another way to support this reasoning is to examine how the marginal value of cash changes when recession risk increases. The marginal value of cash ($\partial_c V = V_c$) is the difference in the value of the firm for a small increase in cash holdings scaled by the size of the small increase in cash holdings. Then we compute the percentage change in the marginal value of cash ($\%\Delta V_c$) across the low-risk expansion regime and the high-risk expansion regime. Consistent with small firms responding more completely in the low-risk regime, Figure 5(b) shows that small firms see a smaller percentage change in the marginal value of cash when recession risk increases.

In general, because a small firm responds more completely when the recession risk is low, the model predicts a greater sensitivity of firm policies to changes in the recession risk when a firm is larger.

3.4.2 Investments and recession risk

Due to recession risk, firms reduce investments to preserve cash to avoid liquidation. This can be seen in Figure 3, as the brightness of the trajectory arrows is higher in the



(a) Minimum cash holdings, c, because of recession risk in the low-risk, expansion regime

(b) Percent change in the marginal value of cash when recession risk increases

Figure 5: **Responses of cash to recession risk**

In panel (a), the vertical axis is the minimum cash holdings, c, that a firm tolerates before issuing equity preemptively due to the risk of recession. This minimum c is given by the issuance boundary (∂E) in the low-risk regime in Figure 2. In panel (b), the vertical axis is the change in a firm's marginal value of cash. We first calculate the marginal value of cash ($\partial_c V = V_c$) as the difference in the firm's value for a small increase in cash holdings scaled by the size of the small increase in cash holdings. Then we calculate the percent change in the marginal value of cash ($\%\Delta V_c$) between the low-risk expansion regime and the high-risk expansion regime. Parameters used are summarized in Table 2.

low-risk expansion regime than in the high-risk expansion regime. Figure 6 plots the percent change in investment, $\%\Delta i$, when recession risk increases, against the size of the firm for two levels of cash. Intuitively, higher cash firms cut investment less because they are more insulated from the effects of a recession. More interestingly, investment rates fall more due to recession risk when a firm is larger. This is because, as discussed in Section 3.4.1, smaller firms have stronger investment incentives because of the assumption of diminishing returns to scale. In fact, in Figure 2, the smaller firms are more likely to continue to grow in the recession regime, while the larger firms are more likely to decrease investment and shrink. Overall, the model predicts that the negative sensitivity of investment to recession risk is more negative for larger firms.

3.4.3 Payouts and recession risk

Due to recession risk, firms also reduce payouts to preserve cash to avoid liquidation. Firms facing recession risk anticipate that their profitability will be lower, that their cash flows will be more volatile, and that issuances will become unavailable at some point in the future when the firm enters a recession. Thus, during expansion regimes, the demand for financial flexibility increases with recession risk, incentivizing firms to hold more cash

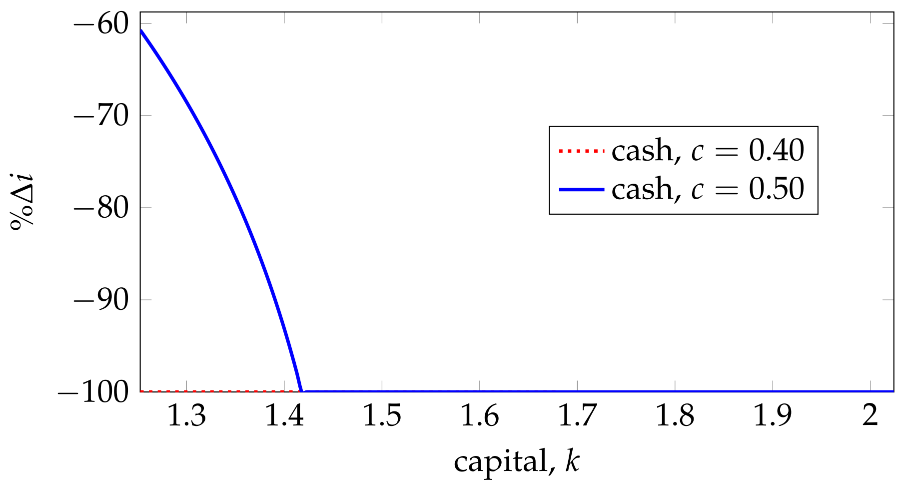


Figure 6: **Change in investment due to higher recession risk**
This figure plots the percent change in investment due to recession risk, $\%\Delta i$, when recession risk increases from the low-risk expansion regime (l) to the high-risk expansion regime (m) against the size of a firm's productive capital stock k. The parameters used are summarized in Table 2.

and cut payouts.

Figure 7 plots the percentage change in the dividend boundary when recession risk increases against firm size. An increase in the dividend boundary corresponds with a drop in payouts. Again, interestingly, the dividend boundary increases by a larger percentage for larger firms. Thus, the model predicts that the negative sensitivity of payouts to recession risk is more negative for larger firms.

3.4.4 Firm value and recession risk

In general, recession risk leads to a decrease in firm value. Figure 8 shows the percentage change in firm value V when the firm transitions from the low-risk to the high-risk regime. Intuitively, firm value declines with increases in recession risk, and a higher cash firm sees less of a drop in firm value. More interestingly, consistent with the previous discussion, the model predicts that the negative sensitivity of firm value to recession risk is more negative when a firm is larger, especially when a firm has lower liquidity. The underlying idea is that, for larger firms, an escalation in recession risk diminishes the value of their option to accumulate cash, a strategy that is less viable for smaller firms.

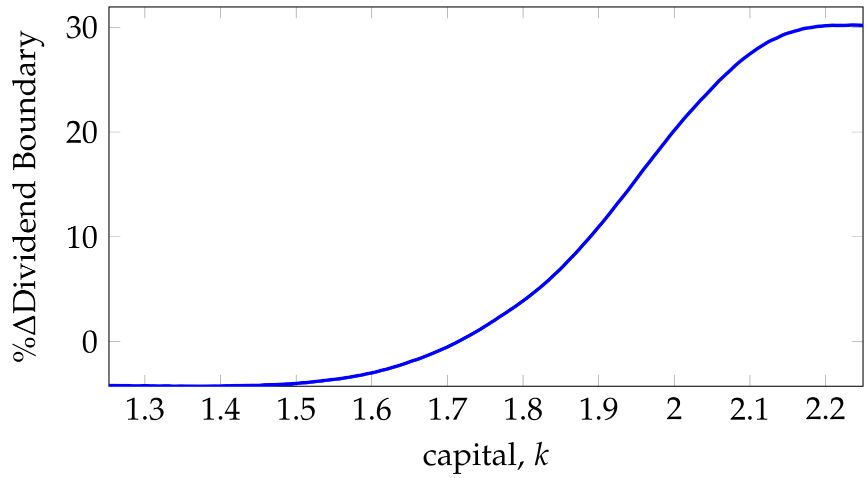


Figure 7: **Change in dividend boundary due to higher recession risk**
This figure plots the percent change in the dividend boundary when recession risk increases from the low-risk expansion regime (l) to the high-risk expansion regime (m) against the size of a firm's productive capital stock k. Parameters used are summarized in Table 2.

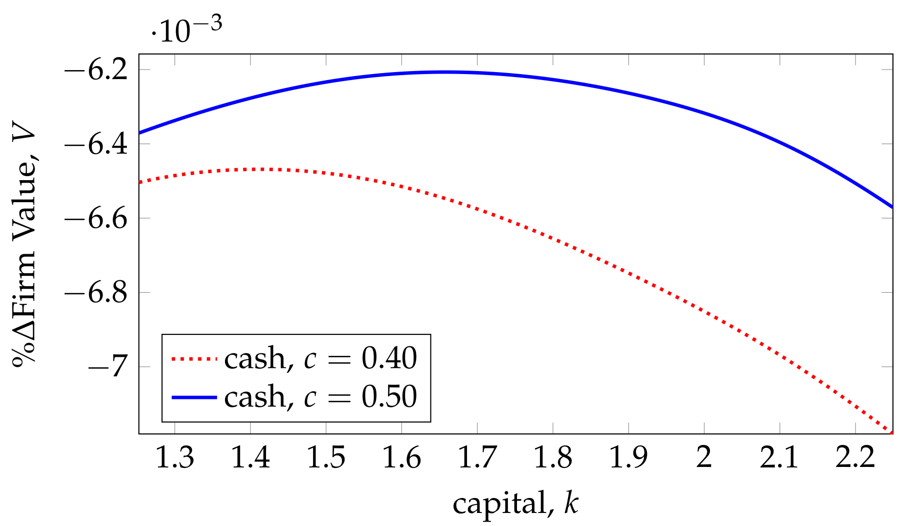


Figure 8: **Change in firm value due to higher recession risk**
Plots the percentage change in firm value when the firm transitions from the low-risk, expansion regime to the high-risk, expansion regime. Parameters used are summarized in Table 2.

4 Empirical Evidence

In this section, we provide empirical evidence to qualitatively validate the findings from the estimated model discussed in Section 3.

4.1 Data and Variable Construction

To proxy for the time-varying risk of a recession, we rely on a monthly time series of recession probabilities from the *The Yield Curve as a Leading Indicator* at the Federal Reserve Bank of New York. Recession probabilities are derived from the term spread, defined as the difference between the 10-year and 3-month Treasury rates, and reflect the chance that the United States is in a recession in twelve months.[4]

Comparing a variety of possible predictors of a recession, Estrella and Mishkin (1998) shows that the slope of the yield curve emerges as the clear individual choice and typically performs better by itself out of sample than in conjunction with other variables.[5] The out-of-sample pseudo R^2 for the term spread measure is approximately 30% at horizons of two-to-four quarters ahead.[6] As is conventional, we use the one-year horizon. The one-year horizon also allows firms to adapt their slower-moving investment, payout, cash, and issuance policies. In addition, it is market-based and continuously observable rather than survey-based.[7] Table C.2 correlates our main measure of recession probability based on term spread with several other measures.[8] It is important to note that our recession probability measure contrasts with the frequent use of the phrase recession probability in the literature on business cycle dating, which is concerned with whether one is in a

[4]The probability measure comes from a probit model, in which the outcome variable is an indicator variable that equals one if an NBER recession occurs 12 months later and the main explanatory variable is the current term spread.

[5]Other predictors examined in that paper include the commercial paper spread, the Stock and Watson (1989) and Stock and Watson (1993) indexes, market indexes like the *NYSE* and *S&P 500*, monetary base deflated by the consumer price index, a composite index of leading indicators from the U.S. Commerce Department, and lagged growth in real GDP.

[6]Kessel (1965) presents graphical evidence that shows that the term spread tends to be negative at cyclical peaks, using data that go back as far as 1858. Bordo and Haubrich (2004) provide regression-based statistical evidence that the term spread predicts recessions using U.S. data from 1875 to 1997.

[7]There is one survey of recession probabilities that extends back to the 1960s. The Survey of Professional Economists has asked economists to estimate the probability of quarter-over-quarter chain-weighted real GDP growth less than zero for the current quarter (RECESS1) and the following four quarters (RECESS2 to RECESS5). RECESS2 is known as the "Anxious Index." See Andrade and Le Bihan (2013). However, in agreement with Estrella and Mishkin (1998), the survey has a very low explanatory power for future recessions. Additionally, because we want to examine whether firms manage recession risk, predicting whether GDP will decline next quarter does not give firms much advance notice.

[8]We correlate it with the forecasts from the Survey of Professional Economists, CBOE Volatility Index, returns on the NYSE and S&P 500, the current state of the business cycle (Chauvet and Piger, 2008), the CBOE Volatility Index, leading indicators from Stock and Watson (1989) and Stock and Watson (1993), and the 3-month commercial paper spread over the federal funds rate. The VIX has a correlation of -0.0048 with our primary measure of recession risk. One reason may be that the VIX captures expected volatility over the next month, while the recession probability measure predicts recessions in 12 months. Another reason may be that the VIX measures short-term expected volatility (second moment), while the recession probabilities predict distant drops in GDP (first moment).

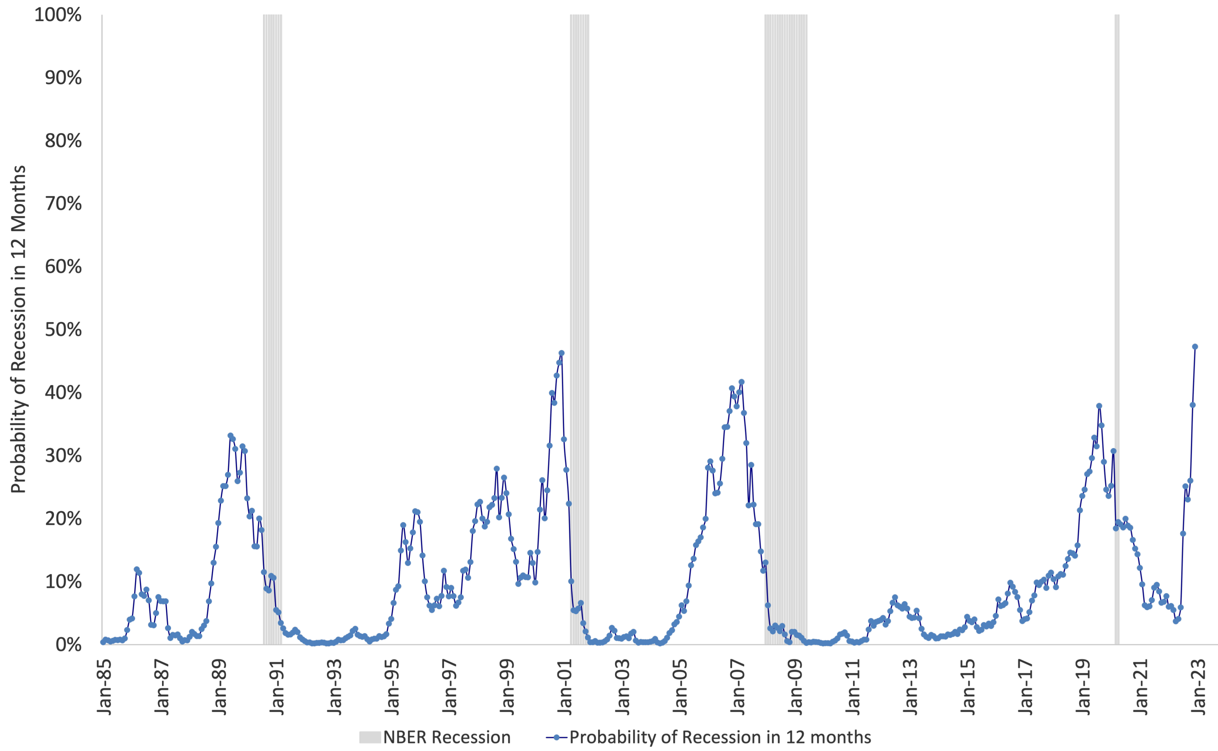


Figure 9: **Probability of Recession in One Year**

From the Federal Reserve Bank of New York. Source: https://www.newyorkfed.org/research/capital_markets/ycfaq#/.

recession *today* (e.g., Chauvet and Piger, 2008).[9]

Figure 9 shows the probability that the U.S. economy is in a recession in 12 months. Gray bars indicate recessions designated by the National Bureau of Economic Research (NBER). The NBER identifies the dates of peaks and troughs that frame economic recessions and expansions. A recession is a period between a peak of economic activity and its subsequent trough, or lowest point. Between trough and peak, the economy is in expansion. Expansion is the normal state of the economy; most recessions are short. The figure shows that the probability of a recession generally spikes ahead of the NBER recessions. On December 31, 2022, the probability of a recession on December 31, 2023, is 47.3%.[10]

[9] For example, in December 2022, the Chauvet and Piger (2008) measure suggests a 5% probability of being in a recession in that month, while the term spread measure suggests a 47.3% probability of being in a recession one year later.

[10] When using the recession probabilities from the Federal Reserve Bank of New York it is important to shift the recession probabilities back 12 months to examine how firms manage current information about future recessions. Specifically, the data file associates each recession probability with the state of the business cycle one year later. For example, the recession probability based on the December 2022 term

Our primary data source for firm fundamentals is the quarterly Compustat data file, which provides detailed financial statement information on public firms. Our sample period covers 1985 to 2021. Although both the recession probability and Compustat data are available from the early 1960s, the Compustat data are missing several key variables in the early years, and the Great Moderation began in the mid-1980s, which resulted in a meaningful difference in the level and standard deviation of recession risk during expansion regimes (excluding NBER recessions). Specifically, before the Great Moderation, the mean risk of recession is 18.7% (standard deviation 18.3%). After the Great Moderation, the mean recession risk is 10.0% (standard deviation 10.6%). To examine how changes in recession risk affect firm dynamics, in our regressions, we remove from our sample the observations during NBER-designated recessions. See Appendix Table C.3 for details on filtering. The final sample has 11,495 unique firms and a total of 385,066 firm quarters. Table 4 Panel A provides summary statistics.

The two continuous state variables in the model are the firm's cash holdings and capital stock. We use the cash and cash equivalents (*cheq*) from the quarter-end balance sheet to proxy for cash holdings. To proxy for the size of a firm's productive capital stock, we use a firm's total assets less cash holdings (*atq-cheq*) from the quarter-end balance sheet. We show robustness to using property, plant, and equipment as a proxy for the size in the Appendix.

The main outcome variables of a firm characterize the issuance, payout, and investment activity of a firm. To proxy for a firm's issuance activity, we compute a firm's quarterly total sales of common stock from the cumulative total sales listed on the cash flow statement (*sstky*). To proxy for a firm's payout activity, we compute a firm's quarterly amount of dividends from the cumulative dividend variable (*dvy*) and cumulative common stock repurchases (*prstkcy*).[11] To proxy for a firm's investment rate, we use a firm's capital expenditures on property, plants, and equipment (*capxq*).

To examine the effects of recession risk on firm values, we also rely on stock return data from the CRSP/Compustat merged database. Our stock analysis is done monthly using monthly recession probabilities. Our stock sample covers 8,761 firms; spans June 1985 to December 2020; and contains about 943,266 million stock-month observations. Table 4 Panel B shows that the average monthly return is 1.2% with a standard deviation of 13.6%. In the stock panel, the recession probabilities have summary statistics similar to

spread is associated with December 2023.

[11] Because *sstky*, *dvy*, and *prstkcy* are cumulative over the fiscal year, we determine the quarterly values by differencing these variables across quarters in the same fiscal year.

those of the quarterly Compustat data. See Table C.4 for our sample selection criteria.

[Insert Table 4 Here]

4.2 Issuance and recession risk

As discussed in Section 3.4.1, the issuance boundary for firms increases with recession risk, especially when a firm is larger. In other words, firms issue equity at higher cash balances when the risk of recession increases, especially larger firms.

To empirically examine the prediction, we examine the cash holdings immediately prior to the issuance activity. That is, we limit the sample to issuances in quarter $t+1$ that exceed various proportions of firm size (total assets less cash holdings) at the end of quarter t. Then, we estimate the following multivariate specification:

$$\begin{aligned}\log(\text{Cash})_{i,t} = \beta_0 &+ \beta_1 \log(\text{Recession Probability}_t) \\ &+ \beta_2 \log(\text{Recession Probability}_t) \times \log(\text{Size})_{i,t} + \beta_3 \log(\text{Size})_{i,t} \\ &+ X_t + \epsilon_{i,t}.\end{aligned} \tag{14}$$

Again, all of the variables are measured as of quarter t, which precedes a known issuance in quarter $t+1$. $Size_{i,t}$ is the assets of a firm minus cash holdings at the end of the quarter t. $Cash_{i,t}$ is the cash holdings of a firm at the end of the quarter t. $Recession\ Probability_t$ is the average monthly probability of recession in the quarter t. β_2 captures the extent to which cash holdings prior to issuance vary differently with recession risk due to differences in firm size. To account for documented cyclicality in cash during the business cycle, X_t is a set of controls for near-term market conditions, including the average Volatility Index in quarter t and the probability that the economy is in a recession in quarter t (not $t+4$) from the business cycle dating literature (Chauvet and Piger, 2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. Table C.2 shows that our measure of the risk of future recession has effectively zero correlation with these controls for near-term market conditions. We cluster standard errors by quarter because our variable of interest — recession risk — is constant across observations in a quarter.

In this and subsequent specifications, and because our variables of interest are a firm's *levels* of cash and capital, we scale variables by each firm's standard deviation of that variable, instead of scaling by some proxy for total firm size. In other words, we standardize these variables within a firm. Standardization within a firm removes differences between firms in variances of variables of interest in addition to differences in their means to facilitate the interpretation of magnitudes and is the recommended approach for within-firm analyses (Mummolo and Peterson, 2018; deHaan, 2021). Thus, any variation with firm size in the sensitivities of firm policies to changes in recession risk results from comparing a firm's policies when recession risk is high with that same firm's policies when recession risk is low.

Table 5 reports estimates from the specification (14). The sample is restricted to firm-quarters t that precede an issuance in quarter $t+1$. To reduce the impact of common stock sales because of employee option exercises, we require the issuance amount to be substantial. In column (1), issuance amounts in quarter $t+1$ are greater than 1% of the value of a firm's total assets less cash holdings at the end of quarter t. In subsequent columns, we raise the cutoff to 5%, 10%, 25%, 50%, and 75%. Consequently, the sample size shrinks with the size of the cut-off. Across the columns of Table 5, we find that the issuance behavior of large firms responds more to recession risk. That is, β_2 is positive and statistically significant (mostly at the 1% level) for all specifications. The magnitudes are considerable, as well. For example, examining column (4), a standard deviation increase in recession risk corresponds with having 0.037 (0.100) standard deviations more cash immediately prior to issuance when a firm is at its average size (when a firm is one standard deviation larger than its average size).[12]

[Insert Table 5 Here]

4.3 Investment and recession risk

As discussed in Section 3.4.2, firms respond to higher recession risk by cutting investment, especially larger firms. To examine this prediction empirically, we use the following

[12]While we do not model debt, if debt issuance costs also increase dramatically during a recession, then large firms may have an incentive to raise debt preemptively during an expansion, especially when recession risk increases. Table C.6 adds long-term debt issuance to Table 5 and shows qualitatively similar results. Table C.7 repeats Table 5 using net plant, property, and equipment to proxy for firm size. Table C.8 uses an indicator that equals one if recession risk exceeds the 75th percentile outside of NBER recessions.

multivariate specification:

$$\left(\frac{\sum_{j=1}^{4}\text{CAPX}_{t+j}}{\sum_{j=-3}^{0}\text{CAPX}_{t+j}}-1\right)=\beta_0+\beta_1\log(\text{Recession Probability}_t)$$
$$+\beta_2\log(\text{Recession Probability}_t)\times\text{Size}_{i,t}$$
$$+\beta_3\text{Size}_{i,t}+X_{i,t}+\epsilon_{i,t}. \qquad (15)$$

The outcome variable is the change in capital expenditures on property, plant, and equipment. To account for seasonality in investment between quarters and to allow firms time to adjust investment, we compare investment in the four future quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to investment in the previous four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize growth in capital expenditures within a firm to account for differences between firms in average growth and volatility. $Size_{i,t}$ is the assets of a firm minus the cash holdings at the end of the quarter t, standardized within the firm. $Recession\ Probability_t$ is the average monthly probability of recession in the quarter t. β_1 captures the extent to which investment responds to the level of recession risk, and β_2 captures the extent to which investment response to recession risk varies with the size of a firm. We do not relate changes in investment to changes in recession risk because investment is unlikely to respond immediately to innovations in recession risk, but rather over time to levels of recession risk. X_t are the aforementioned controls for near-term market conditions and their interactions with $Size_{i,t}$. In addition to clustering the standard errors by quarter because recession risk is quarterly, we also cluster standard errors by the firm to account for the serial correlation induced by the overlap in the outcome variable across quarters.

Table 6 reports estimates from the specification (15). Column (1) of Table 6 shows that investment growth is negatively related to the level of recession risk as the regression coefficient ($\beta_1 = -0.030$ and is statistically significant at 1% level). Additionally, Column (1) shows that larger firms cut investment growth more in response to increases in recession risk ($\beta_2 = -0.018$ and is statistically significant at 1% level). Therefore, in agreement with model predictions, when a firm is larger, investment cuts because of recession risk are more sensitive to the level of recession risk. A one-standard-deviation increase in recession risk corresponds with a 0.03 (0.048) standard-deviation decrease in investment growth for the average (one-standard-deviation larger) firm. Column (2) shows that the results are robust to controlling for business cycle controls.[13]

[13]Table C.9 uses net plant, property, and equipment to proxy for firm size. Table C.10 adds firm fixed

[Insert Table 6 Here]

4.4 Payouts and recession risk

As discussed in Section 3.4.3, firms respond to increases in recession risk by cutting payout rates, especially large firms. To examine this prediction empirically, we use the following multivariate specification:

$$\left(\frac{\sum_{j=1}^{4}\text{Payouts}_{t+j}}{\sum_{j=-3}^{0}\text{Payouts}_{t+j}}-1\right)=\beta_0+\beta_1\log(\text{Recession Probability}_t) + \beta_2\log(\text{Recession Probability}_t)\times\text{Size}_{i,t}+\beta_3\text{Size}_{i,t} + X_{i,t}+\epsilon_{i,t}. \tag{16}$$

The outcome variable is the change in a firm's dividend payments and share repurchases over the next four quarters relative to the past four quarters. We standardize payout growth within a firm to account for differences between firms in average growth and volatility. $Size_{i,t}$ is the assets of a firm minus cash holdings at the end of quarter t, standardized within the firm. $Recession\ Probability_t$ is the average monthly recession probability in quarter t. We do not relate changes in payouts to changes in recession risk because payouts are unlikely to respond immediately to innovations in recession risk but rather over time to levels of recession risk. $X_{i,t}$ are the controls for near-term market conditions and their interactions with $Size_{i,t}$. β_1 captures the extent to which payout growth responds to recession risk, and β_2 captures the extent to which the payout response to recession risk varies with a firm's size. In addition to clustering the standard errors by quarter because the recession risk is quarterly, we also cluster standard errors by the firm to account for the serial correlation induced by the overlap in the outcome variable across quarters.

Table 7 column (1) shows that changes in total payouts are negatively related to recession risk ($\beta_1 = -0.008$ but not statistically significant). Additionally, the decrease in total payouts due to the risk of recession is greater when a firm is larger ($\beta_2 = -0.013$ and is significant at the 5% level). A one-standard-deviation increase in recession risk corresponds with a 0.008 (0.021) standard deviation decrease in payout growth for the average (one-standard-deviation larger) firm. Column (2) shows that the results are robust

effects.

to controlling for the current state of the business cycle.[14]

[Insert Table 7 Here]

4.5 Firm value and recession risk

As discussed in Section 3.4.4, the model predicts that recession risk reduces firm values, especially when a firm is larger. To examine this prediction empirically, we use the following multivariate specification:

$$\begin{aligned} \text{Stock Return}_{i,t} = & \beta_0 + \beta_1 \Delta \log(\text{Recession Probability}_t) \\ & + \beta_2 \Delta \log(\text{Recession Probability}_t) \times \text{Size}_{i,t} \\ & + \beta_3 \text{Size}_{i,t} + X_{i,t} + \epsilon_{i,t}. \end{aligned} \tag{17}$$

The outcome variable is the stock return for firm i in month t. $Size_{i,t}$ is the assets of a firm minus cash holdings at the end of the prior fiscal year, standardized within a firm. $Recession\ Probability_t$ is the recession probability in month t. In this specification, we use month-to-month changes in the recession probability because any changes in firm values (stock returns) because of changes in recession risk in an efficient market occur contemporaneously. In contrast, issuances, investments, and payouts are less likely to change immediately with recession risk. β_1 captures the extent to which stock returns move with recession risk, and β_2 captures the extent to which the stock return response to recession risk varies with the size of a firm. X_t is a set of controls for near-term market conditions. We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. We cluster the standard errors by month.

Table 8 column (1) shows that stock returns are negatively related to recession risk ($\beta_1 = -0.052$ and is significant at the 5% level). Additionally, stock returns are more negatively related to recession risk when a firm is larger ($\beta_2 = -0.032$ and is significant at the 1% level). Column (2) shows that the relations are robust to controls for the business cycle. Column (3) shows that the results hold outside of the 2008-2009 financial crisis.[15]

[14] Table C.11 uses net plant, property, and equipment to proxy for firm size. Table C.12 adds firm fixed effects.

[15] Table C.13 uses net plant, property, and equipment to proxy for firm size. Table C.14 adds firm-by-year fixed effects, using monthly variation within a firm-year. These fixed effects help control for larger changes in firm operations for longer-lived firms in the sample. Table C.15 splits at the median sample month of December 2003. Table C.16 interacts recession risk with firm size standardized over the full cross-section of firms rather than within a firm.

[Insert Table 8 Here]

5 Robustness: Cyclical discount rate r and issuance costs λ_f

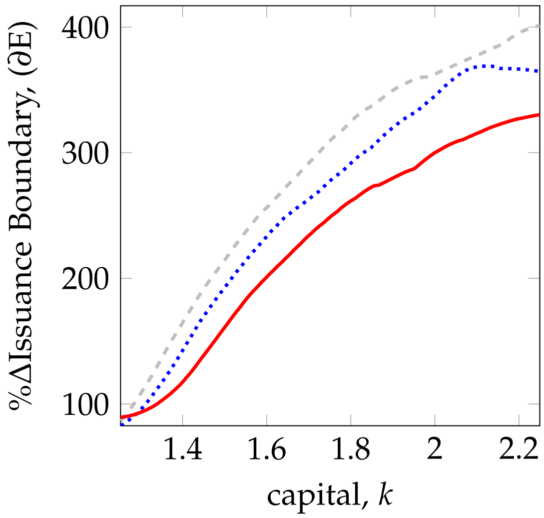
5.1 Cyclical discount rate r

In this section, we consider a natural variation of the model in which the discount rate r is cycle-dependent. Specifically, we consider the role of monetary policy on firms' preemptive actions to manage recession risk. That is, how does the sensitivity of firm policies to recession risk change with the risk-free rate? In our main analysis, we kept the risk-free rate r fixed throughout the business cycle. The first alternative scenario is that monetary policy reduces the discount rate in a recession (h). The second alternative scenario is that monetary policy reduces the discount rate when the risk of recession is high (m).

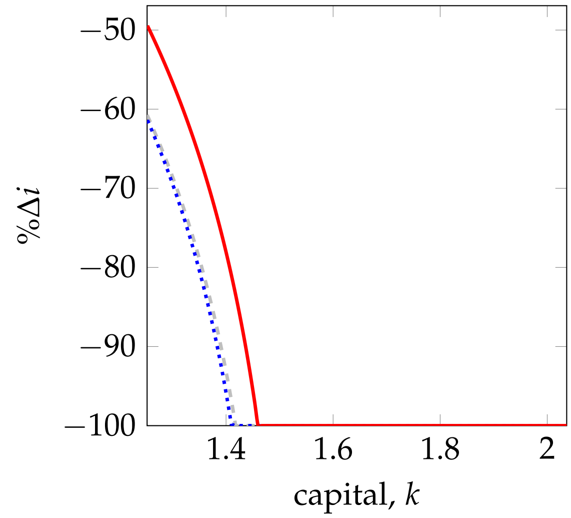
Figure 10 shows that the main predictions of the model are robust to varying the discount rate "r" with the regime. Additionally, the figure shows that preemptive issuance, investment, and dividend policies of firms are less sensitive to changes in recession risk when r declines earlier in the business cycle. The dashed gray line is our reference baseline case, where the discount rate is not cyclical, and we calculate the changes in firm policies between the low-risk, expansion regime and the high-risk, expansion regime. The blue dotted line is the first alternative scenario, and the solid red line is the second alternative. The rationale is that when recession risk is low, and the recession is not imminent, a lower discount rate (indicating more forward-looking behavior) makes the negative effects of a distant recession more important to manage today. Because firms facing a lower discount rate respond more to recession risk when recession risk is low, firms exhibit less sensitivity to increases in recession risk.

5.2 Cyclical issuance costs λ_f

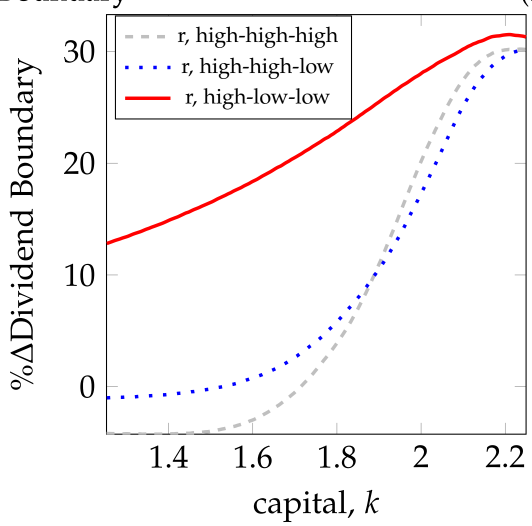
We also allow investors and financial intermediaries to increase the costs for firms to raise equity capital (λ_f) when the risk of recession increases. Figure 11 shows that the main predictions of the model are not affected by cyclical issuance costs. Additionally, the sensitivity of preemptive issuance policies to increases in recession risk decreases more



(a) **Issuance Boundary**



(b) **Investment**



(c) **Dividend**

Figure 10: **Lower sensitivity to risk when r decreases**

The horizontal axis is a firm's capital stock k. The vertical axis is the percentage change in the outcome variable between the low-risk expansion regime (l) and the high-risk expansion regime (m). *high-high-high* represents the benchmark model in which the corresponding interest rate r in the regimes l, m and h, respectively, is constant and does not vary with the business cycle. *high* means $r = 6\%$ (the benchmark value, see Table 2). *high-high-low* means that r is constant in the expansion regimes (i.e., $r_l = r_m = 6\%$) and is lowered (e.g., due to QE policies) in the recession regime (i.e., $r_h = 5\%$). *high-low-low* means that r is lowered earlier, i.e., in the high-risk expansion regime in which recession risk is imminent (i.e., $r_m = 5\%$), and it is at the *low* level in the recession regime ($r_h = 5\%$), while in the low-risk expansion regime the interest rate returns to the baseline level (i.e. $r_l = 6\%$).

when λ_f is cyclical than the sensitivity of investment or payout policies. This differential is consistent with the fact that issuance costs matter more for firm policies when issuance is more likely. The dashed gray line is our reference baseline case, where the issuance costs only increase in the recession to infinity. The dotted blue line is the alternative scenario. Panel (a) shows that there is much less change in the issuance boundary in the alternative scenario. On the contrary, panels (b) and (c) show little effect of higher issuance costs on the results of investment and payout policies.

6 Conclusion

This paper examines both theoretically and empirically how firm policies respond to recession risk. To characterize these sensitivities, one of our main contributions is to solve a dynamic model of a firm that uniquely features time-varying recession risk. Interestingly, we find that the policies of large firms exhibit a higher sensitivity to recession risk because small firms respond more when recession risk is low. The rationale is that small firms invest aggressively, which uses cash and makes liquidation more likely when a recession occurs. Therefore, small firms have stronger incentives to maintain a higher minimum cash holding relative to their size, even when the risk of recession is low. We then proceed to document the empirical support for these predictions.

Lastly, given the real effects of *anticipating* recessions, future research could examine the effectiveness of government policies aimed at mitigating expectations about the severity of future recessions.

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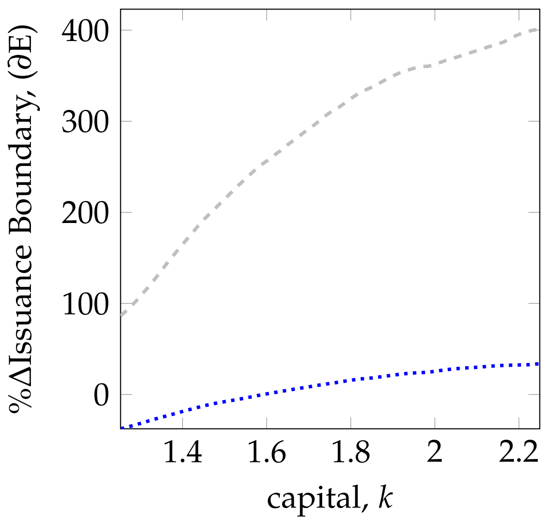
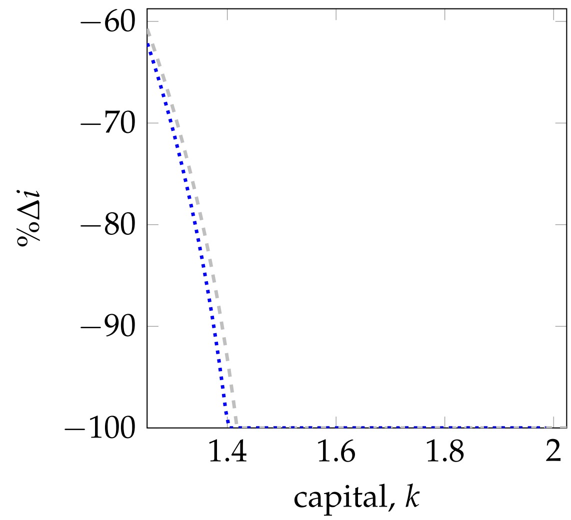
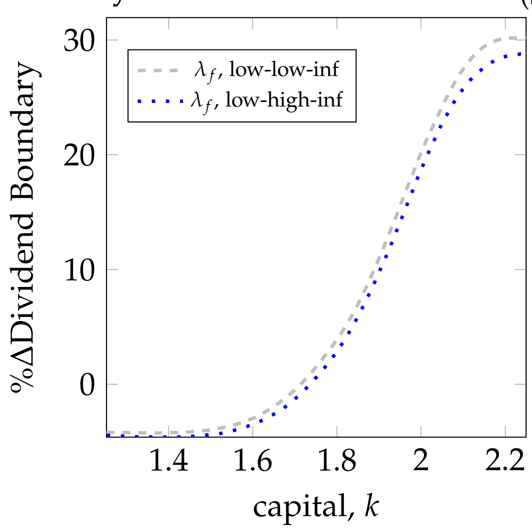


(a) **Issuance Boundary**



(b) **Investment**



(c) **Dividend**

Figure 11: **Counterfactual when λ_f increases in high-risk expansion regime**
The horizontal axis is a firm's capital stock k. The vertical axis is the percentage change in the outcome variable between the low-risk expansion regime (l) and the high-risk expansion regime (m). *low-low-inf* represents the benchmark model in which the corresponding fixed component of the issuance costs is fixed across the regimes l and m and increases to infinity in regime h. *low* means $\lambda_f = 0.005$ (the benchmark value, see Table 2). *low-high-inf* means that λ_f increases by a factor of 10 in the high-risk expansion regime.

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Table 1: Transition Probabilities

This table presents the transition probabilities between the three regimes s. We estimate the transition probabilities empirically. Specifically, we calculate the average quarterly probability of a future recession in one year for the period 1985 to 2022, derived from the term spread. (See Section 4.1 for an additional discussion of the recession risk measure.) We exclude quarters that contain NBER recessions. Then, we identify the 75th percentile cutoff recession probability, and use this threshold to separate quarters into the "expansion, low risk" and "expansion, high risk" regimes. Quarters with an NBER recession are labeled "recession." We annualize the quarterly probabilities.

		To		
		Expansion, Low-Risk	Expansion, High-Risk	Recession
From	Expansion, Low-Risk (l)	0.77	0.18	0.05
	Expansion, High-Risk (m)	0.38	0.46	0.16
	Recession (h)	0.52	0.19	0.29

Table 2: Model Parameters

Parameter	Meaning	Values	Comments
α	Curvature of the production function. When $\alpha < 1$, then diminishing returns to scale	0.84	Calibrated. The average degree of returns to scale across industries is 0.79 in Burnside (1996).
Ξ	Scale parameter for cash flow parameters μ_s and σ_s	1.35	Calibrated. In the data, estimates for μ_s/σ_s are stable across different levels of α. Therefore, μ_s and σ_s are scaled by the same factor A in their calibration. See B.1 for additional details.
μ_s	Expected cash flows are $\mu_s k_t^\alpha$	$l = m = \Xi \times 0.18$, $h = \Xi \times 0.14$	Calibrated using the scalar Ξ, which multiplies the mean cash flow to capital ratio. The mean cash flow to capital ratio of 0.18 is identical to Bolton, Chen and Wang (2011) and approximately the average firm-level mean EBITDA scaled by the lagged total assets less cash during expansions. The 0.14 for recessions is approximately the average firm-level mean of this Compustat ratio during recessions.
σ_s	Volatility of cash flows is $\sigma_s k_t^\alpha$	$l = m = \Xi \times 0.09$, $h = \Xi \times 0.14$	Calibrated using the scalar Ξ, which multiplies the standard deviation of cash flows to capital ratio. The standard deviation of cash flows to capital ratio of 0.09 is identical to that in Bolton, Chen and Wang (2011) and is similar using Compustat data to the average firm-level standard deviation of EBITDA scaled by lagged total assets less cash during expansions. The standard deviation of cash flows in recessions is challenging to measure because recessions are short. We scale the cash flow volatility of 0.09 up to 0.14 in accordance with the increase in the VIX in recessions of approximately 50%.
θ	Degree of adjustment costs	0.004	Provides the best match to empirical moments among three prominent values in the literature, when fitting in the calibration procedure of the calibrated parameters. In line with Catherine et al. (2022).
δ	Depreciation rate	7.24%	In line with the estimates of Eberly, Rebelo and Vincent (2009) for large U.S. firms.
λ_c	Cash holding cost, liquidity premium	1%	Cash may earn low returns because interest earned on a firm's cash holdings is taxed at the corporate tax rate, which generally exceeds the personal tax rate (Graham, 2000; Faulkender and Wang, 2006). Also, agency problems may lower cash returns (Jensen, 1986; Harford, 1999; Dittmar and Shivdasani, 2003; Pinkowitz, Stulz and Williamson, 2006; Dittmar and Mahrt-Smith, 2007; Harford, Mansi and Maxwell, 2008; Caprio, Faccio and McConnell, 2011; Gao, Harford and Li, 2013).
λ_p	Variable issuance cost	2.4%	This is higher than the estimate in Chen, Xu and Yang (2021) of 0.65% and modest relative to the 4%-6% for seasoned equity offerings in Altınkılıç and Hansen (2000).
$\lambda_{f,s}$	Fixed issuance cost	$l = m = 0.005$, $h = \infty$	For regimes l and m, the estimate is in line with the estimates of Altınkılıç and Hansen (2000). For the recession regime h, there is no empirical study on which we can rely for the estimates of issuance costs in a financial crisis for the obvious reason that there are virtually no initial public offerings or secondary equity offerings in a crisis. That is, issuances are procyclical and largely dry up in recessions (Covas and Den Haan, 2011; Bolton, Chen and Wang, 2013). Our choice of the parameter reflects the fact that raising external financing becomes extremely costly in a financial crisis.
ℓ_s	Recovery rate in liquidation of capital	$l = m = 1.0$, $h = 0.3$	The choice of ℓ is consistent with Hennessy and Whited (2007), where the average recovery rate is estimated to be 0.896 for the full sample of firms, so the liquidation value in the expansion regimes should be somewhat higher. As in Bolton, Chen and Wang (2013), the capital liquidation value in recessions is set to 30% to reflect the severe costs of asset fire sales during a crisis, when few investors have sufficiently deep pockets and when there is little appetite to acquire assets.
r	Interest rate	6%	In line with a long-term average yield to maturity on 30-year U.S. Treasuries.

Table 3: Calibration exercise

Panel A presents the two parameters we are calibrating and their calibrated values and standard errors in parentheses. These include the degree of diminishing returns to scale α and a scale parameter A for the cash flow parameters μ and σ. We calibrate their values by matching the five model-generated moments listed in Panel B. The sample moments are averages of the mean EBITDA to total assets ratio; mean cash to total assets ratio; mean net investment (capital expenditures less depreciation) to property, plant, and equipment ratio; standard deviation of the net investment ratio; and the autocorrelation of the net investment ratio. More details of the calibration procedure are presented in B.1, and an examination of how moments help identify the parameters is in B.2.

Panel A: Calibrated Parameters

Diminishing returns to scale (α)	0.84	(0.003)
Scale parameter for the cash flow parameters μ and σ (A)	1.35	(0.012)

Panel B: Sample Moments

	Sample	Model
Avg. firm-level mean EBITDA$_t$/(Total Assets$_{t-1}$) (%)	13.9	12.9
Avg. firm-level mean Cash$_t$/(Total Assets$_t$) (%)	14.1	19.5
Avg. firm-level mean Net Investment$_t$/(PP&E$_{t-1}$) (%)	2.5	0.7
Avg. firm-level standard deviation Net Investment$_t$/(PP&E$_{t-1}$) (%)	9.7	12.5
Avg. firm-level autocorrelation of Net Investment$_t$/(PP&E$_{t-1}$) (%)	43.1	35.6

Table 4: Summary Statistics

Variables winsorized at the 1% level.

Panel A: Firm-Quarter Panel	Obs.	Mean	Std. Dev.	P25	P50	P75
Probability of Future Recession (%)	385,066	10.3	10.8	1.4	6.4	16.9
Total Assets-Cash (Million)	385,066	2123.9	5912.5	82.1	293.6	1234.1
Cash and Short-Term Investments (Million)	385,066	198.9	601.9	4.3	23.7	108
Cash/(Total Assets-Cash) (%)	385,066	23.1	45.9	1.8	6.5	21.8
Net Property, Plant & Equipment (PP&E) (Million)	385,066	779.1	2441.3	20.4	75.1	363.4
Capital Expenditures (Million)	368,539	33.5	101.3	1.0	3.9	17.1
Capital Expenditures/(Total Assets-Cash) (%)	368,539	2.0	2.4	0.6	1.2	2.4
Capital Expenditures/PP&E (%)	368,539	6.1	5.6	2.5	4.5	7.9
%ΔCapital Expenditures from $(t-3,t)$ to $(t+1,t+4)$	236,057	26.5	87.0	-21.0	8.2	46.4
(Dividend+Repurchases)/(Total Assets-Cash) (%)	356,279	0.8	1.9	0.0	0.0	0.7
%ΔDividend+Repurchases from $(t-3,t)$ to $(t+1,t+4)$	158,888	132.1	634.3	-43.3	2.9	53.0
$\mathbb{1}$(Issuance Amount>30% of Total Assets-Cash) (%)	349,562	1.1	10.3	0.0	0.0	0.0
VIX	329,266	18.5	5.5	13.7	17.1	22.2
MKTRF	385,066	2.4	7.7	-.8	3.2	6.4
Probability in Recession Today (Chauvet)	385,066	0.7	2.9	0	0.1	0.3

Panel B: Stock-Month Panel	Obs.	Mean	Std. Dev.	P25	P50	P75
Probability of Future Recession (%)	943,266	10.2	10.9	1.3	6.2	16.8
Total Stock Return (%)	943,266	1.2	13.6	-6.0	0.4	7.5

Table 5: Recession risk and cash holdings immediately prior to issuance

This table reports estimates from specification (14). The sample includes firm-quarter observations immediately preceding an equity issuance in quarter $t+1$ greater than the specified cut-off ranging from 1% of total assets less cash at the end of quarter t to 75% of total assets less cash. We drop the IPO year from our sample. The outcome variable, $Cash_{i,t}$, is a firm's cash holdings at the end of quarter t, standardized within a firm in the full sample (including quarters not preceding issuance). *log(Recession Probability*$_t$*)*, is the quarter t log probability of a recession in one year. $Size_{i,t}$ is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm in the full sample. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP excess market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. The sample starts in 1990 in this table because the Volatility Index is only available starting in 1990. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\log(\text{Cash})_{i,t}$					
	(1)	(2)	(3)	(4)	(5)	(6)
log(Recession Probability$_t$)	-0.016	0.005	0.012	0.037	0.104***	0.170***
	(0.015)	(0.016)	(0.018)	(0.023)	(0.035)	(0.041)
log(Recession Probability$_t$) $\times$ $\log(\text{Size})_{i,t}$	0.024***	0.031**	0.048***	0.063***	0.107***	0.154***
	(0.009)	(0.012)	(0.016)	(0.021)	(0.027)	(0.033)
$\log(\text{Size})_{i,t}$	0.485***	0.336***	0.330***	0.364***	0.371***	0.337***
	(0.028)	(0.040)	(0.051)	(0.065)	(0.078)	(0.099)
Constant	0.064	-0.223***	-0.318***	-0.424***	-0.586***	-0.728***
	(0.058)	(0.066)	(0.068)	(0.078)	(0.120)	(0.139)
Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$	1%	5%	10%	25%	50%	75%
Business Cycle Controls	Yes	Yes	Yes	Yes	Yes	Yes
Mean $\log(\text{Size})_{i,t}$	5.2	4.9	4.8	4.4	4.1	3.9
% Adjusted R^2	18.63	14.04	13.39	13.82	15.06	17.94
Observations	33717	11458	7384	3919	2094	1386

Table 6: Sensitivity of investment to recession risk

This table reports estimates from specification (15). Recession risk decreases investment growth, especially when a firm is larger. The outcome variable is the growth of capital expenditures on property, plant, and equipment. To account for seasonality in investment across quarters and to allow firms time to adjust investment, we compare investment in the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to investment in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize these changes in investment within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession in twelve months. $Size_{i,t}$ is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP excess market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. The sample size decreases in column (2) because the Volatility Index is only available starting in 1990. We double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{CAPX}_{t+j}}{\sum_{j=-3}^{0} \text{CAPX}_{t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.030***	-0.030**
	(0.011)	(0.012)
log(Recession Probability$_t$) × log(Size)$_{i,t}$	-0.018***	-0.020***
	(0.006)	(0.007)
log(Size)$_{i,t}$	-0.186***	-0.215***
	(0.006)	(0.021)
Constant	0.017*	0.091**
	(0.009)	(0.038)
Business Cycle Controls	No	Yes
Mean log(Size)$_{i,t}$	6.1	6.2
% Adjusted R^2	2.73	3.03
Observations	233722	198524

Table 7: Sensitivity of payouts to recession risk

This table reports estimates from specification (16). The outcome variable is the growth in dividends and share repurchases. Because payout policies are sticky, we compare payouts over the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to payouts in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize payout growth within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession. $Size_{i,t}$ is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability that the economy is in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. The sample only includes firms with some variation in payouts, and the sample size decreases in column (2) because the Volatility Index is only available starting in 1990. We double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{Payouts}_{i,t+j}}{\sum_{j=-3}^{0} \text{Payouts}_{i,t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.008	-0.013
	(0.009)	(0.011)
log(Recession Probability$_t$) $\times$ log(Size)$_{i,t}$	-0.013**	-0.010*
	(0.005)	(0.006)
log(Size)$_{i,t}$	-0.041***	-0.052***
	(0.005)	(0.017)
Constant	0.002	-0.004
	(0.008)	(0.028)
Business Cycle Controls	No	Yes
Mean log(Size)$_{i,t}$	6.5	6.6
% Adjusted R^2	0.14	0.15
Observations	155340	128842

Table 8: Sensitivity of firm value to recession risk

This table reports estimates from specification (17). The outcome variable is firm i's total stock return in month t. Δ *log(Recession Probability$_t$)* is the month $t-1$ to t change in the probability of a recession. $Size_{i,t-12}$ is the log of the total assets of the firm i net of cash holdings a year ago, standardized within a firm. Controls for the business cycle include the percentage point change in VIX from month $t-1$ to t and the percentage point change in the probability that the economy is *currently* in a recession from month $t-1$ to t from Chauvet and Piger (2008). We interact these controls with $Size_{i,t-12}$ to allow small and large firms to have different sensitivities to the business cycle. The sample size decreases in column (2) because the Volatility Index is only available starting in 1990. Column (3) excludes the financial crisis years. We cluster the standard errors by month. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Stock Return$_{i,t}$		
	(1)	(2)	
Δ log(Recession Probability$_t$)	-0.052**	-0.067***	-0.070***
	(0.025)	(0.019)	(0.019)
Δ log(Recession Probability$_t$) $\times$ log(Size)$_{i,t-12}$	-0.032***	-0.018***	-0.019***
	(0.007)	(0.005)	(0.005)
log(Size)$_{i,t-12}$	-0.022***	-0.008	-0.010
	(0.006)	(0.040)	(0.041)
Constant	0.012	1.037***	1.029***
	(0.018)	(0.113)	(0.113)
Sample	All	All	Excl. 08/09
Controls	No	Yes	Yes
Mean log(Size)$_{i,t-12}$	5.8	6.0	6.0
% Adjusted R^2	0.31	5.53	5.48
Observations	943190	807664	794202

Appendix

This Appendix contains supplementary theoretical and empirical work. These include the following:

1. Appendix A provides proofs.
2. Appendix B details the numerical algorithm.
3. Appendix C provides additional empirical work.
   (a) Table C.2 shows the correlation of our recession probability measure with other leading indicators.
   (b) Table C.3 shows the Compustat sample selection criteria.
   (c) Table C.4 shows the CRSP sample selection criteria.
   (d) Table C.5 shows the annual Compustat sample selection criteria.
   (e) Robustness for Table 5, examining preemptive issuance to recession risk.
      i. Table C.6 repeats Table 5 adding long-term debt issuance.
      ii. Table C.7 repeats Table 5 using net plant, property, and equipment to proxy for firm size.
      iii. Table C.8 uses an indicator that equals one if recession risk exceeds the 75th percentile outside of NBER recessions.
   (f) Robustness for Table 6, examining investment and recession risk.
      i. Table C.9 uses net plant, property, and equipment to proxy for firm size.
      ii. Table C.10 adds firm fixed effects.
   (g) Robustness for Table 7, examining payouts and recession risk.
      i. Table C.11 uses net plant, property, and equipment to proxy for firm size.
      ii. Table C.12 adds firm fixed effects.
   (h) Robustness for Table 8, examining stock returns and recession risk.
      i. Table C.13 uses net plant, property, and equipment to proxy for firm size.
      ii. Table C.14 adds firm-by-year fixed effects, using monthly variation within a firm-year.
      iii. Table C.15 splits at the median sample month of December 2003.

iv. Table C.16 interacts recession risk with firm size standardized over the full cross-section of firms rather than within a firm.

A Proofs

We simplify the setting of the comparison proof by making the following assumption: For each k and s, there exists a cash level such that dividend payouts are optimal whenever c is above that level, and this level is continuous in k. Furthermore, since the proof compactifies in k, we, for expositional simplification, assume that this level is a constant $\bar{C}$. We may thus write the HJB equation on the domain

$$\mathcal{O} = [0, \infty) \times [0, \bar{C}] \times \{l, m, h\}, \tag{18}$$

with the additional boundary condition

$$\partial_c V = 1 \quad \text{where } c = \bar{C}. \tag{19}$$

This is indeed satisfied by the value function, and in the numerical experiments, we verify that this is correct by solving on larger domains and observing that the dividend boundary does not move.

Theorem 1. *Let u and v be, respectively, continuous viscosity sub- and supersolutions to (12) in $\mathcal{O}$ with the boundary conditions (13) and (19). Assume further that u and v are both of linear growth in c and polynomial growth in k, i.e., they take values in $[c, c + M + p(k)]$ for some constant $M > 0$ and polynomial p. Then, $u \leq v$ everywhere in $\mathcal{O}$.*

In the proof, we will use the result from Altarovici, Reppen and Soner (2017) establishing that the functions obtained from applying the issuance operator to u and v are continuous.

Proof. In this proof, we drop the dependence of μ_s and σ_s on the cycle s from the notation, as this dependence does not affect the arguments.

Suppose there exists a point at which $u > v$. Fix some $\eta_k > 0$ and consider $e^{-\eta_k k}(u - v)$, which, by the growth condition is bounded and attains a maximizer. We may therefore restrict ourselves to maximizers in a compact domain on which k is bounded by k^*, the latter depending only on η_k. Let $\hat{v}_\omega = (1 - \omega)v + \omega(1 + \lambda_p(s))c$, for some $\omega > 0$ small enough that $u > \hat{v}_\omega$ somewhere. From here on, we omit the ω in the notation: $\hat{v} = \hat{v}_\omega$.

Denote by $(\bar{k}, \bar{c}, \bar{s})$ a maximizer of $e^{-\eta_k k}(u - \hat{v})$. We may choose it so that $\{(\bar{k}, c, s) \in \mathcal{O} : c > \bar{c}\}$ does not contain any other maximizer. As a consequence, by the compactness of $\mathcal{O}$ in c, all points above $\bar{c}$ are take strictly lower values.

Let δ_η be the corresponding maximum. Define $\bar{f}(k,c,s) = \|(k,c,s) - (\bar{k},\bar{c},\bar{s})\|^4$ and

$$\begin{aligned}\Phi^\epsilon(k,c,s,\ell,d,t) &= e^{-\eta_k k}u(k,c,s) - e^{-\eta_k \ell}\hat{v}(\ell,d,t) \\ &\quad - \beta\bar{f}(k,c,s) - \frac{1}{2\epsilon}\Big((c-d)^2 + (k-\ell)^2 + (s-t)^2\Big) \quad \text{in } \mathcal{O}\times\mathcal{O}.\end{aligned}$$

Clearly,

$$\sup_{\mathcal{O}\times\mathcal{O}} \Phi^\epsilon \geq \Phi^\epsilon(\bar{k},\bar{c},\bar{s},\bar{k},\bar{c},\bar{s}) = e^{-\eta_k\bar{k}}\Big(u(\bar{k},\bar{c},\bar{s}) - \hat{v}(\bar{k},\bar{c},\bar{s})\Big) = \delta_\eta.$$

In particular, Φ^ϵ has a maximizer $(k_\epsilon, c_\epsilon, s_\epsilon, \ell_\epsilon, d_\epsilon, t_\epsilon)$ because of the growth conditions on u and v. Moreover, the growth conditions give an upper bound for this maximizer, depending only on η_k. Therefore, $(k_\epsilon, c_\epsilon, s_\epsilon, \ell_\epsilon, d_\epsilon, t_\epsilon)$ converges along a subsequence as $\epsilon \to 0$. From here on, let us only consider ϵ along this subsequence. Because the lower bound at the maximum above is independent of ϵ,

$$0 < \delta_\eta \leq \liminf_{\epsilon\to 0} \Phi^\epsilon(k_\epsilon, c_\epsilon, s_\epsilon, \ell_\epsilon, d_\epsilon, t_\epsilon),$$

which implies

$$\limsup_{\epsilon\to 0} \frac{1}{2\epsilon}\Big((c_\epsilon - d_\epsilon)^2 + (k_\epsilon - \ell_\epsilon)^2 + (s_\epsilon - t_\epsilon)^2\Big) < \infty,$$

so $(k_\epsilon, c_\epsilon, s_\epsilon), (\ell_\epsilon, d_\epsilon, t_\epsilon) \to (\bar{k},\bar{c},\bar{s})$. Note that $\bar{k} \leq k^*$, again because of the growth condition.

Rearranging terms and letting $\epsilon \to 0$,

$$\begin{aligned}\lim_{\epsilon\to 0}\beta\bar{f}(k_\epsilon, c_\epsilon, s_\epsilon) &+ \lim_{\epsilon\to 0}\frac{1}{2\epsilon}\Big((c_\epsilon - d_\epsilon)^2 + (k_\epsilon - \ell_\epsilon)^2 + (s_\epsilon - t_\epsilon)^2\Big) \\ &\leq \limsup_{\epsilon\to 0} e^{-\eta_k k_\epsilon}u(k_\epsilon, c_\epsilon, s_\epsilon) - e^{-\eta_k \ell_\epsilon}\hat{v}(\ell_\epsilon, d_\epsilon, t_\epsilon) - \delta_\eta \\ &\leq e^{-\eta_k\bar{k}}\Big(u(\bar{k},\bar{c},\bar{s}) - \hat{v}(\bar{k},\bar{c},\bar{s})\Big) - \delta_\eta \\ &\leq 0.\end{aligned}$$

That is,

$$\lim_{\epsilon\to 0}\beta\bar{f}(k_\epsilon, c_\epsilon, s_\epsilon) + \lim_{\epsilon\to 0}\frac{1}{2\epsilon}\Big((c_\epsilon - d_\epsilon)^2 + (k_\epsilon - \ell_\epsilon)^2 + (s_\epsilon - t_\epsilon)^2\Big) \leq 0. \tag{20}$$

If $\bar{k} = 0$, we directly obtain $u(\bar{c},0) \leq \bar{c} \leq v(\bar{c},0)$, which is a contradiction. If $\bar{c} = 0$, the situation is either similar or the issuance condition is active, in which case it can be treated similarly to the issuance condition on the interior. Hence, we resume with the case that $(\bar{k}, \bar{c}, \bar{s})$ lies in the interior, and therefore also $(k_\epsilon, c_\epsilon, s_\epsilon)$ and $(\ell_\epsilon, d_\epsilon, t_\epsilon)$ for sufficiently small ϵ.

Because the maxima are attained in interior points, we proceed to use Ishii's lemma. Since the equation only has a second derivative in c, we abuse notation and consider the corresponding elements of the jets as only the ∂_{cc}-component. We obtain $(p^u, X) \in \bar{J}^{2,+}(e^{-\eta_k k_\epsilon} u(k_\epsilon, c_\epsilon, s_\epsilon))$ and $(p^v, Y) \in \bar{J}^{2,-}(e^{-\eta_k \ell_\epsilon}(1-\omega)v(\ell_\epsilon, d_\epsilon, t_\epsilon))$ (Crandall, Ishii and Lions, 1992, Theorem 3.2), satisfying

$$\begin{aligned}
p_c &= \frac{c_\epsilon - d_\epsilon}{\epsilon} \\
p^u &= (p^u_c, p^u_k) = \left(p_c + 4\beta(c_\epsilon - \bar{c})^3, p^v_k + 4\beta(k_\epsilon - \bar{k})^3\right), \\
p^v &= (p^v_c, p^v_k) = \left(p_c - e^{-\eta_k \ell_\epsilon}\omega(1 + \lambda_p(t_\epsilon)), \frac{k_\epsilon - \ell_\epsilon}{\epsilon}\right)
\end{aligned}$$

and

$$k_\epsilon^{2\alpha} X - \ell_\epsilon^{2\alpha} Y \leq k_\epsilon^{2\alpha} 12\beta(c_\epsilon - \bar{c})^2 + \frac{(k_\epsilon^\alpha - \ell_\epsilon^\alpha)^2}{\epsilon} + o(1),$$

where $o(1)$ denotes a term that converges to 0 as $\epsilon \to 0$.

Because u is a subsolution, $\tilde{u} = e^{-\eta_k k} u$ satisfies

$$\begin{aligned}
0 \geq \min \Bigg\{ r\tilde{u} - \sup_{i \in [0, i_{\max}]} \Bigg(&\Big[i - \delta k_\epsilon\Big](\eta_k \tilde{u} + \partial_k \tilde{u}) \\
&+ \Big[(r - \lambda_c)c_\epsilon + k_\epsilon^\alpha \mu - i - g(k_\epsilon, i)\Big]\partial_c \tilde{u} \\
&+ \frac{1}{2} k_\epsilon^{2\alpha} \sigma^2 \partial^2_{cc} \tilde{u} \\
&+ \sum_{s'} q_{s_\epsilon, s'} \tilde{u}(k_\epsilon, c_\epsilon, s') \Bigg), \\
&\tilde{u}(k_\epsilon, c_\epsilon, s_\epsilon) - \sup_{I \geq 0} \Big[\tilde{u}(k_\epsilon, c_\epsilon + I, s_\epsilon) - e^{-\eta k_\epsilon}(I + \lambda(I, s_\epsilon))\Big], \\
&\partial_c \tilde{u} - e^{-\eta_k k_\epsilon} \Bigg\}.
\end{aligned} \tag{21}$$

Similarly, $\tilde{v} = e^{-\eta k}(1-\omega)v$ satisfies[16]

$$
\begin{aligned}
0 \leq \min \Bigg\{ r\tilde{v} - \sup_{i \in [0, i_{\max}]} & \Bigg(\Big[i - \delta \ell_\epsilon \Big] (\eta_k \tilde{v} + \partial_k \tilde{v}) \\
& \quad + \Big[(r - \lambda_c) d_\epsilon + \ell_\epsilon^\alpha \mu - i - g(\ell_\epsilon, i) \Big] \partial_c \tilde{v} \\
& \qquad + \frac{1}{2} \ell_\epsilon^{2\alpha} \sigma^2 \partial_{cc}^2 \tilde{v} \\
& \qquad \quad + \sum_{s'} q_{t_\epsilon, s'} \tilde{v}(\ell_\epsilon, d_\epsilon, s') \Bigg), \\
& \hat{v}(\ell_\epsilon, d_\epsilon, t_\epsilon) - \sup_{I \geq 0} \Big[\hat{v}(\ell_\epsilon, d_\epsilon + I, t_\epsilon) - e^{-\eta \ell_\epsilon} (I + \lambda(I, t_\epsilon)) \Big], \\
& \partial_c \tilde{v} - (1 - \omega) e^{-\eta_k \ell_\epsilon} \Bigg\}.
\end{aligned}
\tag{22}
$$

We split into two cases, depending on which expression is smallest in Equation (21). We begin with the simple case of

$$p_c^u \leq e^{-\eta_c k_\epsilon}.$$

Subtracting the two equations (21) and (22) thus gives

$$e^{\eta_k \ell_\epsilon} \omega (1 + \lambda_p(t_\epsilon)) + 4\beta (c_\epsilon - \bar{c})^3 = p_c^u - p_c^v \leq e^{-\eta_k k_\epsilon} - (1 - \omega) e^{-\eta_k \ell_\epsilon}.$$

Letting $\epsilon \to 0$, and dividing out equal factors, $\lambda_p(t_\epsilon) \leq 0$, which is a contradiction.

In the issuance case, because $\tilde{u}$ is continuous and $\lambda_f > 0$, there exist a (uniform as $\epsilon \to 0$) choice of $\underline{I}$ so that the optimization can be restricted to $I \geq \underline{I}$. We subtract the equations and pass to limits. Using the continuity of the issuance operator, $(\bar{k}, \bar{c}, \bar{s}) = (\bar{k}, \bar{c}, \bar{s})$, and the fact that $(\tilde{u} - \hat{v})(\bar{k}, \bar{c} + I, \bar{s})$ is strictly smaller than the maximum,

$$(\tilde{u} - \hat{v})(\bar{k}, \bar{c}, \bar{s}) \leq \sup_{I \geq \underline{I}} \Big[(\tilde{u} - \hat{v})(\bar{k}, \bar{c} + I, \bar{s}) \Big] < (\tilde{u} - \hat{v})(\bar{k}, \bar{c}, \bar{s}),$$

which is a contradiction.

[16] For convenience, we write the issuance expression in terms of $\hat{v}$, which we can do thanks to the growth rate of $1 + \lambda_p(s)$.

This leaves the final case, so we subtract the equations and get

$$
\begin{aligned}
r(\tilde{u}-\tilde{v}) \le \sup_{i\in[0,i_{\max}]} & \Big\{ \Big[i-\delta_\zeta k_\epsilon\Big](\eta_k \tilde{u}(k_\epsilon,c_\epsilon,s_\epsilon)+p_k^v+4\beta(k_\epsilon-\bar{k})^3) \\
& + \Big[(r-\lambda_c)c_\epsilon + k_\epsilon^\alpha \mu - i - g(k_\epsilon,i)\Big](p_c+4\beta(c_\epsilon-\bar{c})^3)+\frac{1}{2}k_\epsilon^{2\alpha}\sigma^2 X \\
& + \sum_{s'} q_{s_\epsilon,s'}\tilde{u}(k_\epsilon,c_\epsilon,s') \\
& - \Big[i-\delta_\zeta \ell_\epsilon\Big](\eta_k \tilde{v}(\ell_\epsilon,d_\epsilon,t_\epsilon)+p_k^v) \\
& - \Big[(r-\lambda_c)d_\epsilon + \ell_\epsilon^\alpha \mu - i - g(\ell_\epsilon,i)\Big](p_c^u - e^{-\eta_k \ell_\epsilon}\omega(1+\lambda_p(t_\epsilon)) \\
& - \sum_{s'} q_{t_\epsilon,s'}\tilde{v}(\ell_\epsilon,d_\epsilon,s') \\
& - \frac{1}{2}\ell_\epsilon^{2\alpha}\sigma^2 Y \Big\} \\
\le \sup_{i\in[0,i_{\max}]} & \Big\{ i\eta_k(\tilde{u}(k_\epsilon,c_\epsilon,s_\epsilon)-\tilde{v}(\ell_\epsilon,d_\epsilon,t_\epsilon)) \\
& + \Big[i-\delta_\zeta k_\epsilon\Big]4\beta(k_\epsilon-\bar{k})^3 \\
& + \Big[(r-\lambda_c)c_\epsilon + k_\epsilon^\alpha\mu - i - g(k_\epsilon,i)\Big]4\beta(c_\epsilon-\bar{c})^3 \\
& + \Big[(r-\lambda_c)d_\epsilon + \ell_\epsilon^\alpha\mu - i - g(\ell_\epsilon,i)\Big]e^{-\eta_k\ell_\epsilon}\omega(1+\lambda_p(t_\epsilon)) \\
& - \delta_\zeta(\ell_\epsilon-k_\epsilon)p_k^u + \Big[(k_\epsilon^\alpha-\ell_\epsilon^\alpha)\mu - (g(k_\epsilon,i)-g(\ell_\epsilon,i))\Big]p_c^v \\
& + 6k_\epsilon^{2\alpha}\sigma^2\beta(c_\epsilon-\bar{c})^2 + \frac{(k_\epsilon^\alpha-\ell_\epsilon^\alpha)^2}{\epsilon}\Big\} + o(1),
\end{aligned}
$$

where we use that $q_{s,s} = -\sum_{s'\neq s} q_{s,s'}$ and

$$
\begin{aligned}
&\sum_{s'} q_{s_\epsilon,s'}\tilde{u}(k_\epsilon,c_\epsilon,s') - \sum_{s'} q_{t_\epsilon,s'}\tilde{v}(\ell_\epsilon,d_\epsilon,s') \\
&\qquad = \sum_{s'} q_{s_\epsilon,s'}e^{-\eta_k k_\epsilon}u(k_\epsilon,c_\epsilon,s') - \sum_{s'} q_{t_\epsilon,s'}e^{-\eta_k\ell_\epsilon}\hat{v}(\ell_\epsilon,d_\epsilon,s') \le o(1),
\end{aligned}
$$

the latter because $e^{-\eta_k k}(u-\hat{v})$ is maximized at the limit $(\bar{k},\bar{c},\bar{s})$.

Let $\eta_k < (r-\Delta)/i_{\max}$ for some $\Delta \in (0,r)$. Then, taking lim sup as $\epsilon \to 0$, and using that $g(\cdot,i)$ and $k \mapsto k^\alpha$ are Lipschitz in the neighborhood of $(\bar{k},\bar{c},\bar{s})$, i.e.,

$$|g(k_\epsilon,i)-g(\ell_\epsilon,i)| + \mu|k_\epsilon^\alpha - \ell_\epsilon^\alpha| \le R|k_\epsilon-\ell_\epsilon|,$$

we get

$$\limsup_{\epsilon\to 0} \Delta(\tilde{u}(k_\epsilon, c_\epsilon, s_\epsilon) - \tilde{v}(\ell_\epsilon, d_\epsilon, t_\epsilon))$$
$$\le \lim_{\epsilon\to 0}\Bigg[(\delta_\zeta + R^2)\frac{(k_\epsilon-\ell_\epsilon)^2}{\epsilon} + R\frac{(c_\epsilon - d_\epsilon)}{\sqrt{\epsilon}}\frac{(k_\epsilon-\ell_\epsilon)}{\sqrt{\epsilon}}$$
$$+ R'(|c_\epsilon - \bar{c}|^2 + |c_\epsilon - \bar{c}|^3 + |k_\epsilon - \bar{k}|^3 + d_\epsilon\omega) + o(1)\Bigg] = R'\bar{c}\omega,$$

for some constant R', depending on k^* (i.e., η_k), $i_{\max}$, β, and the model parameters. Finally, because $\Delta > 0$, for small enough ω,

$$\delta_\eta/2 \le e^{-\eta\bar{k}}(u - (1-\omega)v)(\bar{k}, \bar{c}, \bar{s}) \le \frac{R'}{\Delta}\bar{c}\omega,$$

which is a contradiction, because $\bar{c} \le \bar{C}$ and ω can be chosen arbitrarily small. Hence, there cannot exist a point (c, k) such that $(u - v)(c, k) > 0$.

□

The value function is bounded by the value of a firm that is permanently in an expansion, which is bounded by $M + c + k$. As a consequence, V satisfies the assumptions of Theorem 1. The following results are standard consequences of the comparison of viscosity solutions.

Corollary 2. *The value function V is the unique solution to Equation (12) on (18) with its boundary conditions.*

For computations, in addition to (13), the boundary conditions where $c = c_{\max}$ and $k_{\max}$ are given by

$$0 = \partial_c V - 1 \qquad \text{at } c = c_{\max}$$
$$0 = \min\Bigg\{rV + \delta k\partial_k V - \Big[rc + k^\alpha\mu\Big]\partial_c V - \frac{1}{2}k^{2\alpha}\sigma^2\partial^2_{cc}V, \qquad \text{at } k = k_{\max}$$
$$\partial_c V - 1, V(k,c,s) - \sup_{I\ge 0}\Big(V(k, c+I, s) - I - \lambda(I,s)\Big)\Bigg\}$$

At the corners, the c-conditions are used.

Another consequence of the comparison result in Theorem 1 is the convergence of the numerical scheme (see Section B).

Corollary 3. *Numerical solutions converge to the value function as the discretization gets finer.*

B Numerical Algorithm

In this section, we provide a detailed overview of the policy iteration method as described in Kushner and Dupuis (2001) (Chapters 5 and 6), which is utilized to address the model at hand. Notably, the algorithm we propose has been proven to reliably converge to the unique solution of the Hamilton-Jacobi-Bellman (HJB) equation. The foundation for this convergence – anchored in the viscosity comparison theorem – along with the proof of the uniqueness of the value function that satisfies the HJB equation, is thoroughly documented in Appendix A. It is important to underscore some subtleties in applying the policy iteration method within this framework, particularly due to the impulsive and singular control of dividend payouts and equity issuance. To effectively navigate these singularities, our approach involves refining the problem through policy iteration, applied to a model that approximates the original by discretizing the problem space and introducing a penalty for singular behavior. This methodological adaptation is critical to handling the unique challenges posed by singular controls. For a deeper discussion of the convergence of our approach and its comparison with alternative strategies, we direct readers to the works of Azimzadeh and Forsyth (2016) and Reppen, Jean-Charles and Soner (2020).

For some policy $\pi = (\pi_{\text{inv}}, \pi_{\text{div}}, \pi_{\text{iss}})$, let π_{inv} denote the investment intensity, π_{div} denote whether dividends are paid, and π_{iss} the issuance amount. Let $\mathcal{C}_{\pi_{\text{inv}}} V$ be the expression in (11) with $i = \pi_{\text{inv}}$, and let $\mathcal{I}_{\pi_{\text{iss}}} V(k, c, s) = V(k, c + \pi_{\text{iss}}, s) - \pi_{\text{iss}} - \lambda(\pi_{\text{iss}}, s)$. For an optimal policy, we can then write the HJB equation (12) as

$$0 = \min\{\mathcal{C}_{\pi_{\text{inv}}} V, \mathcal{D}V, \mathcal{I}_{\pi_{\text{iss}}} V\}.$$

Next, define

$$\mathcal{M}_\pi V = \mathcal{C}_{\pi_{\text{inv}}} V + m 1_{\pi_{\text{div}}} \mathcal{D}V + m 1_{\{\pi_{\text{iss}} > 0\}} \mathcal{I}_{\pi_{\text{iss}}} V,$$

for some large $m \gg 1$. The equation

$$0 = \inf_\pi \mathcal{M}_\pi V$$

is referred to as a penalized version of the problem and has a natural stochastic representation as randomized activation of the control actions.

Finally, let $\mathcal{B}$ denote the discretized domain of computation[17] and, with some abuse of

[17] We select this domain to be substantially large and impose the following boundary conditions. At $k = 0$, the adjustment cost g is infinite for $i > 0$. Conversely, at $k = k_{max}$ (which is sufficiently large), the advantage of investment becomes negligible in comparison to the adjustment cost, because of diminishing

notation, $\mathcal{M}_\pi(k,c,s,k',c',s')$ the coefficient in the discretization of $\mathcal{M}_\pi$ for point (k',c',s') in the equation for (k,c,s). With an initial policy π^0, we iterate the following.

Policy iteration algorithm (step *i*)

1. Compute V^i such that

$$\sum_{(k',c',s')\in\mathcal{B}} \mathcal{M}_{\pi^i}(k,c,s,k',c',s')V^i(k',c',s') = 0, \quad \forall (k,c,s) \in \mathcal{B}.$$

   Halt if $V^i = V^{i-1}$.

2. For each $(k,c,s) \in \mathcal{B}$, compute $\pi^{i+1}(k,c,s)$ according to

$$\pi^{i+1}(k,c,s) \in \arg\min_{\hat{\pi}} \sum_{(k',c',s')\in\mathcal{B}} \mathcal{M}_{\hat{\pi}}(k,c,s,k',c',s')V^i(k',c',s').$$

   Set $\pi^{i+1} = \pi^i$ if possible.

3. Return to step (i).

Finally, it is crucial to ensure that $\mathcal{M}$ is discretized to become weakly diagonally dominant. This condition is met when the discretized operator can be interpreted as the transition matrix of a (continuous time) Markov chain. Then, Theorem 1 and Corollary 3 prove convergence (see Appendix A).

B.1 Estimation procedure

We implement the simulated method of moments (SMM) to calibrate the parameters Ξ, α, and θ in Table 3 (Gourieroux, Monfort and Renault (1993) and Gourieroux and Monfort (1996)). We denote the vector of parameters $\Phi = (\Xi, \alpha, \theta)$. The parameter Ξ is a scaling parameter for the cash flow parameters μ and σ. Within the Compustat dataset, we commence by computing both the average and standard deviation at the firm level for

$$\frac{\text{Cash Flow}_t}{(\text{Total Assets}_{t-1} - \text{Cash}_{t-1})^{\tilde{\alpha}}}$$

returns to scale and depreciation. Therefore, at both extremes, we set the boundary condition to no investment. With k_{max} set, we anticipate that the firm will optimally pay out excess cash for sufficiently large cash levels. Thus, we impose $\partial_c V = 1$ at $c = c_{max}$ and $k \in [0, k_{max}]$ as the boundary conditions, for c_{max} sufficiently large. We verify that the first group of terms on the right-hand side of equation (12) is positive, ensuring that c_{max} is of appropriate magnitude.

for different $\tilde{\alpha} \in [0,1]$. We denote them as $\text{Mean\_CK}_i(\tilde{\alpha})$ and $\text{Std\_CK}_i(\tilde{\alpha})$ for the firm i. Then we take cross-sectional mean of these two firm-level quantities:

$$\text{Mean\_CK}(\tilde{\alpha}) = \frac{1}{N}\sum_i \text{Mean\_CK}_i(\tilde{\alpha}) \quad \text{and} \quad \text{Std\_CK}(\tilde{\alpha}) = \frac{1}{N}\sum_i \text{Std\_CK}_i(\tilde{\alpha}),$$

where N denotes the number of firms in our sample. These are our empirical proxy for our model cash flow quantities $\mu k^{\alpha-\tilde{\alpha}}$ and $\sigma k^{\alpha-\tilde{\alpha}}$. In the data, the stability of the ratio $\frac{\text{Mean\_CK}(\tilde{\alpha})}{\text{Std\_CK}(\tilde{\alpha})}$ between different values of $\tilde{\alpha}$ suggests that the empirical mean and standard deviation of the firm cash flows are scaled by the same power function of k. Therefore, we can estimate the ratio μ/σ via $\text{Mean\_CK}(1)/\text{Std\_CK}(1)$. Subsequently, we introduce a scaling parameter, Ξ, to facilitate the identification of μ and σ:

$$\mu = \Xi \times \text{Mean\_CK}(1) \quad \text{and} \quad \sigma = \Xi \times \text{Std\_CK}(1).$$

For each vector of parameters given, we solve first for the optimal policy functions of the firm following the numerical algorithm outlined at the beginning of Section B. Then, we determine the firm's capital by randomly selecting from a uniform distribution over the interval $[0, \bar{k}(\Phi)]$, where $\bar{k}(\Phi)$ represents the maximum capital level at which the firm continues to invest in capital for some cash level. For each randomly sampled initial capital level k_0, the firm's initial cash holdings c_0 start from the dividend payout boundary at k_0.[18] Starting from the initial state (k_0, c_0), we discard the first four years of simulated dynamics to remove the effect of the initial conditions and then simulate the state dynamics of the firm for an additional 10 years using the optimal strategies of the firm. For each (k_0, c_0), we simulate 200 such paths and treat these as state trajectories of one firm. During the simulation for each firm, we calculate the firm-level average (1) EBITDA to total assets ratio (expected cash flow to capital ratio), (2) cash to total assets ratio, and (3) net investment (capital expenditures less depreciation) to property, plant, and equipment ratio. We also calculate (4) the standard deviation of the net investment ratio and (5) the autocorrelation of the net investment ratio. These moments are thus calculated for 200 paths for each (k_0, c_0). Finally, we take cross-sectional average of these firm-level moments and denote these five model-generated moments as the (column) vector $\Psi(\Phi)$.

[18]From the perspective of investors, this approach represents an optimal strategy. If investors start a firm by transfer of their own cash to the firm, they choose c_0 to maximize $V(k_0, c_0) - c_0 - pk_0$, where p is the price of capital. The first-order condition in c_0 implies that $V_c(k_0, c_0) = 1$, so c_0 is at least higher than the dividend boundary at k_0. The initial cash position is selected at the dividend boundary to ensure the firm avoids disbursing a lump-sum dividend immediately following its establishment. If that were the situation, investors would have the option to invest a smaller amount of cash into the firm at the outset.

Let $\{X_i\}_{i \in \{i,\dots,N\}}$ be the set of vectors of firm-level data (column). X_i represents the five firm-level moments for firm i. The cross-sectional mean of firm-level moments are

$$\Psi_D = \frac{1}{N}\sum_{i=1}^{N} X_i.$$

Define the function

$$g(\Phi, X) = X - \Psi(\Phi) \quad \text{and} \quad G(\Phi, \{X_i\}_{i=1}^N) = \frac{1}{N}\sum_{i=1}^{N} g(\Phi, X_i) = \Psi_D - \Psi(\Phi).$$

Denote the sample covariance of firm-level moments as

$$\Omega_D = \frac{1}{N}\sum_{i=1}^{N}(X_i - \Psi_D)(X_i - \Psi_D)'$$

Our calibrated parameters $\widehat{\Phi}$ in Table 3 are obtained by a two-step procedure. First, we obtain an initial point estimate for Φ, $\widetilde{\Phi}$, as

$$\widetilde{\Phi} = \text{arg min}_{\Phi} G(\Phi, \{X_i\}_{i=1}^N)' G(\Phi, \{X_i\}_{i=1}^N),$$

with the identity weight matrix. We calculate the updated weight matrix, $\widehat{W}$, via

$$\begin{aligned}
\widehat{W}^{-1} =& \frac{1}{N}\sum_{n=1}^{N} g(\widetilde{\Phi}, X_i) g(\widetilde{\Phi}, X_i)' \\
=& \frac{1}{N}\sum_{n=1}^{N} \Big(X_i - \Psi_D - (\Psi(\widetilde{\Phi}) - \Psi_D)\Big)\Big(X_i - \Psi_D - (\Psi(\widetilde{\Phi}) - \Psi_D)\Big)' \\
=& \frac{1}{N}\sum_{n=1}^{N} (X_i - \Psi_D)(X_i - \Psi_D)' + (\Psi(\widetilde{\Phi}) - \Psi_D)(\Psi(\widetilde{\Phi}) - \Psi_D)' \\
=& \Omega_D + (\Psi(\widetilde{\Phi}) - \Psi_D)(\Psi(\widetilde{\Phi}) - \Psi_D)'.
\end{aligned}$$

Second, we update the estimator of Φ to $\widehat{\Phi}$:

$$\widehat{\Phi} = \text{arg min}_{\Phi} G(\Phi, \{X_i\}_{i=1}^N)' \widehat{W} G(\Phi, \{X_i\}_{i=1}^N)'.$$

We optimize over Φ with $(\Xi, \alpha) \in [0.5, 1.5] \times [0.7, 0.9]$. Out of practical considerations, we restrict $\theta \in \{0.004, 1.5, 5.428\}$, which are the values found in Catherine et al. (2022), Whited (1992), Steri, Nikolov and Schmid (2019), respectively, and covers a wide range of magnitudes. We obtain the calibrated parameters $\widehat{\Phi}$ as an interior minimizer of the second step optimization problem, and we report them in Table 3.

The asymptotic distribution of $\widehat{\Phi}$ is given by[19]

$$\sqrt{N}(\widehat{\Phi} - \Phi_0) \sim N(0, \Omega),$$

where an estimate of the covariance matrix is given by

$$\widehat{\Omega} = \left\{ \left(\frac{\partial G}{\partial \Phi}(\widehat{\Phi}, \{X_i\}_{i=1}^N) \right)' \widehat{W} \left(\frac{\partial G}{\partial \Phi}(\widehat{\Phi}, \{X_i\}_{i=1}^N) \right) \right\}^{-1},$$

where the gradient $\frac{\partial G}{\partial \Phi}$ is approximated numerically by the difference quotient. Denote the diagonal matrix of $\widehat{\Omega}$ as $\text{diag}(\widehat{\Omega})$. Then the standard error of $\widehat{\Phi}$ is

$$\frac{1}{\sqrt{N}} \sqrt{\text{diag}(\widehat{\Omega})}.$$

[19]Because θ is optimized discretely, the well understood formulas used here cannot be applied to θ. Instead, we apply them to (Ξ, α) and note that they are to be understood as the θ-conditional values. In these formulas, we thus take $\Phi = (\Xi, \alpha)$.

Table B1: Comparative statics of the targeted moments with respect to the four estimated parameters

We simulate the model increasing one parameter at a time and report the change to the moments from the moments with the baseline parameterization. α is the curvature of the production function. Ξ scales the cash flow parameters μ and σ. We make negative perturbations simply to make sure that the computational domain does not need to be changed. The moments are averages of the mean EBITDA to total assets ratio; mean cash to total assets ratio; mean net investment (capital expenditures less depreciation) to property, plant, and equipment ratio; standard deviation of the net investment ratio; and the autocorrelation of the net investment ratio.

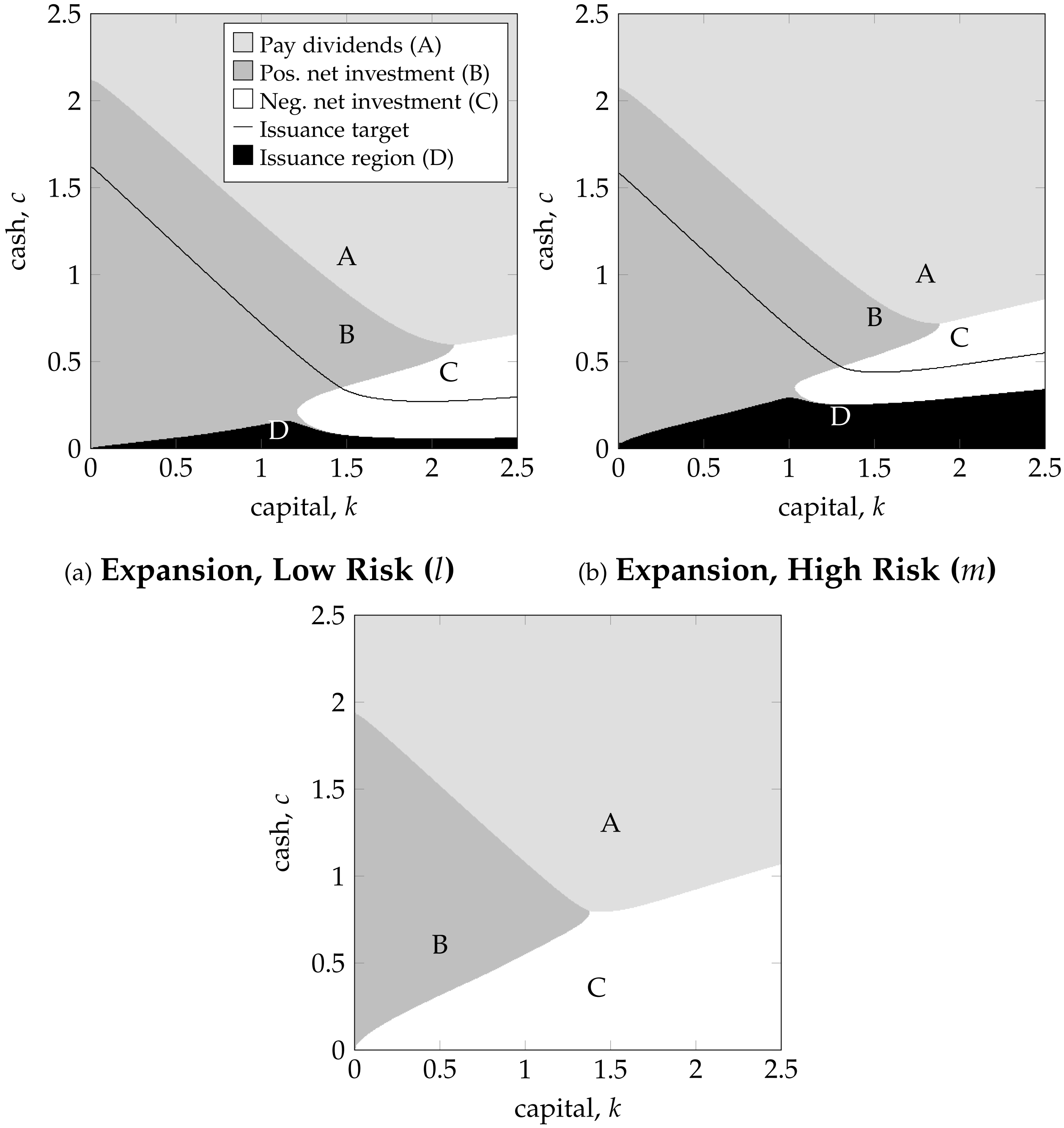
		Parameters	
		α	Ξ
	Change in parameter	-0.01	-0.05
		Change in moment	
Moments	Avg. firm-level mean $\text{EBITDA}_t/(\text{Total Assets}_{t-1})$ (%)	0.48	0.16
	Avg. firm-level mean $\text{Cash}_t/(\text{Total Assets}_t)$ (%)	-0.24	-0.18
	Avg. firm-level mean $\text{Net Investment}_t/(\text{PP\&E}_{t-1})$ (%)	-0.18	0.06
	Avg. firm-level standard deviation $\text{Net Investment}_t/(\text{PP\&E}_{t-1})$ (%)	-2.98	-3.7
	Avg. firm-level autocorrelation of $\text{Net Investment}_t/(\text{PP\&E}_{t-1})$ (%)	0.05	-0.03

B.2 Identification of parameters

We use an over-identified approach with two parameters and five moments. The two parameters are: the curvature of the production function α and a scalar A for the cash flow parameters μ and σ. The five data moments are firm averages of (1) the mean EBITDA to total assets ratio, (2) the mean cash to total assets ratio, (3) the mean net investment (capital expenditures less depreciation) to property, plant, and equipment ratio, (4) the standard deviation of the net investment ratio, and (5) the autocorrelation of the net investment ratio.

Table B1 shows how each moment varies with each parameter, which helps to identify the parameters.

B.3 Full state space figures



(a) **Expansion, Low Risk (l)**

(b) **Expansion, High Risk (m)**

(c) **Recession (h)**

Figure B1: **Optimal policies with time-varying recession risks**
This figure shows the firm's optimal policies in the (k, c) state space for low-risk expansion (panel a), high-risk expansion (panel b), and recession (panel c) regimes. Parameters used are summarized in Table 2.

C Empirical Appendix

Table C.1: Anecdotal Support

Source	Quote
Ann Hand (CEO, President, Chair) of Super League Gaming, Inc. (NASDAQ:SLGG) on Q1 2023 Results Conference Call May 15, 2023 5:00 PM ET	The continued uncertainty related to the federal interest rate policy, **potential recession** continuing to loom **cause large corporations to delay** finalizing 2023 advertising budgets.
Jordan Kaplan (President, CEO) of Douglas Emmett, Inc. (NYSE:DEI) Q1 2023 Earnings Conference Call May 3, 2023 2:00 PM ET	We continue to have strong demand from tenants under 10,000 square feet who dominate our markets, but because **larger tenants** have become more conservative in **response to recessionary concerns**, we leased less total square footage.
Chris Leahy (President, CEO, Chair) of CDW Corporation (CDW) Q1 2023 Results Conference Call May 3, 2023 8:30 AM ET	As the quarter progressed, IT demand weakened more than expected as a confluence of events intensified already **heightened economic concerns and recession fears**. This led to a **fairly rapid shift in customer behavior, most notably in our large commercial customers**. Projects that drove cost reduction, productivity, and financial returns were prioritized. Project justification and budget scrutiny ruled the day. And although deals were not canceled, sales cycles elongated, written sales slowed, and deal sizes compressed.
Scott Turicchi (CEO) of Consensus Cloud Solutions, Inc. (NASDAQ:CCSI) on Q4 2022 Results Conference Call February 22, 2023 5:00 PM ET	As you know, everybody's got their own view of the economy and whether we'll go into a recession...So, we don't see the economy being in a recession right now. Now independent of that, the **uncertainty of the economy**...has **delayed our larger customer decision-making**, which can impact and we did see it certainly impact revenue to some extent in Q3 and definitely in Q4.
Thomas Amato (President, CEO) of TriMas Corporation (NASDAQ:TRS) on Q3 2022 Earnings Conference Call October 27, 2022 10:00 AM ET	This effect, along with continued new cycles mentioning a **pending recession** is indeed creating a cautious planning environment, which we are most acutely seeing within products sold into personal care applications. For example, **several of our largest consumer goods customers** are faced with higher dispenser stocks than normal and have therefore **decided to take a much more conservative approach** to increasing stock in anticipation of their seasonal selling period.
Bob Rivers (CEO, Chair) of Eastern Bankshares, Inc. (NASDAQ:EBC) on Q2 2022 Earnings Conference Call July 29, 2022 9:00 AM ET	Despite the uncertainty brought about by COVID and the shift to remote work, the impacts of higher inflation in the **spectre of recession**, Greater Boston is considered by many among the best-performing office markets in the country, **bolstered by** high diversity industry sectors, **relatively low reliance on large tenants** and the tailwinds of strong demand for life sciences space.

Table C.2: Correlation of the recession probability measure with other leading indicators

Recession Prob. is the month *t* probability of the U.S. being in a recession in one year according to the term spread, calculated as the difference between the 10-year and 3-month Treasury rates. It gives the probability of the U.S. being in a recession in one year. *VIX* is the month *t* level of the CBOE Volatility Index. *BC* is the current state of the business cycle, which is the month *t* probability that the U.S. is *currently* in a recession (Chauvet and Piger, 2008). *CPSB* is the 3-month commercial paper rate minus the federal funds rate. *XRI* is the month *t* value of the Experimental Recession Index from Stock and Watson (1989). It gives the probability of the U.S. being in a recession in six months. The index includes industrial production, real personal income, real manufacturing, total employee hours, housing permits, real manufacturers' unfilled orders, exchange rates, number of people working part-time, the 10-year Treasury bond yields, the spread between the 3-month commercial paper rate and the interest rate on 3-month Treasury bills, and the spread between the 10-year Treasury bonds and the 1-year Treasury bonds. *XRI-2* is the month *t* value of the Alternative Experimental Recession Index from Stock and Watson (1993). It gives the probability of being in a recession in six months. The index includes building permits, manufacturers' unfilled orders, exchange rates, help wanted advertising, average weekly hours of production workers, vendor performance, and manufacturing capacity utilization rates. *S&P 500* is the month *t* return on the S&P 500 index. *NYSE* is the month *t* return on the NYSE index. *AI* is the Anxious Index based on the Survey of Professional Economists, which has asked economists to estimate the probability of quarter-over-quarter chain-weighted real GDP growth less than zero for the current quarter (RECESS1) and the following four quarters (RECESS2 to RECESS5). RECESS2 is known as the "Anxious Index." See Andrade and Le Bihan (2013).

Variables	Recession Prob.	VIX	BC	CPSB	XRI	XRI-2	S&P 500	NYSE	AI
Recession Prob.	1.00								
VIX	-0.00	1.00							
BC	0.05	0.50	1.00						
CPSB	-0.18	0.23	0.44	1.00					
XRI	0.60	0.27	0.60	-0.16	1.00				
XRI-2	0.33	-0.29	0.73	-0.41	0.68	1.00			
S&P 500	0.03	-0.39	-0.15	-0.18	-0.07	0.05	1.00		
NYSE	0.05	-0.41	-0.16	-0.23	-0.08	0.06	0.97	1.00	
AI	0.16	0.39	0.60	0.24	0.58	0.55	-0.02	-0.01	1.00

Table C.3: Quarterly Compustat Sample Selection

This table presents the criteria used to prepare the firm-quarter dataset.

Criteria	Obs. Lost	Obs. Remaining
COMPUSTAT, 1961Q1 – 2021Q2		1,863,593
Less:		
Pre-IPO Data	(114,054)	1,749,539
Firms headquartered outside of USA	(321,773)	1,427,766
Firms incorporated outside of USA	(20,026)	1,407,740
Financials (SIC-1=6)	(396,540)	1,011,200
Utilities (SIC-2=49)	(72,154)	939,046
Public Administration (SIC-1=9)	(18,930)	920,116
Missing or zero assets	(114,561)	805,555
Missing cash and cash equivalents	(2,607)	802,948
Drop gvkey-quarter duplicates	(712)	802,236
PP&E less than $5M or missing PP&E	(274,469)	527,767
Negative cash and cash equivalents	(371)	527,396
Less than $1M in sales	(12,433)	514,963
Drop if data before 1971	(9)	514,954
Singleton Firms	(373)	514,581
SIC-4 industries-quarters with one firm	(9,226)	505,355
Drop quarters in NBER recessions	(62,019)	443,336
Drop quarters before Great Moderation (1985Q1)	(58,270)	385,066
Final sample (11,495 firms, 1985Q1-2021Q4)		385,066

Table C.4: CRSP Sample Selection

This table presents the criteria used to prepare the monthly stock return dataset. We start with the full CRSP/Compustat Merged Database (LC and LU Linktypes only). However, these data do not include cash holdings and property, plant, and equipment (PP&E). We use cash and PP&E to sort firms. Also, we need to apply similar filtering across the CRSP stock return data and the Compustat data. To do so, we merge the CRSP/Compustat data file with the filtered annual Compustat data. See Table C.5 for the sample selection criteria for the annual Compustat data.

Criteria	Obs. Lost	Obs. Remaining
CRSP/Compustat Merged Database , 1962-Jun — 2020-Dec		3,709,031
Merge with annual Compustat sample lagged two years	(2,281,677)	1,427,354
Missing stock returns	(7,337)	1,420,017
Drop months in NBER recessions	(172,254)	1,247,763
Drop months before Great Moderation (Jan 1985)	(304,497)	943,266
Final sample, 1985-Jan — 2020-Dec (8,761 firms)		943,266

Table C.5: Annual Compustat Sample Selection

The table presents the criteria used to prepare the firm-annual dataset that is merged with the CRSP/Compustat dataset in Table C.4. The criteria are similar to those used in Table C.3 to construct the quarterly Compustat sample.

Criteria	Obs. Lost	Obs. Remaining
COMPUSTAT, 1950 – 2020		579,219
Less:		
Pre-IPO data	(43,700)	535,519
Firms headquartered outside of USA	(91,666)	443,853
Firms incorporated outside of USA	(5,501)	438,352
Financials (SIC-1=6)	(140,116)	298,236
Utilities (SIC-2=49)	(20,915)	277,321
Public administration (SIC-1=9)	(5,127)	272,194
Missing or zero assets	(12,326)	259,868
Missing cash and cash equivalents	(482)	259,386
Drop duplicates gvkey-year	(1,252)	258,134
PP&E less than $5M or missing PP&E	(94,889)	163,245
Negative cash and cash equivalents	(13)	163,232
Less than $1M in sales	(1,345)	161,887
Singleton firms	(1,317)	160,570
SIC-4-by-year groups one firm	(3,739)	156,831
Drop if prior to 1980	(38,386)	114,943
Final sample (10,828 firms)		114,943

Table C.6: Recession risk and cash holdings immediately prior to total issuance (equity plus long-term debt)

This table reports estimates from specification (14). The sample includes firm-quarter observations immediately preceding an equity plus long-term debt issuance in quarter $t+1$ greater than the specified cut-off ranging from 75% to 115% of total assets less cash at the end of quarter t. The outcome variable, $Cash_{i,t}$, is a firm's cash holdings at the end of quarter t, standardized within a firm. We drop the IPO year from our sample. *log(Recession Probability$_t$)*, is the quarter t log probability of a recession in twelve months. $Size_{i,t}$ is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\log(\text{Cash})_{i,t}$		
	(1)	(2)	(3)
log(Recession Probability$_t$)	0.101***	0.102**	0.126**
	(0.039)	(0.043)	(0.051)
log(Recession Probability$_t$) $\times$ $\log(\text{Size})_{i,t}$	0.118***	0.123***	0.146***
	(0.031)	(0.035)	(0.041)
$\log(\text{Size})_{i,t}$	0.443***	0.437***	0.505***
	(0.103)	(0.102)	(0.114)
Constant	-0.481***	-0.539***	-0.558***
	(0.119)	(0.131)	(0.158)
Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$	75%	90%	115%
Business Cycle Controls	Yes	Yes	Yes
% Adjusted R^2	17.62	17.39	17.11
Observations	1820	1405	959

Table C.7: Robustness of Table 5 to using plant, property, and equipment to proxy for firm size

The sample includes firm-quarter observations immediately preceding an equity issuance in quarter $t+1$ greater than 30% (columns 1-2), 50% (column 3), and 70% (column 4) of total assets less cash holdings at the end of quarter t. The outcome variable, $Cash_{i,t}$, is a firm's cash holdings at the end of quarter t, standardized within a firm. We drop the IPO year from our sample. *log(Recession Probability*$_t$*)*, is the quarter t log probability of a recession in twelve months. *log(PP&E)*$_{i,t}$ is the log of firm i's net property, plant, and equipment at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with *log(PP&E)*$_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	log(Cash)$_{i,t}$			
	(1)	(2)	(3)	(4)
log(Recession Probability$_t$)	0.044**	0.050**	0.077***	0.064*
	(0.022)	(0.021)	(0.028)	(0.035)
log(Recession Probability$_t$) $\times$ log(PP&E)$_{i,t}$	0.048***	0.043**	0.078***	0.064**
	(0.017)	(0.017)	(0.020)	(0.027)
log(PP&E)$_{i,t}$	0.313***	0.076**	0.021	0.045
	(0.020)	(0.033)	(0.037)	(0.042)
Constant	0.660***	0.566***	0.463***	0.326***
	(0.027)	(0.092)	(0.102)	(0.113)
Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$	30%	30%	50%	70%
Business Cycle Controls	No	Yes	Yes	Yes
% Adjusted R^2	9.18	12.29	12.13	12.64
Observations	3700	3341	2094	1488

Table C.8: Robustness of Table 5 to using an indicator for above 75th-percentile recession risk

The sample includes firm-quarter observations immediately preceding an equity issuance in quarter $t+1$ greater than 30% (columns 1-2), 50% (column 3), and 70% (column 4) of total assets less cash holdings at the end of quarter t. The outcome variable, $Cash_{i,t}$, is a firm's cash holdings at the end of quarter t, standardized within a firm. We drop the IPO year from our sample. $\mathbb{1}(High\ Risk)_t$ is an indicator that equals one if the quarter t average probability of a recession in twelve months exceeds the 75th percentile of recession risk outside of NBER recessions. $Size_{i,t}$ is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with $Size_{i,t}$ to allow small and large firms to have different sensitivities to the business cycle. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	log(Cash)$_{i,t}$			
	(1)	(2)	(3)	(4)
$\mathbb{1}$(High Risk)$_t$	-0.014	0.003	0.018	-0.016
	(0.045)	(0.048)	(0.065)	(0.064)
$\mathbb{1}$(High Risk)$_t$ $\times$ log(Size)$_{i,t}$	0.093**	0.098***	0.164***	0.162***
	(0.036)	(0.031)	(0.043)	(0.049)
log(Size)$_{i,t}$	0.351***	0.291***	0.189**	0.180*
	(0.021)	(0.062)	(0.077)	(0.095)
Constant	0.727***	0.690***	0.578***	0.436***
	(0.032)	(0.093)	(0.106)	(0.116)
Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$	30%	30%	50%	70%
Business Cycle Controls	No	Yes	Yes	Yes
% Adjusted R^2	11.82	12.58	12.30	13.05
Observations	3700	3341	2094	1488

Table C.9: Robustness of Table 6 to using plant, property, and equipment to proxy for firm size

Recession risk decreases investment growth, especially when a firm is larger. The outcome variable is the growth of capital expenditures on property, plant, and equipment. To account for seasonality in investment across quarters, we compare investment in the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to investment in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize these changes in investment within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession in twelve months. *Size$_{i,t}$* is the log of firm i's net plant, property, and equipment assets at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with *log(PP&E)$_{i,t}$* to allow small and large firms to have different sensitivities to the business cycle. We double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{CAPX}_{t+j}}{\sum_{j=-3}^{0} \text{CAPX}_{t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.029***	-0.031***
	(0.011)	(0.012)
log(Recession Probability$_t$) × log(PP&E)$_{i,t}$	-0.017***	-0.019**
	(0.006)	(0.007)
log(PP&E)$_{i,t}$	-0.278***	-0.385***
	(0.006)	(0.009)
Constant	0.025***	0.072**
	(0.009)	(0.035)
Business Cycle Controls	No	Yes
% Adjusted R^2	5.80	6.72
Observations	233722	198524

Table C.10: Robustness of Table 6 to using firm fixed effects

This table reports estimates from specification (15). Recession risk decreases investment growth, especially when a firm is larger. The outcome variable is the growth of capital expenditures on property, plant, and equipment. To account for seasonality in investment across quarters, we compare investment in the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to investment in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize these changes in investment within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession in twelve months. *Size$_{i,t}$* is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with *Size$_{i,t}$* to allow small and large firms to have different sensitivities to the business cycle. We include firm fixed effects and double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{CAPX}_{t+j}}{\sum_{j=-3}^{0} \text{CAPX}_{t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.028**	-0.028**
	(0.012)	(0.014)
log(Recession Probability$_t$) × log(Size)$_{i,t}$	-0.019**	-0.027***
	(0.008)	(0.008)
log(Size)$_{i,t}$	-0.204***	-0.229***
	(0.008)	(0.027)
Constant	0.019**	0.105**
	(0.009)	(0.043)
Firm FE	Yes	Yes
% Adjusted R^2	-0.42	0.69
Observations	233681	198500

Table C.11: Robustness of Table 7 to using plant, property, and equipment

The outcome variable is payout (dividends and repurchases) growth. Because payout policies are sticky, we compare payouts over the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to payouts in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize payout growth within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession. *Size$_{i,t}$* is the log of firm i's net plant, property, and equipment at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with *log(PP&E)$_{i,t}$* to allow small and large firms to have different sensitivities to the business cycle. We double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{Payouts}_{i,t+j}}{\sum_{j=-3}^{0} \text{Payouts}_{i,t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.009	-0.015
	(0.009)	(0.011)
log(Recession Probability$_t$) $\times$ log(PP&E)$_{i,t}$	-0.011**	-0.006
	(0.005)	(0.005)
log(PP&E)$_{i,t}$	-0.044***	-0.045***
	(0.005)	(0.006)
Constant	0.001	-0.013
	(0.008)	(0.029)
Firm Size	All	All
Business Cycle Controls	No	Yes
% Adjusted R^2	0.16	0.19
Observations	155340	128842

Table C.12: Robustness of Table 7 to using firm fixed effects

This table reports estimates from specification (16). The outcome variable is payout (dividends and repurchases) growth. Because payout policies are sticky, we compare payouts over the future four quarters ($t+1$, $t+2$, $t+3$, and $t+4$) to payouts in the prior four quarters ($t-3$, $t-2$, $t-1$, and t). We standardize payout growth within a firm. *log(Recession Probability$_t$)*, is the quarter t average monthly probability of a recession. *Size$_{i,t}$* is the log of firm i's total assets less cash holdings at the end of quarter t, standardized within a firm. Controls for the business cycle include the average Volatility Index in quarter t, the CRSP market return in quarter t, and the probability of the economy being in a recession in quarter t (not $t+4$) from Chauvet and Piger (2008). We interact these controls with *Size$_{i,t}$* to allow small and large firms to have different sensitivities to the business cycle. We include firm fixed effects and double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	$\left(\frac{\sum_{j=1}^{4} \text{Payouts}_{i,t+j}}{\sum_{j=-3}^{0} \text{Payouts}_{i,t+j}} - 1\right)$	
	(1)	(2)
log(Recession Probability$_t$)	-0.008	-0.018
	(0.010)	(0.011)
log(Recession Probability$_t$) $\times$ log(Size)$_{i,t}$	-0.016***	-0.017**
	(0.006)	(0.006)
log(Size)$_{i,t}$	-0.047***	-0.046**
	(0.006)	(0.020)
Constant	0.004	0.007
	(0.008)	(0.030)
Firm FE	Yes	Yes
% Adjusted R^2	-3.51	-2.42
Observations	155313	128819

Table C.13: Robustness of Table 8 to using property, plant, and equipment to proxy for firm size

This table reports estimates from specification (17). The outcome variable is firm i's total stock return in month t. Δ *log(Recession Probability$_t$)* is the month $t-1$ to t change in the probability of a recession. *log(PP&E)$_{i,t}$* is the log of firm i's net property, plant, and equipment a year ago, standardized within a firm. Controls for the business cycle include the percentage point change in VIX from month $t-1$ to t and the percentage point change in the probability that the economy is *currently* in a recession from month $t-1$ to t from Chauvet and Piger (2008). We interact these controls with *log(PP&E)$_{i,t-12}$* to allow small and large firms to have different sensitivities to the business cycle. Column (3) excludes the financial crisis years. We cluster the standard errors by month. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Stock Return$_{i,t}$		
	(1)	(2)	(3)
Δ log(Recession Probability$_t$)	-0.051**	-0.067***	-0.070***
	(0.025)	(0.019)	(0.019)
Δ log(Recession Probability$_t$) $\times$ log(PP&E)$_{i,t}$	-0.026***	-0.016***	-0.017***
	(0.006)	(0.005)	(0.005)
log(PP&E)$_{i,t}$	-0.020***	-0.005	-0.004
	(0.005)	(0.006)	(0.006)
Constant	0.011	1.037***	1.028***
	(0.018)	(0.113)	(0.114)
Sample	All	All	Excl. 08/09
Controls	No	Yes	Yes
% Adjusted R^2	0.28	5.53	5.47
Observations	943190	807664	794202

Table C.14: Robustness of Table 8 to using firm fixed effects

This table reports estimates from specification (17). The outcome variable is firm i's total stock return in month t. Δ *log(Recession Probability$_t$)* is the month $t-1$ to t change in the probability of a recession. $Size_{i,t-12}$ is the log of the total assets of the firm i net of cash holdings a year ago, standardized within a firm. Controls for the business cycle include the percentage point change in VIX from month $t-1$ to t and the percentage point change in the probability that the economy is *currently* in a recession from month $t-1$ to t from Chauvet and Piger (2008). We interact these controls with $Size_{i,t-12}$ to allow small and large firms to have different sensitivities to the business cycle. Column (3) excludes the financial crisis years. We include firm-by-year fixed effects and cluster the standard errors by month. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Stock Return$_{i,t}$		
	(1)	(2)	(3)
Δ log(Recession Probability$_t$)	-0.051*	-0.062***	-0.065***
	(0.027)	(0.022)	(0.022)
Δ log(Recession Probability$_t$) $\times$ log(Size)$_{i,t-12}$	-0.033***	-0.017***	-0.019***
	(0.008)	(0.006)	(0.006)
Constant	0.010	1.032***	1.027***
	(0.019)	(0.121)	(0.121)
Sample	All	All	Excl. 08/09
Firm $\times$ Year FE	Yes	Yes	Yes
Controls	No	Yes	Yes
% Adjusted R^2	-0.40	5.11	5.04
Observations	942653	807196	793749

Table C.15: Robustness of Table 8 to splits at the median sample month of December 2003

This table reports estimates from specification (17). The outcome variable is firm *i*'s total stock return in month *t*. Δ *log(Recession Probability$_t$)* is the month $t-1$ to t change in the probability of a recession. $Size_{i,t-12}$ is the log of the total assets of the firm *i* net of cash holdings a year ago, standardized within a firm. Controls for the business cycle include the percentage point change in VIX from month $t-1$ to t and the percentage point change in the probability that the economy is *currently* in a recession from month $t-1$ to t from Chauvet and Piger (2008). We interact these controls with $Size_{i,t-12}$ to allow small and large firms to have different sensitivities to the business cycle. Column (1) includes firm-month observations up to December 2003. Column (2) includes firm-month observations after December 2003. We cluster the standard errors by month. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Stock Return$_{i,t}$	
	(1)	(2)
Δ log(Recession Probability$_t$)	-0.061**	-0.077***
	(0.027)	(0.028)
Δ log(Recession Probability$_t$) × log(Size)$_{i,t-12}$	-0.014**	-0.022***
	(0.007)	(0.007)
log(Size)$_{i,t-12}$	-0.037	0.030
	(0.034)	(0.032)
Constant	1.078***	1.007***
	(0.164)	(0.140)
Sample Period	Pre Dec 2003	Post Dec 2003
% Adjusted R^2	3.75	7.93
Observations	405561	402103

Table C.16: Table 8 in the cross-section of firms

This table reports estimates from specification (17). The outcome variable is firm i's total stock return in month t. Δ *log(Recession Probability$_t$)* is the month $t-1$ to t change in the probability of a recession. **$Size_{i,t-12}$ is the log of the total assets of the firm i net of cash holdings a year ago, standardized over the full sample rather than within a firm.** Controls for the business cycle include the percentage point change in VIX from month $t-1$ to t and the percentage point change in the probability that the economy is *currently* in a recession from month $t-1$ to t from Chauvet and Piger (2008). We interact these controls with $Size_{i,t-12}$ to allow small and large firms to have different sensitivities to the business cycle. Column (3) excludes the financial crisis years. We cluster the standard errors by month. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

	Stock Return$_{i,t}$		
	(1)	(2)	(3)
Δ log(Recession Probability$_t$)	-0.048*	-0.064***	-0.067***
	(0.025)	(0.019)	(0.019)
Δ log(Recession Probability$_t$) $\times$ log(Size)$_{i,t-12}$	-0.035***	-0.020**	-0.021**
	(0.011)	(0.009)	(0.009)
log(Size)$_{i,t-12}$	-0.004	0.003	0.002
	(0.008)	(0.007)	(0.007)
Constant	0.011	1.034***	1.026***
	(0.018)	(0.114)	(0.114)
% Adjusted R^2	0.30	5.54	5.49
Observations	943225	807664	794202