# Before the Storm: Firm Policies and Varying Recession Risk *

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**Abstract**

Recession risk fluctuates substantially "before the storm," yet little is known about how firms of different sizes adapt their policies accordingly. We embed time-varying recession risk into a model of liquidity management and investment, allowing firms to time their precautionary policies. Estimation reveals that small firms are less sensitive than large firms in their issuance, payout, and investment strategies to variations in recession risk. This is because small firms proactively build larger cash reserves relative to their current cash flow volatility during periods of low recession risk, anticipating that aggressive investment will gradually drain liquidity, grow cash flow volatility and raise the risk of liquidation if a recession occurs. In contrast, large firms rely on robust cash flows to replenish liquidity during periods of low recession risk, deferring other precautionary actions until recession risk intensifies. These results have important implications for estimating the impact of recessions and macroprudential policy.

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# 1 Introduction

Firm policies vary with macroeconomic conditions (e.g., Chen, 2010; Bhamra et al., 2023). During economic expansions, firms may anticipate recessions and increase precautionary cash holdings by adjusting issuance, investment, and payout policies. However, little is known about how firms respond to *changes* in the risk of a future recession during economic expansions and, especially, how these responses vary with the firm's size. That is, we still do not know which firms act preemptively when the recession risk is low, versus those that *endogenously delay* action until the recession risk becomes high.

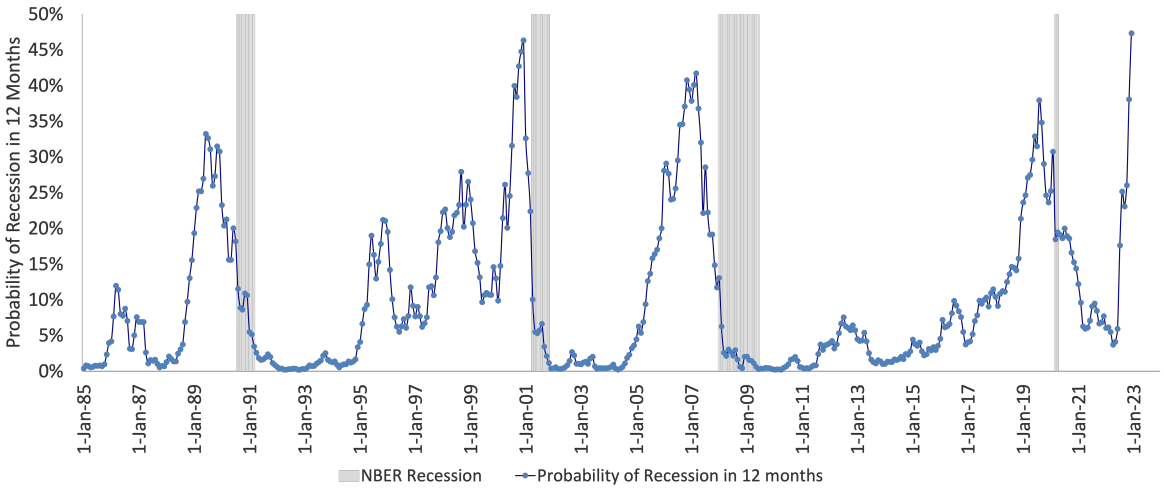



Figure 1: **Time Varying Recession Risk**
Shows the probability of being in a recession one year later, for the period 1985-2022. Gray bars indicate recessions identified by the NBER. Source: Federal Reserve Bank of New York.
www.newyorkfed.org/research/capital_markets/ycfaq#/

Modeling time-varying recession risk is important for several reasons. First, as shown in Figure 1, recession risk fluctuates considerably—contrary to the common assumption of constancy in the theoretical literature. The estimated probability of a U.S. recession one year ahead, based on the Treasury term spread, has a monthly standard deviation of about 11 percentage points.[1] Second, understanding when and how firms prepare for future regime shifts—including whether they delay preparations until risk increases—has important implications for estimating the impact of recessions (Bolton, Chen and Wang, 2013) and macroprudential policy, such as banking regulation, economic stimulus, and monetary policy. Third, our finding that larger firms defer precautionary actions until

[1]Among various predictors, Estrella and Mishkin (1998) finds the term spread to be the most reliable. It is widely cited, including by The Wall Street Journal, which calls it "Wall Street's Top Recession Gauge." See www.wsj.com/articles/what-wall-streets-top-recession-gauge-is-saying-now-67232353.

recession risk increases contributes to the limited literature on size-based differences in business cycle sensitivity, as noted by Crouzet and Mehrotra (2020).

In our theoretical framework, a representative firm cycles between expansions and recessions. In a recession, external financing frictions tighten and a firm's cash flows decrease and are more volatile. In expansions, we distinguish between two regimes—one with low and one with high recession probability—that are otherwise identical, allowing us to isolate the effects of time-varying recession risk on firm policies. Unlike traditional two-regime models with constant recession risk that capture preemptive actions (e.g., Bolton, Chen and Wang, 2013), our three-regime framework—with time-varying recession risk—allows firms to decide whether to delay preemptive actions until the recession risk rises, which is the focus of our analysis. This economic setting contrasts with studies that vary other macroeconomic factors between multiple expansion regimes (e.g., Chen, 2010; Bhamra et al., 2023), making it difficult to isolate the effect of the recession risk. We later relax the assumption that expansion regimes are identical except for recession risk to explore how recession risk's effects interact with other macroeconomic factors.

To answer how firms of *different sizes* respond to changes in recession risk, we solve a non-homothetic model. 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 when the same firm is large because companies operate capital equipment with diminishing returns to scale. Also, when small, a firm faces higher financing costs relative to its size due to a fixed component of issuance costs, in line with Altınkılıç and Hansen (2000). Incorporating size is another difference with Chen (2010) and Bhamra et al. (2023), who model capital structure decisions instead of investment and cash policies.

The novel mechanism in the model is that larger firms delay preemptive actions until the recession risk increases, resulting in their issuance, investment, and payout policies changing more with recession risk than those of smaller firms. The rationale is that smaller firms face more attractive investment opportunities and thus pursue more aggressive investment strategies. They anticipate that increased investment will drive growth, but also amplify nominal cash flow shocks and deplete cash reserves, leaving them more vulnerable to liquidation if the economy abruptly enters a recession and external financing becomes unavailable. Consequently, smaller firms place a higher value on cash in low-risk periods and take greater precautions—such as preemptively issuing equity at higher cash levels—to ensure sufficient liquidity to manage recession risks after

growth, without incurring repeated costly issuances. This advance preparation means they hold more cash relative to current needs, allowing them to manage rising recession risk with fewer adjustments.

In contrast, a large firm has a lower marginal value of cash than a small firm when recession risk is low, as it invests less aggressively and its larger capital stock generates higher cash flows. Over time, this leads to increased cash balances and reduces the firm's exposure to liquidation risk. As a result, large firms can tolerate lower cash holdings before precautionary issuance is triggered. However, upon entering the high-risk expansion regime, when a recession becomes imminent, the large firm no longer has time to build cash holdings through accumulated cash flows and loses the option to delay precautionary actions. Because the large firm delays precautionary actions in the low-risk regime, the large firm's marginal value of cash increases by a greater percentage with recession risk. Consequently, large firms focus more on managing the risk of recession by adjusting their issuances, payouts, and investments with changes between low- and high-risk expansions.

After estimating the model (using the simulated method of moments), model simulations show that as recession risk increases, firms one standard deviation larger than average increase their preemptive propensity to issue equity, issuance amounts, and cash issuance boundary by 35%, 47%, and 7% more than the average firm, respectively. To account for net issuance, we also examine the payout behavior. As the risk of recession increases, smaller firms change their payouts little, while larger firms sharply reduce payouts to build cash reserves in anticipation of greater cash flow volatility. Our model also predicts that, in response to rising recession risk, investment decreases by 206% more for firms one standard deviation larger than the average firm. When the risk of recession increases, it is optimal for larger firms to shrink their size, resulting in them cutting investment more sharply than smaller firms, which continue to invest, though at a slower pace. Because larger firms already invest at lower nominal rates, they have limited ability to raise cash by reducing investment and must therefore make more aggressive adjustments to issuance and payout policies as well.

These results, based on simulated data from the estimated model, broadly align with the qualitative patterns observed in our empirical specifications—even though the estimation does not directly target these moments. The empirical analysis mirrors the simulation setup but measures recession risk continuously rather than as a binary variable. For example, in the data (simulations), issuance amounts are 55% (47%) and investment

cuts are 41% (206%) more sensitive to recession risk for firms one standard deviation larger than average.

We contribute to the theoretical literature on how macroeconomic conditions influence firm decisions. Bhamra et al. (2023) model optimal default and capital structure with expansion and recession regimes that interact with inflation regimes. Chen (2010) models a firm's capital structure across multiple economic regimes. Chen, Xu and Yang (2021) model firms' maturity choices with constant recession risk and call for future work like ours that examines how firms adjust cash, investments, and payouts to prepare for future recessions. Other works also model a firm's capital structure with changing macroeconomic conditions: Hackbarth, Miao and Morellec (2006), Bhamra, Kuehn and Strebulaev (2010*b*,*a*), Chen and Manso (2016) and Anschukov, Bhamra and Kuehn (2023). Bolton, Chen and Wang (2013) models the preemptive issuance motive in a two-regime model with constant recession risk, and we provide new empirical support for this theoretical insight. However, while binary regime-switching models with constant recession risk compare firm policies inside and outside recessions, our focus is on how firms endogenously adjust their preparations in response to changing recession risk during expansions.

Our paper also adds new insights to the theoretical literature on dynamic liquidity management outside of regime-switching models. Bolton, Chen and Wang (2011) is a seminal homothetic liquidity management model, and Bolton, Wang and Yang (2019) model cash and investment in the form of real options without recession risk. Kakhbod et al. (2024) finds that cash holdings do not always increase with firm size; instead, they decline as small private firms invest. Many liquidity management models focus on specific aspects—such as equity issuance (Décamps et al., 2011), persistent cash flows (Anderson and Carverhill, 2012; Abel and Panageas, 2023), or key talent risk (Dou et al., 2021)—without incorporating investment behavior or recession risk.

Our paper contributes to the debate on which firms are the most cyclical. Some studies find greater sensitivity among small firms (e.g., Gertler and Gilchrist, 1994), others find no size-based differences (Chari, Christiano and Kehoe, 2013; Kudlyak and Sánchez, 2017), and some report heightened sensitivity among large firms in specific episodes like the 2008 crisis (Moscarini and Postel-Vinay, 2012). Crouzet and Mehrotra (2020) finds little difference in cyclicality in sales between the bottom 99% of firms and shows that only the top 1% are significantly less cyclical, attributing this to their broader industry scope. Covas and Den Haan (2011) only finds differences in the pro-cyclicality of equity issuances between the bottom 99% and the top 1%, with the largest firms' equity issuances

being even counter-cyclical. Using a more precise measure of issuances, Begenau and Salomao (2018) finds the top 25% are less pro-cyclical. Within expansionary regimes, and controlling for the contemporaneous GDP fluctuations examined in prior studies, we find that a firm's *precautionary* actions respond more strongly to changes in the risk of a *future* recession when it is larger than when it is smaller. This pattern reflects a greater ability to delay precautionary actions as firm size increases.

Our framework also sheds new light on the well-documented spike in equity issuance at business cycle peaks just before periods of poor market returns. While prior studies attribute these surges to managers' market-timing skill (Baker and Wurgler, 2000), ex-post selection in efficient markets (Schultz, 2003), or investment-based theories (Butler et al., 2011), we show that issuance spikes can instead reflect precautionary cash-building in response to rising recession risk. In our model, entering a high-risk regime sharply increases the value of liquidity, prompting firms—especially those with volatile cash flows—to issue more equity and hold proceeds as cash, independent of mispricing. This mechanism aligns with David McLean (2011), who documents that issuance surges are strongest among high-precautionary-motive firms, that more proceeds are retained at peaks, and that low flotation costs amplify the effect. In sum, cyclical equity supply may partly reflect a rational forward-looking response to time-varying recession risk.

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), Haushalter, Klasa and Maxwell (2007), and Duchin, Ozbas and Sensoy (2010) find that cash allowed firms to invest and emerge stronger from a recession. Bliss, Cheng and Denis (2015) finds that firms in recessions cut dividends. Bachmann, Elstner and Sims (2013) empirically tests Bloom (2009)'s hypothesis that increased uncertainty from economic upheavals immediately reduces industrial output. Our paper builds on Bolton, Chen and Wang (2013)'s insight that firms often take preemptive actions in anticipation of recessions, which can obscure the full impact of downturns—particularly when the recession is anticipated rather than unexpected.

Section 2 presents the model, Section 3 describes the solution and simulation results, and Section 4 reports the empirical findings. Section 5 concludes. The Appendix includes proofs and additional results.

# 2 Model

Our baseline model extends the seminal Bolton, Chen and Wang (2011) model in two important ways: (1) adding *varying* recession risk and (2) solving a non-homothetic model to differentiate firms by size. These extensions lead to a novel mechanism—the option to delay precautionary actions until recession risk increases—and enable us to examine the differential sensitivity of a firm when it is small versus large to changes in recession risk.

A representative firm is owned by risk-neutral shareholders who discount cash flows at a constant interest rate (cf. Section C.3 for a relaxation) $r > 0$. A firm's cash flows are stochastic and are a function of the size of its productive capital stock and a stochastic process $Z_t$, which evolves according to

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

where $W_t$ is a one-dimensional Brownian motion and $\mu_s$ and $\sigma_s$ are positive constants that vary with the business cycle indexed by $s$. Thus, shocks $dZ_t$ are assumed to be i.i.d. with mean $\mu_s dt$ and variance $\sigma_s^2 dt$. The firm's cumulative cash flows $Y_t$ follow the dynamics

$$dY_t = k_t^{\alpha} dZ_t, \tag{2}$$

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). Thus, production exhibits decreasing returns to scale, which makes firms differ along the size dimension. A firm has stronger investment incentives when it is small. Following other studies estimating $\alpha$ from firm-level data, we find $\alpha < 1$ (e.g., Hennessy and Whited, 2007; Nikolov and Whited, 2014; Li, Whited and Wu, 2016).

The model incorporates multiple risks. A diffusion shock to productivity, $W_t$, is one source of risk. The second source of risk is a large, persistent shock when the economic regime changes. The economic regime $s$ varies stochastically between expansions ($l$), recessions ($h$), and an intermediate regime ($m$) with expansive properties but a high risk of entering a recession.

Like in Chen (2010) and Bhamra et al. (2023), we capture the changes of the economic regime by the states of a continuous-time Markov chain. Our Markov chain $s$ takes the value $s_t \in \{l, m, h\}$ at time $t$. The firm is in one of these three (observable) regimes. 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 $s$. We assume that the Markov chain is ergodic, ensuring that the regime

process has a unique stationary distribution and visits all regimes infinitely often over time. In particular, the firm can transition directly between any pair of regimes, which guarantees the chain is irreducible and captures the possibility of abrupt changes in economic conditions. Figure C.2 illustrates the three regimes and the probability of transition between regimes. We discuss these transition rates in Section 3.[2]

The firm invests in productive capital that depreciates at a rate $\delta \geq 0$. As is standard in capital accumulation models, for an investment process $i$, $k$ evolves according to

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

For simplicity, we assume that the investment is irreversible ($i \geq 0$). When the incentive to liquidate is greatest—during recessions—used capital markets often break down, making this a realistic proxy for disinvestment constraints. Firms rarely sell capital to manage recession risk, as downturns are uncertain and short-lived, and round-trip transactions are costly. Instead, they adjust cash buffers through payouts or issuance. Appendix Figure C.6 confirms that allowing reversible investment does not alter our main results.

Following capital accumulation models in the neoclassical investment literature (e.g., Hayashi, 1982; Bolton, Chen and Wang, 2011), investment faces convex adjustment costs:

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

where $\theta$ 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, a 1-unit investment is proportionally smaller—and therefore less costly—for a $k = 13$ firm (7.7%) than for a $k = 7$ firm (14.3%).[3]

[2] If we model two regime states and two recession risks, then the four-state Markov model $\{rec, exp\} \times \{low, high\}$ admits two variants: (i) risk transitions independent of the macro regime state (five parameters) or (ii) risk transitions regime-dependent (seven parameters). Variant (i) is parsimonious but makes the post-recession risk distribution depend on pre-recession risk—contradicting the data and obscuring identification. Variant (ii) can remove this dependence, yet adds complexity; driving its risk-transition intensities to infinity simply collapses it back to our three-regime model. Our three-regime specification (six parameters) therefore strikes the best balance between empirical realism, tractability, and parsimony.

[3] Without capital adjustment costs and allowing for disinvestment, firms instantaneously adjust capital so that $\partial_k V_s = \partial_c V_s$, eliminating meaningful liquidity risk and the incentive for precautionary cash holdings, even as recession risk rises. In contrast, adjustment frictions in the full model constrain capital resizing, increasing exposure to volatile cash flows, and costly financing during downturns. This dynamic motivates firms—especially smaller ones—to maintain higher cash buffers and preemptively adjust investment in anticipation of recession risk, clarifying the central role of adjustment costs in our results.

The firm chooses its investment and cash management strategies, including timing and amount of equity raised and dividend payouts, resulting in the following cash reserve dynamics

$$dc_t = (r - \lambda_c)c_t dt + dY_t - i_t dt - g(k_t, i_t)dt - \underbrace{dD_t}_{\geq 0} + \underbrace{dI_t}_{\geq 0}. \tag{5}$$

Here, $\lambda_c$ is the regime- and time-independent cash holding cost, $D_t$ is the cumulative dividend payout, and $I_t$ is the cumulative equity issuance. Both $D_t$ and $I_t$ are non-decreasing processes. Cash earns a return equal to the risk-free rate ($r$) net of the carry cost of holding cash ($\lambda_c$).[4] Despite cash earning lower returns, the firm holds cash for precautionary reasons to reduce expected issuance or liquidation costs when funds are low. The firm optimizes its cash policy to balance the benefits of cash reserves with the delay in dividend payouts. Payouts save shareholders the carry cost of cash. Firms finance their investments with cash, cash flows, and external financing.

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

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

The first term, $\lambda_p$, is 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 (Hennessy and Whited, 2007), causing the size-relative issuance costs to scale down with size (Altınkılıç and Hansen, 2000; Benzoni et al., 2022). Together, $\lambda_{f,s}$ and $\lambda_p$ summarize the information, incentive, and transaction costs of issuing equity. Firms intermittently access equity markets, raising large amounts of funds, as observed. The parameter $\lambda_{f,s}$ varies with economic conditions, reducing issuances during recessions (e.g. Choe, Masulis and Nanda, 1993). Table D.2 shows that the issuance frequency declines by about 45% during NBER recessions. Following Bolton, Chen and Wang (2013), we keep $\lambda_p$ constant and focus on changes in fixed equity issuance costs to capture variations in financing opportunities.

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

[4] If $\lambda_c = 0$, shareholders optimally defer dividends to avoid costly equity issuance. A more realistic scenario is $\lambda_c > 0$. Low cash returns may be due to higher corporate tax rates on cash interest (Graham, 2000; Faulkender and Wang, 2006). Agency issues may also reduce cash returns (e.g., Jensen, 1986).

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 $k_\tau$ is fire sold. The recovery rate $\ell_s$ depends on the regime of the business cycle and is constant across sizes of productive capital. Even with a positive cash reserve, the firm may liquidate strategically and disburse its remaining cash.

## 2.1 The firm's problem

The firm chooses 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. Due to the fixed component of the equity issuance cost, issuance times and amounts can be enumerated as lump sum amounts of $\Delta I_j$ at issuance times $\eta_j$. The firm's optimization problem is then

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

The firm's state variables are capital stock $k$, cash reserve $c$, and economic regime $s$. The firm's value function is

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

where the subscript $s$ emphasizes the need to determine the value for all $k$ and $c$ in the three (mutually dependent) regimes. Because $dZ_t$ is not persistent, the firm does not condition decisions on $dZ_t$. Persistence arises from changes in the regime $s$.

The firm has several 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

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

satisfied with equality if a lump sum dividend of (at least) size $\Delta D$ 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 $\Delta D$, and let $\Delta D \to 0$ to obtain

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

The equality holds if the dividend payouts are optimal. Second, a firm can pay all its liquid assets ($\Delta D = c$) as a dividend and then liquidate:

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

Liquidating all cash is a special case, as $\partial_c V_s - 1 \geq 0$ implies $V_s(k, c) - V_s(k, 0) - c = \int_0^c \partial_c (V_s(k, c') - c')dc' \geq 0$.[5]

Next, the firm may issue equity. Issuance increases cash by $\Delta I$, at a shareholder cost of $\Delta I + \lambda(\Delta I, s)$. The net value to shareholders is

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

and issuance is not optimal if the firm's value without issuance is greater than the value it could achieve through any feasible issuance amount:

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

If issuance is optimal, the above inequality turns into equality, as the pre-issuance value reflects the optimal issuance in the next instant.

Finally, if the firm neither pays a dividend nor issues equity, it only chooses its optimal instantaneous investment. By standard control arguments, $V$ must satisfy the inequality

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

with equality when investment is optimal. Here, $rV_s$ represents the required equity return, with $r$ equal to the risk-free rate for risk-neutral investors. The term $\partial_k V_s$ is the marginal

[5] Liquidation affects moment estimation but is negligible under current parameters. For any small negative cash flow drift independent of $k$, there exists a region where liquidation occurs regardless of cash holdings, for any combination of other parameters. This was more pronounced in an earlier version with fixed cost $b$, which created a strategic liquidation zone. The parameter $b$ was removed for parsimony and to simplify the estimation.

benefit of capital; therefore, $[i - \delta k] \cdot \partial_k V_s$ captures the marginal effect of net investment on equity value. The term $\partial_c V_s$ is the 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 expected savings on equity value. The term $\frac{1}{2}k^{2\alpha}\sigma_s^2 \partial_{cc}^2 V_s$ captures the effect of the volatility of cash holdings due to the volatility of production on equity value. The last term in the first expression, $\sum_{s'} q_{s,s'} V_{s'}(k,c)$, captures the gain or loss of value due to a potential regime transition from $s$ to $s'$, with $q_{s,s'}$ being entries of the transition rate matrix.

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 HJB equation for the value function $V_s(k,c)$:

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

The equation shows the firm's three alternatives: investment (first two lines), dividend payout (first group, third line), and equity issuance (second group, third line).

At $c = 0$, the boundary condition compares the liquidation and issuance values:

$$0 = \min \Big\{ V_s(k,0) - \ell_s k,\ V_s(k,0) - \sup_{\Delta I \geq 0} \Big[ V_s(k, \Delta I) - \Delta I - \lambda(\Delta I) \Big] \Big\}. \tag{13}$$

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

We formalize and prove the existence and uniqueness of the value function in Appendix A, using a comparison theorem for viscosity solutions. The proof handles significant technical challenges introduced by endogenous issuance in the interior of the domain. This supports the convergence of our numerical scheme to this unique solution.

Although our model features three economic regimes—compared to nine in Chen (2010) and six in Bhamra et al. (2023)—we address a distinct problem by uniquely modeling two continuous state variables to capture firm size and cash holdings. Modeling size and liquidity enables us to capture heterogeneity in investment opportunities and issuance costs by firm size, which drives firm-size asymmetries in precautionary issuance; otherwise, scale invariance ensures proportional behavior across firms.[6] Moreover, unlike Chen (2010) and Bhamra et al. (2023), who analyze capital structures under different macroeconomic conditions, we keep the firm's financing environment simpler as in Nikolov and Whited (2014) because we are interested in cash management rather than the composition of external finance. Moreover, our focus is on how the sensitivities of cash policies to recession risk vary with firm size, and empirically, Crouzet and Mehrotra (2020) do not find a differential sensitivity between small and large firms in debt use during the business cycle. However, they find that the sensitivity of investment policies varies with the firm size during the business cycle.

# 3 The Model Solution

We present the model solution with figures and simulations showing how recession risk impacts a firm's issuances, investments, and payouts. We also analyze how these effects vary with a firm's size and financial flexibility, indicated by cash holdings. Several of the model mechanisms are illustrated in the absence of economic regime switching in a sequence of simpler models in Appendix C.1.

To numerically solve the model, we must determine parameters, including transition rates between regimes $s$. We empirically estimate transition probabilities using the monthly probability of a future U.S. recession in 12 months from 1985 to 2022, based on the term spread. (See Section 4.1 for more on the recession risk measure.) Because our firm-level data are at the quarterly frequency, we calculate the average quarterly recession

[6] With $\alpha = 1$ (constant returns to scale) and $\lambda_{f,s} = 0$ (no size-invariant issuance costs), the model becomes *homothetic*: the value function is homogeneous of degree one, $V_s(k, c) = kV_s(1, c/k)$, so a large firm is just a scaled-up small firm. Optimal policies are proportional to firm size, equity is issued only in infinitesimal amounts at the issuance boundary (there are no fixed costs to amortize), the issuance boundary is $c = 0$ since $\lambda_p$ does not vary between regimes, and recession risk has no size-dependent effect on issuance, investment, or payouts. Adding either diminishing returns ($\alpha < 1$) *or* fixed issuance costs ($\lambda_{f,s} > 0$) breaks perfect scale invariance but only partially: the former creates heterogeneity in investment but no lumpy issuance, while the latter gives small firms an incentive to grow to reduce per-unit issuance costs, which reduces incentives for lumpy issuance. Only when *both* diminishing returns and size-invariant issuance costs are present does the model generate the core prediction of pronounced firm-size asymmetries in precautionary issuance behavior.

probability and, excluding quarters with NBER recessions, use the 75th percentile cutoff (15.2%) to classify quarters into "expansion, low risk" and "expansion, high risk" regimes. Quarters with NBER recessions are labeled "recession." Table 1 shows transition probabilities. The "expansion, low-risk" regime is most stable, with a 77% chance of persisting. The "expansion, high-risk" regime has a 46% chance of persisting, and a "recession" has a 29% chance of persisting and a 52% chance of shifting to the low-risk expansion regime. Figure C.2 in Section 2 illustrates Table 1.

[Insert Table 1 Here]

Table 2 shows all parameter values and their rationale. We categorize the parameters into two subgroups.

[Insert Table 2 Here]

The first group includes the returns to scale (RTS) parameter, $\alpha$, the adjustment cost parameter $\theta$, and a cash flow scaling parameter $\Xi$ for expected cash flows $\mu_s$ and cash flow volatility $\sigma_s$. These influential but unobserved parameters are estimated using the simulated method of moments. Table 2 shows the estimated values, and Table 3 panel A includes the standard errors for $\alpha$ and $\Xi$. Panel B of Table 3 reports the calibrated moments, which are close to the sample moments. Section B.1 provides calibration details, and Section B.2 discusses the identification of parameters.

Our structural estimate of the RTS parameter, $\alpha = 0.84$, aligns well with firm-level evidence of diminishing returns. For example, Burnside (1996) report an average RTS parameter of 0.79 across industries, while Gao and Kehrig (2017) estimate RTS parameter at 0.86 in traditional sectors. More recent micro-level structural studies using plant-level data also report similar values (e.g., McAdam et al., 2024). Pagano and Schivardi (2003) provide evidence of increasing returns to scale at an aggregate level, but Burnside (1996) shows that aggregate estimates exceed non-aggregate estimates.

Our estimate of the investment adjustment cost parameter adds to the literature, which provides a wide range of values from 0.004 in Catherine et al. (2022) to 1.5 in Whited (1992) to 5.428 in Steri, Nikolov and Schmid (2019). Our estimation supports the estimate in Catherine et al. (2022). The selected value provides the best fit to the empirical moments among the three prominent benchmarks during calibration. As in Catherine et al. (2022), a key moment for identifying the adjustment cost parameter is the

autocorrelation of investment serves, which is 0.431 in our data (Table 3).[7]

[Insert Table 3 Here]

For the second group of parameters, we use plausible numbers based on available empirical evidence. The last column of Table 2 discusses these choices.

In our baseline, expected cash flows, cash flow shocks, issuance costs, and recovery rates only change between expansion and recession regimes. Following Hackbarth, Miao and Morellec (2006), the interest rate is held constant (this assumption is relaxed in Appendix C.3).

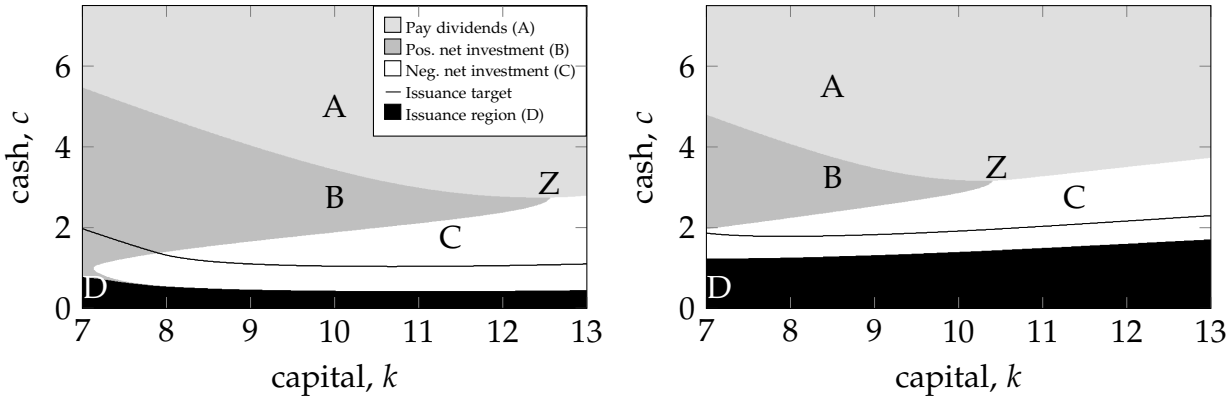
## 3.1 Firm policies in the three regimes

Figures 2a and 2b show a firm's optimal policies in an expansion regime with low and high recession risk, respectively. The vertical axis shows the firm's cash reserve, $c$, and the horizontal axis shows its capital stock, $k$. The legend indicates firm behaviors in different $k$ and $c$ regions. Simulations show that the firm remains near point $Z$ 95% of the time, with capital $k$ typically ranging between 7 and 13. (Figure C.3 shows the policy diagram for the recession regime $h$. And, Figure C.4 shows similar predictions in $(k, c/k)$-space.)

A firm distributes dividends in the payout region $A$ in $(k, c)$-space where the marginal benefit of distributing cash to shareholders is no less than the marginal cost of reducing cash holdings by the same amount. For low cash $c$, firms save to avoid issuance costs, but the marginal value of cash decreases as $c$ rises. Payouts occur when holding more cash becomes uneconomical due to the liquidity premium $\lambda_c$. If $c$ is initially above the payout boundary, where region $A$ meets investment regions $B$ and C, a lump-sum dividend is paid to bring $(k, c)$ to the boundary. If $(k, c)$ reaches the boundary from below, a minimal dividend keeps it below. The payout boundary is U-shaped—most pronounced in the high-risk expansion regime $m$—declining for small firms and rising for larger firms, reflecting the U-shape of the marginal value of cash (see Figure C.7).[8]

[7] As Catherine et al. (2022) note, many models omit financing constraints, which can themselves generate investment persistence without requiring adjustment costs. As a result, such models may overstate adjustment cost parameters to match observed persistence. Additionally, plant-level models often rely on fixed costs to capture lumpy investment, which induces negative autocorrelation in investment rates—necessitating larger quadratic costs to align with the data. In contrast, firm-level data show smoother investment patterns that do not require fixed or large adjustment costs.

[8] Small firms with limited cash flow maintain internal cash reserves to finance investment and avoid costly external funding. As firms grow, diminishing investment incentives lower cash demand, and higher expected cash flows cover a larger portion of continuing investment needs. This results in increased payouts,




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

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) and high-risk expansion (panel b) regimes. Analysis in $(k, c/k)$ space yields similar predictions (See Figure C.4). Parameters used are summarized in Table 2.

Diminishing returns to scale lead to two investment regions: $B$ (positive net investment) and $C$ (negative net investment). Let $i^*$ be the firm's optimal investment policy. In $B$, $i^* > \delta k$, so the firm grows its capital stock. In $C$, $i^* < \delta k$, leading to net disinvestment. A firm is in $B$ when small and $C$ when large. At the $B$-$C$ interface, $i^* = \delta k$.

The issuance target (Figure 2, solid black line) denotes optimal cash holdings after external financing. The issuance boundary ($\partial D$), the upper edge of the black region $D$, exists due to the risk of increased external financing frictions in a recession. The boundary $\partial D$ reflects a firm's minimum cash holdings tolerated due to recession risk before issuing new equity. Issuance is lumpy to save on the fixed component of issuance costs. Facing recession risk, firms issue at positive cash levels without immediate investment needs (Bolton, Chen and Wang, 2013). Low-cash firms issue equity preemptively to avoid future financing unavailability and reduce liquidation risk. High cash firms do not issue preemptively due to lower liquidation risk and reduced need for external financing, making fixed costs $\lambda_f$ less justifiable.

Figure 3a and 3b illustrate the *expected instantaneous state direction* of firms not actively paying dividends or issuing equity. These vectors reflect the drift in state space induced

as investment opportunities are a key driver of the payout policy (e.g., Grullon, Lyandres and Zhdanov, 2012). However, cash balances eventually increase again because cash flow variance rises with $k^{2\alpha}\sigma^2$ while expected cash flow increases more slowly with $k^{\alpha}\mu$. As larger cash flow shocks become the dominant concern, higher buffers are required, leading to reduced payouts (e.g., Chay and Suh, 2009). For further mathematical intuition, see Appendix C.1.

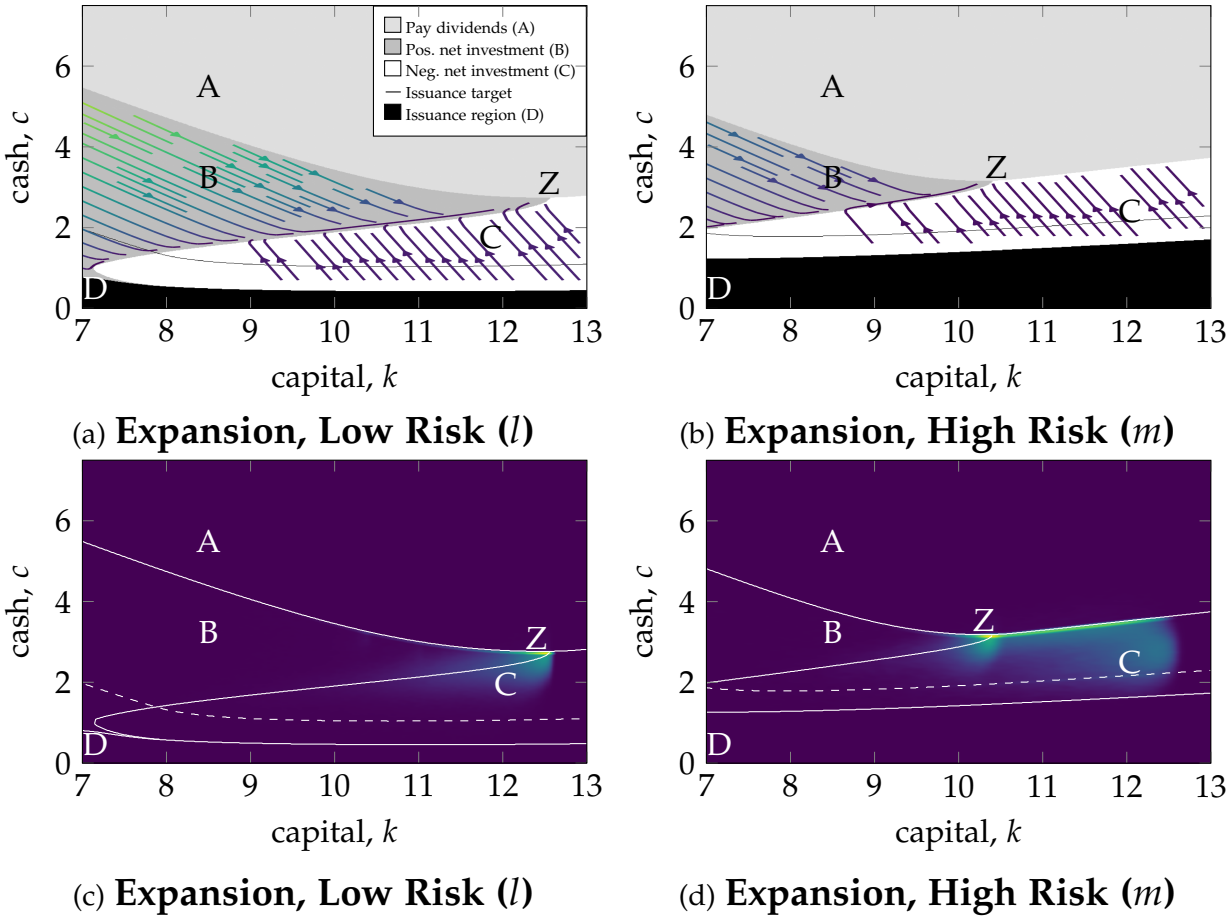
by productivity shocks and investment policy, conditional on being in the continuation region. Importantly, the Brownian motion and regime-switch shocks both contribute to deviations from these paths. Thus, while all the arrows point toward the lower edge of Region B, this edge is only the path in the absence of shocks. To the right of the lower boundary of Region B, depreciation exceeds investment, causing firms to move leftward. Cash flow—absent shocks—exceeds investment, resulting in upward-pointing arrows. Left of the boundary, investment is higher than depreciation and cash flows, leading to a net negative cash flow; thus, arrows point downward and to the right, reflecting the impact of investment. Along the bottom boundary of Region A, the reasoning is the same, but any upward movement from positive cash flow drift is canceled out by dividend payouts. This results in arrows that, again, absent shocks, point toward the center point Z.

Figure 3c and 3d display the simulated distribution of firms conditional on being in the $\ell$ and $m$ regimes, respectively, with brighter areas indicating higher densities. In both regimes, firm density clusters around point $Z$, a natural rest point where incentives to adjust capital or cash are minimal and excess cash flows are paid out as dividends. In regime $\ell$, density is skewed to the left of $Z$, reflecting firms' strong incentives to grow when recession risk is low. In contrast, in regime $m$, the density shifts to the right of $Z$ as higher recession risk prompts firms to contract from their larger scale in regime $\ell$.

## 3.2 Differential responses of small & large firms to recession risk

The focus of our paper is on which firms delay preemptive actions until recession risk increases. Figure 4 illustrates the policy changes of small and large firms as the economy transitions from a low-risk expansion regime (Figure 2a) to a high-risk expansion regime (Figure 2b). More importantly, we assess these dynamics through simulation, generating panels of 10- to 500-thousand firms[9] over 120 monthly periods using the parameters from Section 3, after a four-year (48-month) burn-in, similar to the structure used in estimation. After simulating, we drop recession months to focus on policy changes during expansions. Simulations offer several advantages: they account for the dynamics of state variables (such as drift and diffusion), produce a cross-sectional distribution of firms, and allow us to validate predictions from policy function changes. Moreover, they allow for the analysis of outcomes—such as issuance propensity and issuance amounts—that are less readily discernible in Figure 2.

[9]Due to the relative scarcity of issuance events, we use a larger panel for issuance related regressions.




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

(c) **Expansion, Low Risk ($l$)** (d) **Expansion, High Risk ($m$)**

Figure 3: **Expected optimal state trajectories and conditional distributions**
Figures (a) and (b) illustrate the *expected* state trajectories of a firm not paying dividends or issuing equity. The actual path depends on Brownian productivity, regime changes, and interactions with the issuance or dividend boundaries. The arrow shade indicates speed (slow/dark to fast/light). Figures (c) and (d) show the conditional distribution of firms in the $(k, c)$-space, with the color intensity indicating the density of firms. The solid lines represent the boundaries of regions A, B, C, and D, while the dashed line indicates the optimal issuance target. Generated using the same path length and burn-in period as in the estimattion.

Regarding equity issuances, Column (1) of Table 4 examines how issuance propensity varies with recession risk and firm size in the simulated data with the following specification:

$$\begin{aligned}\mathbb{1}(\text{Issuance})_{i,t} = \beta_0 + \beta_1 \mathbb{1}(\text{High Risk}_t) \\ + \beta_2 \mathbb{1}(\text{High Risk}_t) \times k_{i,t} + \beta_3 k_{i,t} + \epsilon_{i,t}.\end{aligned} \tag{14}$$

The outcome is an indicator equal to 100 in month $t$ if firm $i$ issues equity. The independent variable $k_{i,t}$ denotes firm $i$'s productive capital stock in month $t$, and $\mathbb{1}(\text{High Risk}_t)$ equals one if the firm is in the high-risk regime $m$ (zero for the low-risk regime $\ell$) in month $t$.

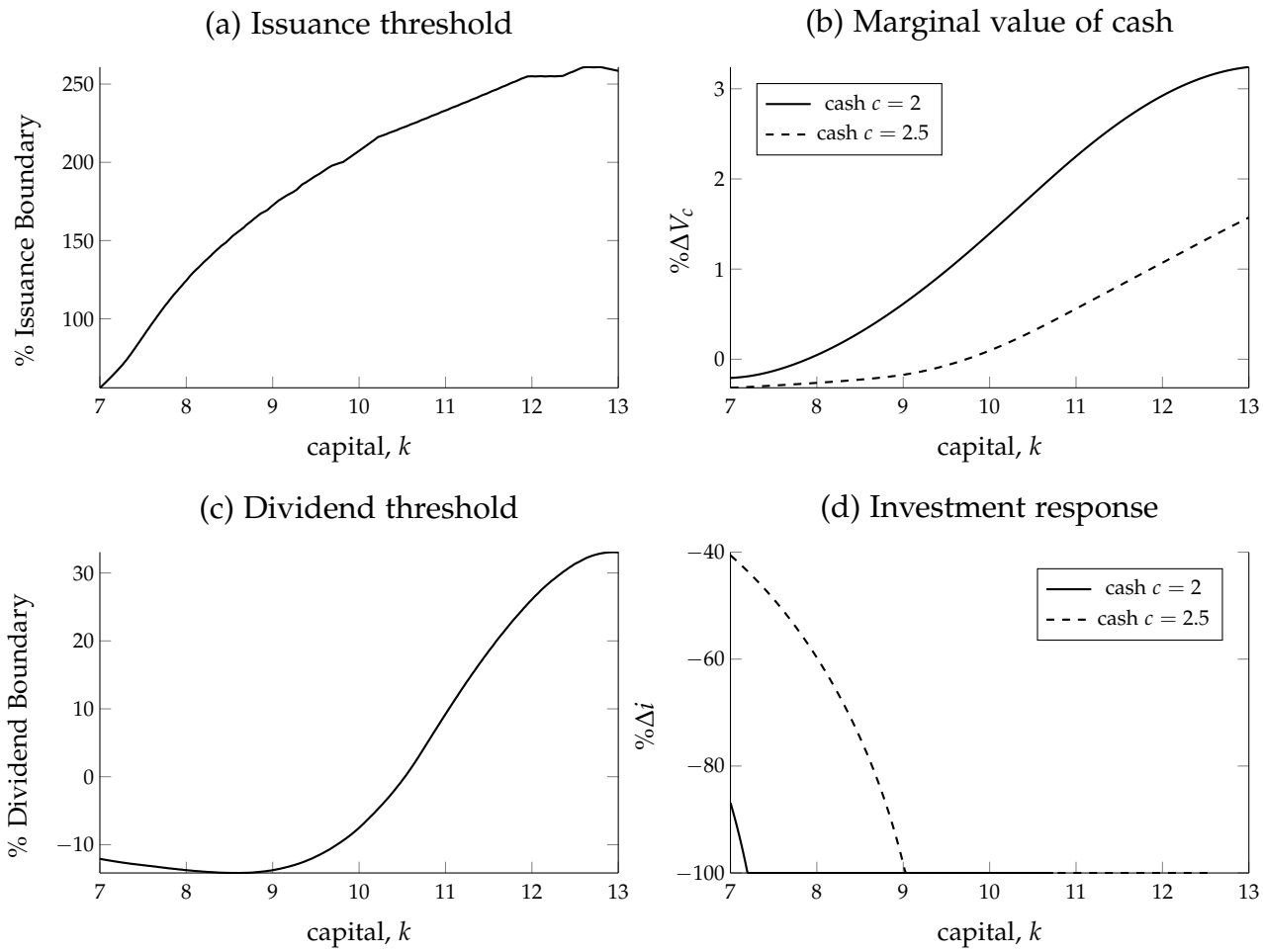



Figure 4: **Key firm responses to higher recession risk.** As recession-probability rises from low ($l$) to high ($m$) in the expansion regime (see Figure 2), panels show percent changes in the: (a) equity issuance boundary, (b) marginal value of cash, (c) dividend boundary, and (d) investment. We calculate the marginal value of cash ($\partial_c V = V_c$) as the value difference for a small cash increase, scaled by the size of the cash increase. Then, we determine the percent change in the marginal value of cash ($\%\Delta V_c$) between the low-risk and high-risk expansion regimes. Parameter values are in Table 2.

The sample excludes recession months to focus on how firm policies respond to recession risk during expansions. The coefficient $\beta_1$ captures how issuance propensity varies with recession risk, while $\beta_2$ measures how this sensitivity differs by firm size. To match the empirical analysis in Section 4, we standardize explanatory variables within each firm by subtracting the firm's sample mean and dividing by its sample standard deviation.

[Insert Table 4 Here]

Table 4 Column (1) shows that moving from the low- to the high-risk regime increases the probability that the representative firm issues equity by about 30 basis points (bp)—from roughly 1bp in the low-risk state to just over 30 basis points in the high-risk

state. Larger firms are slightly less likely to issue when risk is low (–0.9bp per standard deviation of size), but they ramp up much more aggressively when risk rises: the probability jump for a one-standard-deviation larger firm is about 39bp. That is, the issuance propensity of a firm one standard deviation larger than average is 35% (0.103/0.296) more sensitive to changes in recession risk than that of an average-sized firm.

Turning to issuance amounts, Table 4 Column (2) uses a similar specification as Eq. 14, with the outcome variable now defined as the amount issued, scaled by $k$ and standardized within a firm. The sample is restricted to months in which issuance occurs. Column (2) shows that firms increase issuance amounts by 0.357 standard deviations after transitioning to the high-risk regime, and this effect is 47% (0.169/0.357) larger for firms that are one standard deviation larger than their average size.

Column (3) of Table 4 examines the cash levels immediately before issuance, implementing a similar specification as Eq. 14 with the cash holdings immediately prior to issuance as the outcome, and the sample is limited to the months with issuance. Cash holdings are standardized within a simulated firm over the full simulation sample. Column (3) shows that in the low-risk regime, firms issue equity when cash holdings are 5.7 standard deviations below average—consistent with issuing only when running low on cash. When recession risk rises, cash at issuance increases by 2.641 standard deviations, and this effect is approximately 7% (0.180/2.641) larger for firms that are one standard deviation larger.

These issuance results are consistent with Figure 4a, which presents the percentage change in the issuance boundary ($\partial$D, the upper threshold of region $D$) across low- and high-risk expansion regimes, by firm size. A firm of size $k = 7$ raises its minimum cash threshold before issuing by roughly 50%, compared to 250% for a firm of size $k = 13$. This implies a stronger positive sensitivity of the minimum required cash to recession risk for larger firms. Additionally, these predicted magnitudes are comparable to empirical evidence from Gustafson and Iliev (2017) and Umar, Yimor and Zufarov (2023), which shows deregulation that lowered issuance costs by about 66% (by extending shelf offerings to small firms) increased the probability of issuing equity by 49% and raised total annual issuance volume by 45%.

The mechanism operates through firm behavior during low-risk expansions. Smaller firms build larger cash reserves in these periods, anticipating that higher investment rates will deplete liquidity and amplify future cash flow volatility as the firm grows—raising liquidation risk even when the probability of an imminent recession is just 5%. Consistent

with this, Figure 3 shows that the expected state trajectories of small firms point southeast, reflecting the use of cash to invest and grow. As a result, they maintain higher cash balances (e.g., a higher minimum cash threshold—reflected in an elevated issuance boundary—even in low-risk regimes; see Figure 2a) to ensure sufficient liquidity to manage recession risks after growth, without incurring repeated costly issuances. This precautionary buffer reduces the need to adjust issuance policies as recession risk rises, since existing cash holdings are already calibrated to meet the demands of a larger, riskier future firm.

Figure 4b shows that as recession risk rises within an expansion, the marginal value of cash (MVC) declines slightly for smaller firms—since weaker investment incentives slow cash burn and free up cash previously reserved for the firm's future, larger scale—while it increases by about 2–3% for larger firms. The increase in MVC for larger firms is greater at lower cash levels. Thus, when recession risk rises from regime $\ell$ to regime $m$, a \$1 billion cash stock is revalued upward by about \$20-\$30 million, reflecting the 2%-3% increase in the marginal value of cash. Although this change is smaller than the multi-fold differences documented when researchers compare financially constrained to unconstrained firms or crisis to non-crisis periods, the settings are not comparable. We measure how the same firm's MVC moves when recession probability increases but capital markets remain open; Denis and Sibilkov (2009), Acharya and Viswanathan (2011), and Faulkender and Wang (2006) compare firms at opposite ends of the financing-friction spectrum or during episodes of severe funding stress, where cash can be worth €1.22–€1.79 versus €0.84, or even triple under moderate stress. Thus, our more modest 2–3% rise is consistent with a narrower, probabilistic shock and with firms' own precautionary cash buffers.

To consider net issuance, we examine the relationship between payouts and recession risk. Column (4) of Table 4 implements a similar specification as Eq. 14 with payout growth as the outcome variable. We apply exponential smoothing with a 3-period window to account for the lumpy nature of dividends, which are more irregular than investment both in the model and in the data (includes repurchases). Payout growth is standardized within a firm. Column (4) shows that payout growth rises modestly for average-sized firms (0.023) but falls sharply for larger firms, with a large negative coefficient (–0.090) on the interaction between firm size and recession risk. This aligns with small firms scaling back investment as recession risk rises, freeing up cash originally reserved for post-investment growth. This cash now appears ample relative to the firm's near-term needs in the event of a downturn, allowing for modest increases in payouts. By contrast,

although larger firms reduce investment by a greater percentage, they derive less nominal benefit from doing so, as their investment rates are already lower. Moreover, their larger capital stock exposes them to greater expected cash flow uncertainty, which increases in expectation when recession risk increases. Thus, larger firms also need to decrease payout growth to a greater extent. Figure 4c further shows that the dividend boundary in Figure 2 decreases by about 13% for small firms but increases by roughly 30% for large firms. Since higher boundaries imply lower payouts, the model predicts that larger firms exhibit greater negative sensitivity of payouts to recession risk.

Empirical studies support substantial payout reductions during crises. Mazur, Dang and Vo (2023) report an 81% decline in repurchases and a 50% drop in total payouts among S&P 1500 firms during early COVID-19. Similarly, Floyd, Li and Skinner (2015) document a 50% decline in industrial payouts from 2007 to 2009, driven by a 71% fall in repurchases, while Bliss, Cheng and Denis (2015) find a 65% decline in total payouts among all non-financial Compustat firms over the same period. These findings suggest that elevated financing costs during crises led firms to reduce payouts as an alternative financing source. Our model differs by predicting heterogeneous payout responses to rising recession risk during expansions rather than payout changes during an ongoing crisis. It also emphasizes within-firm variation—how the same firm adjusts payouts depending on its size—whereas prior studies largely focus on cross-sectional differences.

Regarding investment, Column (5) of Table 4 reports a similar specification to Eq. 14, but with investment growth as the outcome, measured as the percent change in investment from month $t-1$ to $t$. Investment growth is standardized within each firm. Column (5) of Table 4 shows that as recession risk increases, firms preserve cash by scaling back investment to reduce liquidation risk, especially when a firm is larger. A standard deviation larger firm than average is 206% (0.397/0.193) more sensitive to recession risk. Consistent with this reasoning, Figure 4d quantifies the percent reduction in investment ($\%\Delta i$) across firm sizes at two cash levels. When cash levels are 2.5, small (large) firms invest approximately 40% (100%) less when recession risk increases. Thus, larger firms, having weaker investment incentives, reduce investment more sharply, showing greater negative sensitivity to rising risk. Firms with higher cash buffers cut investment less.

The investment effects of recession risk in our model align with prior research on firm responses to uncertainty shocks and recessions. For example, Kahle and Stulz (2013) find that firms cut capital expenditures by approximately 34% during downturns. Survey data from the 2008 financial crisis further support this: Campello, Graham and Harvey

(2010) report that 71% of financially constrained firms canceled planned investments, with average reductions in employment of 11%, technology spending of 22%, capital investment of 9%, and marketing of 33%.[10] While these magnitudes in 2008 are substantial, our model predicts that many firms had already begun reducing investment before the crisis as recession risk rose in 2007.

In the Appendix, we examine how these predictions—specific to changes in recession risk—interact with variations in other macroeconomic conditions. That is, we relax the assumption that the two expansion regimes differ only in their transition rates into recession. Our counterfactuals in Appendix C.3.1 show that if the Fed lowers rates as recession risk rises, firms become more forward-looking and take preemptive actions even in low-risk periods, which mitigates the impact of rising risk but also reduces investment when risk is low. Similarly, Appendix C.3.2 shows that when financing costs increase with recession risk, firms prepare more aggressively in low-risk periods, dampening later sensitivity but again lowering investment in low-risk periods. To counter these effects, policymakers could reduce the sensitivity of issuance costs to recession risk—for instance, by opening bond-purchase windows for large issuers or offering early liquidity tools to small, cash-constrained firms. For large systemic firms that tend to delay, earlier interventions—such as tightening loan-to-value limits or releasing countercyclical capital buffers—may help reduce bailout risk.

In Figure C.5, we also show that the model's distinctive policy shifts across the low-risk ($l$), intermediate-risk ($m$), and recession ($h$) regimes persist when allowing equity issuance in regime $h$ at a high yet finite cost—100 times the expansion-regime fixed cost, following Bolton, Chen and Wang (2013), rather than the baseline assumption of an infinite cost. In this case, firms still optimally delay issuance until cash is exhausted in the hope of reverting to a lower-cost regime.

# 4 Empirical Evidence

This section presents empirical evidence consistent with the estimated model findings discussed in Section 3. Table D.1 provides additional anecdotal evidence from earnings

[10] Structural estimates from Bloom (2009) predict that a doubling of uncertainty reduces aggregate output by 1% within four months, with recovery by six months. Bachmann, Elstner and Sims (2013) and Basu and Fernald (1997) find similar output contractions of 1.1% and 0.2%, respectively. While not directly comparable, as those models focus on transitory uncertainty shocks while ours captures persistent recession risk, it is likely that firm-level capital expenditures—being more volatile and discretionary—are significantly more sensitive than aggregate output to such shocks.

call transcripts, where CEOs highlight the heightened sensitivity of larger customers to changes in recession risk—consistent with the model's predictions.

## 4.1 Data and Variable Construction

We use monthly recession probabilities from the *The Yield Curve as a Leading Indicator* at the Federal Reserve Bank of New York. These probabilities, based on the term spread (the difference between the 10-year and 3-month Treasury rates), indicate the likelihood of a U.S. recession in twelve months. The probabilities are derived from a probit model where the outcome variable equals one if an NBER recession occurs 12 months later, and the main explanatory variable is the current term spread.[11]

Comparing recession predictors, Estrella and Mishkin (1998) shows the yield curve slope is the best individual predictor, outperforming others out of sample.[12] The term spread's out-of-sample pseudo $R^2$ is about 30% at two-to-four quarter horizons. We use a one-year horizon, allowing firms to adjust slower-moving policies. Another advantage is that the measure is market-based and continuously observable as opposed to survey-based.[13] Table D.3 correlates our recession probability measure from term spreads with other measures. In contrast, the business cycle dating literature predicts whether one is in a recession *today* (e.g., Chauvet and Piger, 2008). For example, in July 2024, Chauvet and Piger (2008) assigns a 0.2% probability that the NBER will retroactively designate that month as a recession, whereas the term spread implies a 57.3% probability of an NBER recession occurring one year later, in July 2025.

Figure 1 shows the 12-month U.S. recession probability. Gray bars indicate recessions identified by the NBER, which dates peaks and troughs of economic cycles. The figure indicates that recession probabilities generally rise before NBER recessions. Going back farther, Kessel (1965) presents evidence that term spreads tend to be negative at cyclical peaks, using data back to 1858. Bordo and Haubrich (2004) provide regression-based evidence that the term spread predicts U.S. recessions from 1875 to 1997.

Our primary data source for firm fundamentals is the quarterly Compustat data file, covering 1985 Q1 to 2022 Q2. We exclude observations during NBER-designated reces-

[11] When accessed from the Federal Reserve Bank of New York, shift the probabilities back 12 months. For instance, the Dec. 2022 probability of a recession in Dec. 2023 is in a cell next to Dec. 2023, not Dec. 2022.

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

[13] The Survey of Professional Economists starts in the 1960s but lacks predictive power.

sions to approximate our theoretical laboratory, which examines firm policies between expansion states with differing recession risks. Despite data availability from the early 1960s, Compustat data lack several key variables in the early years. Additionally, as noted by Jermann and Quadrini (2012), among others, the Great Moderation, which began in the mid-1980s, significantly altered U.S. financial markets. Accordingly, we document marked changes in recession risk. Before the Great Moderation, the mean risk of recession was 18.7% (standard deviation 18.3%), while afterward, it was 10.0% (standard deviation 10.6%). See Appendix Table D.4 for filtering details. The final sample comprises 11,926 unique firms and 400,955 firm quarters. Table 5 provides summary statistics.

The model's continuous state variables are the firm's cash holdings and capital stock. We proxy cash holdings using quarter-end cash and cash equivalents (*cheq*), and productive capital stock with total assets minus cash holdings (*atq-cheq*). This measure of firm size is common in the literature, as documented by Dang, Li and Yang (2018). The Appendix shows robustness checks using property, plant, and equipment.

The main outcome variables of a firm characterize its issuance, payout, and investment activities. Based on external financing defined by Jermann and Quadrini (2012), our measure uses cash flows between external capital providers and the firm. We proxy issuance with sales of common stock from the cash flow statement (*sstky*). Payout is determined by dividends (*dvy*) and stock repurchases (*prstkcy*). We difference these across fiscal quarters as they are cumulative within a fiscal year. Investment is proxied by capital expenditures on property, plants, and equipment (*capxq*).

[Insert Table 5 Here]

## 4.2 Empirical Results

Our empirical specifications using Compustat data closely mirror those applied to the simulated model data. However, while recession risk is modeled as a binary variable in the simulations, it is measured continuously in the data.

Regarding issuance, simulations of the estimated model predict that increases in recession risk lead to larger increases in the likelihood of issuance, the amount issued, and the cash level at which issuance occurs when the firm is large (see Columns (1)–(3) of Table 4). This is because the firm's issuance boundary rises with recession risk, especially for larger firms.

Column (1) of Table 6 examines issuance propensity:

$$\begin{aligned}\mathbb{1}(\text{Issuance}_{i,t+1}) = \beta_0 + \beta_1(\text{Recession Probability}_t) \\ + \beta_2(\text{Recession Probability}_t) \times \text{Size}_{i,t} + \beta_3 \text{Size}_{i,t} + \epsilon_{i,t}.\end{aligned} \tag{15}$$

The outcome is an indicator for whether issuance occurred in quarter $t+1$. We focus on substantive capital raising, excluding routine executive option-related sales. The indicator equals one if issuance exceeds 50% of total assets net of cash (approximately 15% of the firm's market-based enterprise value).[14] All explanatory variables are measured as of the quarter $t$. $Size_{i,t}$ represents a firm's assets minus cash holdings at the end of quarter $t$. $Recession\ Probability_t$ is the average monthly recession probability in quarter $t$. $\beta_1$ captures how issuance propensity varies with recession risk, and $\beta_2$ measures differences in this sensitivity due to firm size differences. We cluster standard errors by quarter since recession risk is constant across firms in a quarter. We standardize explanatory variables within a firm, subtracting a firm's sample mean and scaling by the firm's standard deviation. This standardization removes firm differences in variances and means (Mummolo and Peterson, 2018; Breuer and deHaan, 2024).

Column (1) of Table 6 supports the model's prediction that the likelihood of issuance generally increases with recession risk. A one standard deviation increase in recession risk raises the quarterly issuance propensity by 0.102 percentage points, equivalent to approximately 17% (0.102/0.600) of the mean propensity shown in Table 5. While the empirical results do not reveal a significant interaction with firm size in the full sample, Table D.11, Column (1), which focuses on firms in the top 10% of cyclicality, provides some evidence that larger, more cyclical firms exhibit a greater increase in the propensity to issue equity as recession risk rises.[15]

[Insert Table 6 Here]

Column (2) of Table 6 examines issuance amounts using a specification similar to Equation 15, with the sample restricted to firm-quarters that precede an issuance in

[14] The Appendix uses alternative cutoffs between 2% and 50%. McKeon (2013) finds that issuances below 2% of market value are almost always compensation-related.

[15] Overall, Tables D.11 and D.12 do not reveal meaningful differences in most sensitivities for firms in the top 10% and bottom 10% of the cyclicality distribution. Highly procyclical firms, anticipating a higher cyclicality in their sales and thus deeper downturns, may accumulate larger precautionary cash buffers even in tranquil times, dampening their incremental sensitivity to heightened recession risk. Indeed, firms with more cyclical cash flows are empirically shown to hold more cash as a buffer against downturns (Palazzo, 2012).

quarter $t+1$. The outcome variable is the amount issued, standardized within each firm's full sample. In this context, $\beta_1$ captures how issuance amounts respond to recession risk, while $\beta_2$ reflects how this sensitivity varies with firm size. The results show that issuance amounts increase with recession risk, and this effect is amplified for larger firms—consistent with both the simulations and the empirical data. A one standard deviation increase in recession risk corresponds to a 0.21 standard deviation increase in issuance amounts, and the effect is 55% (0.116/0.211) larger for firms that are one standard deviation larger than average.

Column (3) of Table 6 analyzes cash holdings at the time of issuance using a specification similar to Equation 15, with the sample restricted to firm-quarters preceding an issuance in the quarter $t+1$. The outcome variable is cash holdings at the end of the quarter $t$, standardized within each firm's full sample. In this setup, $\beta_1$ captures how cash holdings at issuance respond to recession risk, while $\beta_2$ measures how this sensitivity varies with firm size. The results show that both in the simulations and in the data, firms hold more cash at issuance when recession risk is higher—and this effect is stronger for larger firms. Specifically, a one standard deviation increase in recession risk is associated with a 0.087 standard deviation increase in cash at issuance, and the effect is 108% (0.094/0.087) larger for firms that are one standard deviation larger than average.

Column (4) of Table 6 confirms the prediction that payout growth decreases with recession risk for large firms using a specification similar to Equation 15, where the outcome variable is payout growth. Specifically, payout growth is measured as the change in a firm's combined dividend payments and share repurchases over the next four quarters ($t+1$ to $t+4$) relative to the previous four quarters ($t-3$ to $t$), and is standardized within each firm. The results show a negative relation between payout growth and recession risk, particularly for larger firms. A one standard deviation increase in recession risk leads to a 0.026 standard deviation decline in payout growth, with the effect being 69% (0.018/0.026) larger for firms that are one standard deviation larger.

Column (5) of Table 6 confirms the model's prediction that investment growth declines with rising recession risk, using a specification analogous to Equation 15 with investment growth as the outcome. Investment growth is measured as the change in capital expenditures on property, plant, and equipment, comparing the sum over four future quarters ($t+1$ to $t+4$) to the sum over the previous four quarters ($t-3$ to $t$). We standardize investment growth within a firm. Column (5) shows a negative relation between investment growth and recession risk, especially when a firm is larger. A standard deviation

increase in recession risk results in a 0.039 standard-deviation reduction in investment growth. The effect is 41% (0.016/0.039) larger when a firm is a standard deviation larger than average.

The Appendix shows that the empirical results in the paper are robust to using net property, plant, and equipment as a proxy for firm size and to including controls for near-term market conditions, such as the HP-filtered log real GDP series, broad market return in quarter $t$ (MKTRF), and the probability of being in a recession in quarter $t$ (not $t+4$) from the business cycle dating literature (Chauvet and Piger, 2008). These controls interact with $Size_{i,t}$ to allow different sensitivities to the business cycle when a firm is small or large. When feasible, we also include year fixed effects to exploit variation within a year in recession risk.

Overall, Table 7 shows that the model's predictions closely track the data even though these moments are not directly targeted in estimation. There are two exceptions. First, in the full data sample the interaction between recession risk and firm size is not a significant predictor of issuance propensity, yet it turns positive and significant for the top 10% most cyclical firms (See Figure D.11). Second, for small firms, recession probability is positively related to payout growth in the simulations but negatively related in the data; this gap is muted because the simulated baseline coefficient on recession risk is small relative to the offsetting interaction term. Despite these differences, the empirical increases in policy sensitivity to recession risk—55% for issuance amounts, 108% for cash at issuance, and 41% for investment growth—are qualitatively similar to those produced by the model simulations in Table 4 (47%, 7%, and 206%, respectively).

[Insert Table 7 Here]

# 5 Conclusion

There is much to learn about the differences in firms' sensitivity to the business cycle, as noted by Crouzet and Mehrotra (2020). We explore how the policies of differing firm types vary with recession risk, an important macroeconomic condition. Specifically, we explore which firms delay precautionary actions until recession risk increases. When a firm is small or large, do its cash and investment policies respond more to recession risk?

To address this, we solve a dynamic model of firm liquidity management and investment decisions under time-varying recession risk. The model predicts that small firms are less sensitive than large firms in their issuance, payout, and investment strategies to

variations in recession risk. Small firms have abundant investment opportunities but low internal cash flows. As a result, investment depletes their liquidity reserves, leaving them more exposed to liquidation if the economy suddenly enters a recession and external financing dries up. Anticipating that, once larger, they will face proportionally greater cash-flow shocks while holding relatively smaller cash buffers, small firms accumulate liquidity in advance to ensure they can manage recession risks after growth without incurring repeated costly issuances. Consequently, when the risk of recession increases, small firms already have sufficient liquidity to cushion the impact of increased expected cash flow volatility at their current scale of operations. In contrast, large firms maintain lower cash-to-size ratios than small firms when the risk of recession is low because their modest investment needs and ample cash flows are sufficient for rapid liquidity replenishment. Expecting to be cash rich in the future, large firms postpone precautionary actions until the recession risk intensifies; when it does, they must adjust issuance, investment, and payouts more sharply.

An important takeaway for future research is that assessing a recession's impact requires understanding firms' preemptive actions, which during expansions may smooth out recessions' effects on firm-level policies such as investments and payouts. Furthermore, delays in preemptive actions can cause differences in policy behavior between firms of different sizes. Moreover, our finding that firms respond meaningfully to changes in recession risk suggests promising avenues for future research—such as investigating how other economic agents, including investor portfolios, respond to shifts in recession risk. Overall, these results underscore the value of monitoring forward-looking recession indicators and tailoring macroprudential policy to firms most likely to defer precautionary action.

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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 |
|---|---|---|---|
| $\alpha$ | Curvature of the production function. When $\alpha < 1$, there are diminishing returns to scale | 0.84 | Calibrated. Previous firm-level data estimates show $\alpha$ less than one (e.g., Hennessy and Whited, 2007; Nikolov and Whited, 2014; Li, Whited and Wu, 2016). Returns to scale average 0.79 across industries (Burnside, 1996). |
| $\Xi$ | Scale parameter for cash flow parameters $\mu_s$ and $\sigma_s$ | 1.35 | Calibrated. We estimate the cash flow scaling parameter $\Xi$ to calibrate the absolute levels of $\mu$ and $\sigma$, whose units depend on the estimated output elasticity $\alpha$ since cash flows scale with $k^\alpha$. While $\mu/\sigma$ is empirically identified and stable across different values of $\alpha$, estimating $\Xi$ allows us to maintain empirical comparability and avoid arbitrary normalization. Because $\Xi$ is a scaling factor to account for levels of $k^\alpha$, $\mu_s$ and $\sigma_s$—both scaled by $k^\alpha$ to produce the cash flow—are scaled by the same factor $\Xi$ in calibration. See Section B.1 for details. |
| $\mu_s$ | Expected cash flows are $\mu_s k_t^\alpha$ | $l = m = \Xi \times 0.18$, $h = \Xi \times 0.14$ | Calibrated using the scalar $\Xi$, 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. |
| $\sigma_s$ | 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 $\Xi$, which multiplies the standard deviation of cash flows to capital ratio. The cash flow to capital ratio's standard deviation (0.09) matches Bolton, Chen and Wang (2011) and the Compustat average firm-level standard deviation of EBITDA scaled by lagged total assets less cash in expansions. The standard deviation of cash flows in recessions is hard to measure due to their brevity. We increase the cash flow volatility from 0.09 to 0.14 to reflect the approximate 50% rise in the VIX during recessions. |
| $\theta$ | Degree of adjustment costs | 0.004 | Calibrated with restriction that $\theta \in \{0.004, 1.5, 5.428\}$, corresponding to values used in Catherine et al. (2022), Whited (1992), and Steri, Nikolov and Schmid (2019), respectively, based on practical considerations. The selected value provides the best fit to the empirical moments among the three prominent benchmarks during calibration. |
| $\delta$ | Depreciation rate | 7.24% | In line with the estimates of Eberly, Rebelo and Vincent (2009). |
| $\lambda_c$ | 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 (e.g., Jensen, 1986). |
| $\lambda_p$ | Variable issuance cost | 2.4% | This is similar to Gomes (2001), who uses data from Smith (1977) and estimates that the marginal flotation cost is 2.8%. 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 aligns with Altınkılıç and Hansen (2000). In the recession regime $h$, no empirical study exists for issuance costs due to the short nature of recessions and the significant decline in offerings. Issuances are procyclical, declining on average in recessions (e.g., Covas and Den Haan, 2011). Table D.2 shows a 45% decline in issuance frequency during NBER recessions. In Appendix Figure C.5, we set $\lambda_f = 0.5$ in regime $h$, or 100x larger than in expansions, as in (Bolton, Chen and Wang, 2013). |
| $\ell_s$ | Recovery rate in liquidation of capital | $l = m = 1.0$, $h = 0.3$ | The choice of $\ell$ aligns with Hennessy and Whited (2007), which estimates an average recovery rate of 0.896 across firms, suggesting a higher liquidation value in expansions. As in Bolton, Chen and Wang (2013), the liquidation value in recessions is set to 30%, reflecting the high costs of asset fire sales when few investors are willing to buy (Shleifer and Vishny, 1992; Acharya and Viswanathan, 2011; Campello et al., 2011). |
| $r$ | Interest rate | 6% | 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 $\alpha$ and a scale parameter $\Xi$ for the cash flow parameters $\mu$ and $\sigma$. We calibrate their values by matching the five model-generated moments listed in Panel B, computed using annual Compustat data from 1985 to 2022. 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. We calibrate with the restriction that $\theta \in \{0.004, 1.5, 5.428\}$, corresponding to values used in Catherine et al. (2022), Whited (1992), and Steri, Nikolov and Schmid (2019), respectively, based on practical considerations. The selected value of $\theta = 0.004$ provides the best fit to the empirical moments among the three prominent benchmarks during calibration. However, this method does not allow for standard errors. 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 ($\alpha$) | 0.84 | (0.003) |
| Scale parameter for the cash flow parameters $\mu$ and $\sigma$ ($\Xi$) | 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 | 12.4 |
| Avg. firm-level autocorrelation of Net Investment$_t$/(PP&E$_{t-1}$) (%) | 43.1 | 35.6 |

Table 4: Simulation Regression Results
The dependent variable in Column (1) is an indicator equal to 100 when an issuance occurs. Columns (2) and (3) condition on issuance. Column (2) shows the issuance amount $\Delta I$ relative to a firm's capital $k$ as a percent. Column (3) is the level of pre-issuance cash at the time of issuance. Column (4) examines payout growth, applying exponential smoothing with a three-period window to account for the lumpy nature of payouts, which are more irregular than investment in both the model and the data (includes repurchases). Smoothing allows us to retain more observations without discarding firms that pay dividends infrequently. Column (5) uses investment growth as the outcome variable, measured as the change from month $t-1$ to $t$. Results for investment growth are robust to smoothing, and findings for both outcomes remain consistent across alternative smoothing windows and weighting schemes. The dependent variables in Columns (2)-(5) are standardized within a firm's full path after burn-in. The sample size is larger in Column (1) because we simulate more firms to account for the relative rarity of issuance. Columns (4) and (5) drop observations where the denominator is zero. The variable $k_{i,t}$ denotes the productive capital stock standardized within a simulated firm's full path after burn-in. $\mathbb{1}(\text{High Risk})_t$ is an indicator equal to one in the $m$ regime and zero in the $\ell$ regime. ** and *** denote significance at the 5% and 1% levels, respectively.

| | Issuance Propensity$_{i,t}$ (1) | Issuance Amount$_{i,t}$ (2) | Cash at Issuance$_{i,t}$ (3) | Payout Growth$_{i,t}$ (4) | Investment Growth$_{i,t}$ (5) |
|---|---|---|---|---|---|
| $\mathbb{1}(\text{High Risk})_t$ | 0.296*** | 0.357*** | 2.641*** | 0.023*** | -0.193*** |
| | (0.001) | (0.033) | (0.025) | (0.004) | (0.004) |
| $\mathbb{1}(\text{High Risk})_t \times k_{i,t}$ | 0.103*** | 0.169*** | 0.180*** | -0.090*** | -0.397*** |
| | (0.001) | (0.031) | (0.024) | (0.003) | (0.004) |
| $k_{i,t}$ | -0.009*** | -0.177*** | -0.050* | 0.018*** | 0.169*** |
| | (0.001) | (0.030) | (0.023) | (0.002) | (0.002) |
| Intercept | 0.010*** | 10.037*** | -5.715*** | -0.026*** | -0.065*** |
| | (0.001) | (0.032) | (0.025) | (0.002) | (0.002) |
| Adjusted $R^2$ | 0.20 | 0.30 | 29.70 | 0.20 | 2.20 |
| N | 53,039,648 | 41,252 | 41,252 | 563,941 | 597,124 |

Table 5: Summary Statistics

$N$ denotes the number of firm-quarter observations outside of quarters with NBER recessions between 1985Q1 and 2022Q2. The primary variable of interest in the subsequent regression table is *Recession Probability*, which is a measure derived from the term spread that reflects the likelihood of the U.S. entering a NBER-designated recession four quarters ahead. By contrast, *Probability in Recession Today (Chauvet)* is the probability that the NBER retroactively designates that current quarter as a recession (Chauvet and Piger, 2008). Variables winsorized at the 1% level.

| | $N$ | Mean | SD | P25 | Median | P75 |
|---|---|---|---|---|---|---|
| Panel A: Macroeconomic Controls | | | | | | |
| Recession Probability (%) | 400,955 | 10.2 | 10.7 | 1.4 | 6.4 | 15.4 |
| Probability in Recession Today (Chauvet) (%) | 400,955 | 0.6 | 2.8 | 0.0 | 0.1 | 0.2 |
| MKTRF (%) | 400,955 | 2.2 | 7.8 | -0.8 | 3.2 | 6.4 |
| Panel B: Size & Liquidity | | | | | | |
| Total Assets–Cash (million) | 400,955 | 2204.4 | 6163.6 | 83.9 | 302.0 | 1279.8 |
| Cash & Short–Term Investments (million) | 400,955 | 210.1 | 634.9 | 4.5 | 24.9 | 114.1 |
| Cash/(Total Assets–Cash) (%) | 400,955 | 23.8 | 48.0 | 1.9 | 6.6 | 22.2 |
| Net PP&E (million) | 400,955 | 794.3 | 2485.8 | 20.7 | 76.9 | 372.5 |
| Panel C: Investment | | | | | | |
| Capital Expenditures (million) | 382,902 | 34.0 | 102.5 | 1.0 | 4.0 | 17.4 |
| CapEx/(Total Assets–Cash) (%) | 382,902 | 2.0 | 2.3 | 0.6 | 1.2 | 2.4 |
| CapEx/PP&E (%) | 382,902 | 6.1 | 5.5 | 2.4 | 4.5 | 7.8 |
| %Δ CapEx, $(t-3,t) \rightarrow (t+1,t+4)$ | 232,276 | 7.0 | 59.4 | -22.1 | 8.6 | 38.7 |
| Panel D: Payout (Dividend+Repurchase) | | | | | | |
| Payout/(Total Assets–Cash) (%) | 384,206 | 0.8 | 1.9 | 0.0 | 0.0 | 0.7 |
| %Δ Payout, $(t-3,t) \rightarrow (t+1,t+4)$ | 141,776 | 10.8 | 120.1 | -25.6 | 7.6 | 52.2 |
| Panel E: Equity Issuance | | | | | | |
| *Propensity to Issue* | | | | | | |
| $\mathbb{1}$(Issuance > 2% TA–Cash) (%) | 361,674 | 6.6 | 24.8 | 0.0 | 0.0 | 0.0 |
| $\mathbb{1}$(Issuance > 25% TA–Cash) (%) | 361,674 | 1.2 | 11.0 | 0.0 | 0.0 | 0.0 |
| $\mathbb{1}$(Issuance > 50% TA–Cash) (%) | 361,674 | 0.6 | 7.9 | 0.0 | 0.0 | 0.0 |
| *Issuance Amount* | | | | | | |
| Iss./(TA–Cash) (%): Issuers w/ Iss.>2% | 23,778 | 23.7 | 76.3 | 3.1 | 6.0 | 17.0 |
| Iss./(TA–Cash) (%): Issuers w/ Iss.>25% | 4,397 | 98.0 | 156.7 | 33.9 | 51.4 | 96.1 |
| Iss./(TA–Cash) (%): Issuers w/ Iss.>50% | 2,256 | 157.7 | 201.3 | 65.5 | 94.0 | 166.9 |

Table 6: Empirical Regression Results

This table presents regression results examining how firm behavior responds to recession risk. Column (1) reports the effect on the probability of equity issuance, defined as a binary variable equal to 100 when issuance in quarter $t+1$ exceeds 50% of firm $i$'s size (total assets less cash at the end of quarter $t$), which is about 15% of market-based enterprise value. Column (2) shows the issuance amount, conditional on issuing, standardized within firm. Column (3) reports firm cash holdings in quarter $t$, prior to issuance in $t+1$, also conditional on such issuance and standardized within firm. Column (4) examines the within-firm standardized percent change in payouts (dividends plus repurchases) over the four future quarters ($t+1$ to $t+4$) to the four prior quarters ($t-3$ to $t$), including only firms with nonzero payouts in the prior year and some variation over time. Column (5) reports the within-firm standardized percent change in investment over the same horizon, smoothing out seasonal effects. *Recession Probability*$_t$ is the quarter $t$ average log monthly probability of a recession occurring in quarter $t+4$, standardized within firm. *Size*$_{i,t}$ is the log of firm $i$'s total assets less cash holdings at the end of quarter $t$, standardized within firm. Standard errors are double-clustered by firm and quarter. ** and *** denote significance at the 5% and 1% levels, respectively.

| | Issuance Propensity$_{i,t+1}$ (1) | Issuance Amount$_{i,t+1}$ (2) | Cash at Issuance$_{i,t}$ (3) | Payout Growth$_{i,t}$ (4) | Investment Growth$_{i,t}$ (5) |
|---|---|---|---|---|---|
| Recession Probability$_t$ | 0.102*** | 0.211*** | 0.087** | -0.026** | -0.039*** |
| | (0.034) | (0.078) | (0.038) | (0.013) | (0.013) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.060 | 0.116*** | 0.094*** | -0.018** | -0.016** |
| | (0.036) | (0.040) | (0.029) | (0.008) | (0.007) |
| Size$_{i,t}$ | -0.520*** | -0.517*** | 0.356*** | -0.039*** | -0.159*** |
| | (0.040) | (0.039) | (0.026) | (0.010) | (0.009) |
| Intercept | 0.619*** | 2.682*** | -0.419*** | 0.002 | 0.000 |
| | (0.048) | (0.073) | (0.037) | (0.012) | (0.011) |
| Adjusted $R^2$ | 0.56 | 6.69 | 11.68 | 0.21 | 2.30 |
| $N$ | 361,674 | 2,241 | 2,256 | 140,916 | 231,696 |

Table 7: Comparison of Simulated (Table 4) and Empirical (Table 6) Coefficients
This table compares coefficients from simulations using a binary indicator for high recession risk (see Table 4) with empirical coefficients estimated using a continuous measure of recession risk (see Table 6). The last column indicates whether the sign of the simulated coefficient matches that of the empirical estimate. ** and *** denote significance at the 5% and 1% levels, respectively.

| **Variable** | **Simulated Coefficient** (binary risk) | **Empirical Coefficient** (continuous risk) | **Match Sign** |
|---|---|---|---|
| *Equity Issuance Likelihood* | | | |
| Recession Probability | $0.296^{***}$ | $0.102^{***}$ | ✓ |
| Recession Probability×Size | $0.103^{***}$ | $-0.060$ | |
| *Equity Issuance Amount* | | | |
| Recession Probability | $0.357^{***}$ | $0.211^{***}$ | ✓ |
| Recession Probability×Size | $0.169^{***}$ | $0.116^{***}$ | ✓ |
| *Cash at Equity Issuance* | | | |
| Recession Probability | $2.641^{***}$ | $0.087^{**}$ | ✓ |
| Recession Probability×Size | $0.180^{***}$ | $0.094^{***}$ | ✓ |
| *Payout Growth* | | | |
| Recession Probability | $0.023^{***}$ | $-0.026^{**}$ | |
| Recession Probability×Size | $-0.090^{***}$ | $-0.018^{**}$ | ✓ |
| *Investment Growth* | | | |
| Recession Probability | $-0.193^{***}$ | $-0.039^{***}$ | ✓ |
| Recession Probability×Size | $-0.397^{***}$ | $-0.016^{**}$ | ✓ |

# Online Appendix

This Appendix contains supplementary theoretical and empirical work.

1. Appendix A provides proofs.
2. Appendix B details the numerical algorithm.
3. Appendix C provides additional theoretical work.
    - Section C.1 illustrate several main mechanisms in simpler models.
    - Figure C.2 shows the transition probabilities diagram.
    - Figure C.3 shows the policy diagram for the recession regime $h$.
    - Figure C.4 shows optimal policies in $(k, c/k)$ space.
    - Figure C.5 shows optimal policies when issuance allowed in recession.
    - Figure C.6 shows optimal policies when disinvestment is allowed.
    - Section C.3 Robustness: Cyclical discount rate $r$ & issuance costs $\lambda_f$
4. Appendix D provides additional empirical work.
    - Table D.1 provides anecdotal evidence that large firms are more sensitive to changes in recession risk.
    - Table D.2 shows issuances decline in NBER recessions.
    - Table D.3 shows the correlation of our recession probability measure with other leading indicators.
    - Table D.4 shows the Compustat sample selection criteria.
    - Table D.5 repeats Table 6 using PP&E.
    - Table D.6 shows robustness for Table 6 column (1) on issuance propensity.
    - Table D.7 shows robustness for Table 6 column (2) on equity issuance amounts.
    - Table D.8 shows robustness for Table 6 column (3) on cash at issuance.
    - Table D.9 shows robustness for Table 6 column (4) on dividend growth.
    - Table D.10 shows robustness for Table 6 column (5) on investment growth.
    - Table D.11 examines whether the most cyclical firms are different.
    - Table D.12 examines whether the least cyclical firms are different.

# A Proofs

For notational convenience, in this section, we write the subscript in $V_s$ as an additional argument, e.g., $V(k, c, s) = V_s(k, c)$.

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

$$\mathcal{O} = [0, \infty) \times [0, \bar{C}] \times \{l, m, h\}, \tag{16}$$

with the additional boundary condition

$$\partial_c V = 1 \quad \text{where } c = \bar{C}. \tag{17}$$

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 (17). 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. Although (12) shares a lot of similarity with that in Kakhbod et al. (2024), the added economic regimes leads to issuance in the interior of the domain, which significantly increases the difficulty of the comparison proof.

*Proof.* In this proof, we drop the dependence of $\mu_s$ and $\sigma_s$ 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 $\eta_k$. 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 $\omega$ 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 $\delta_\eta$ be the corresponding maximum. Define $\bar{f}(k, c, s) = \|(k, c, s) - (\bar{k}, \bar{c}, \bar{s})\|^4$ and

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

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, $\Phi^\epsilon$ 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 $\eta_k$. 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 $\epsilon$ along this subsequence. Because the lower bound at the maximum above is independent of $\epsilon$,

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

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,

$$\lim_{\epsilon\to 0} \beta \bar{f}(k_\epsilon, c_\epsilon, s_\epsilon) + \lim_{\epsilon\to 0} \frac{1}{2\epsilon}\Big((c_\epsilon - d_\epsilon)^2 + (k_\epsilon - \ell_\epsilon)^2 + (s_\epsilon - t_\epsilon)^2\Big) \leq 0. \tag{18}$$

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 $\epsilon$.

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 $\partial_{cc}$-component. We obtain $(p^u, X) \in \overline{J}^{2,+}(e^{-\eta_k k_\epsilon} u(k_\epsilon, c_\epsilon, s_\epsilon))$ and $(p^v, Y) \in \overline{J}^{2,-}(e^{-\eta_k \ell_\epsilon}(1-\omega)v(\ell_\epsilon, d_\epsilon, t_\epsilon))$ (Crandall, Ishii and Lions, 1992, Theorem 3.2), satisfying

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

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

$$
\begin{aligned}
0 \geq \min \Bigg\{ & r\tilde{u} - \sup_{i \in [0, i_{\max}]} \Bigg( \Big[ i - \delta k_\epsilon \Big] (\eta_k \tilde{u} + \partial_k \tilde{u}) \\
& \qquad + \Big[ (r - \lambda_c) c_\epsilon + k_\epsilon^\alpha \mu - i - g(k_\epsilon, i) \Big] \partial_c \tilde{u} \\
& \qquad\qquad + \frac{1}{2} k_\epsilon^{2\alpha} \sigma^2 \partial_{cc}^2 \tilde{u} \\
& \qquad\qquad + \sum_{s'} q_{s_\epsilon, s'} \tilde{u}(k_\epsilon, c_\epsilon, s') \Bigg), \\
& \tilde{u}(k_\epsilon, c_\epsilon, s_\epsilon) - \sup_{\Delta I \geq 0} \Big[ \tilde{u}(k_\epsilon, c_\epsilon + \Delta I, s_\epsilon) - e^{-\eta k_\epsilon} (\Delta I + \lambda(\Delta I, s_\epsilon)) \Big], \\
& \partial_c \tilde{u} - e^{-\eta_k k_\epsilon} \Bigg\}.
\end{aligned}
\tag{19}
$$

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

$$\begin{aligned} 0 \leq \min \Bigg\{ & r\tilde{v} - \sup_{i \in [0, i_{\max}]} \Bigg( \Big[ i - \delta \ell_\epsilon \Big] (\eta_k \tilde{v} + \partial_k \tilde{v}) \\ & + \Big[ (r - \lambda_c) d_\epsilon + \ell_\epsilon^\alpha \mu - i - g(\ell_\epsilon, i) \Big] \partial_c \tilde{v} \\ & + \frac{1}{2} \ell_\epsilon^{2\alpha} \sigma^2 \partial_{cc}^2 \tilde{v} \\ & + \sum_{s'} q_{t_\epsilon, s'} \tilde{v}(\ell_\epsilon, d_\epsilon, s') \Bigg), \\ & \hat{v}(\ell_\epsilon, d_\epsilon, t_\epsilon) - \sup_{\Delta I \geq 0} \Big[ \hat{v}(\ell_\epsilon, d_\epsilon + \Delta I, t_\epsilon) - e^{-\eta \ell_\epsilon} (\Delta I + \lambda(\Delta I, t_\epsilon)) \Big], \\ & \partial_c \tilde{v} - (1-\omega) e^{-\eta_k \ell_\epsilon} \Bigg\}. \end{aligned} \tag{20}$$

We split into two cases, depending on which expression is smallest in Equation (19). We begin with the simple case of

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

Subtracting the two equations (19) and (20) 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,

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

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

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

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

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

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.,

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

we get

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

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

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

which is a contradiction, because $\bar{c} \leq \bar{C}$ and $\omega$ 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 (16) with its boundary conditions.*

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

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

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 $\pi_{\text{inv}}$ denote the investment intensity, $\pi_{\text{div}}$ denote whether dividends are paid, and $\pi_{\text{iss}}$ 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 $\pi^0$, 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 $\Xi$, $\alpha$, and $\theta$ 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 $\Xi$ is a scaling parameter for the cash flow parameters $\mu$ and $\sigma$. 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 $\mu/\sigma$ via $\text{Mean_CK}(1)/\text{Std_CK}(1)$. Subsequently, we introduce a scaling parameter, $\Xi$, to facilitate the identification of $\mu$ and $\sigma$:

$$\mu = \Xi \times \text{Mean_CK}(1) \quad \text{and} \quad \sigma = \Xi \times \text{Std_CK}(1).$$

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 $[0, \overline{k}(\Phi)]$, where $\overline{k}(\Phi)$ 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 $\{X_i\}_{i\in\{i,\ldots,N\}}$ 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 $\Phi$, $\widetilde{\Phi}$, as

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

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

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

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

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

We optimize over $\Phi$ 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 $\mathrm{diag}(\widehat{\Omega})$. Then the standard error of $\widehat{\Phi}$ is

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

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

## 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 $\alpha$ and a scalar $\Xi$ for the cash flow parameters $\mu$ and $\sigma$. 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.

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. $\alpha$ is the curvature of the production function. $\Xi$ scales the cash flow parameters $\mu$ and $\sigma$. 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 | |
|---|---|---|---|
| | | $\alpha$ | $\Xi$ |
| | Change in parameter | -0.01 | -0.05 |
| | | Change in moment | |
| Moments | Avg. firm-level mean EBITDA$_t$/(Total Assets$_{t-1}$) (%) | 0.48 | 0.16 |
| | Avg. firm-level mean Cash$_t$/(Total Assets$_t$) (%) | -0.24 | -0.18 |
| | Avg. firm-level mean Net Investment$_t$/(PP&E$_{t-1}$) (%) | -0.18 | 0.06 |
| | Avg. firm-level standard deviation Net Investment$_t$/(PP&E$_{t-1}$) (%) | -2.98 | -3.7 |
| | Avg. firm-level autocorrelation of Net Investment$_t$/(PP&E$_{t-1}$) (%) | 0.05 | -0.03 |

# C Theoretical Appendix

## C.1 Mechanism intuition from simpler models

Below we present a sequence of models that, although not strict extensions of one-another, highlight the major mechanisms, in the absence of regime shocks. With $\alpha = 1$, all policies are asymptotically linear, so our focus lies on the case $\alpha < 1$.

**First best** In the absence of financing and investment frictions, the firm optimizes its net expected, discounted cash flow:[20]

$$V_1(k_0) = \sup_{\mathcal{I}^+, \mathcal{I}^-} \mathbb{E}\left[\int_0^\infty (k_t^\alpha \mu \, \mathrm{d}t - \mathrm{d}\mathcal{I}_t^+ + \mathrm{d}\mathcal{I}_t^-)\right].$$

Here $\mathcal{I}_t^\pm$ denotes the cumulative investment and disinvestment by time $t$:

$$\mathrm{d}k_t = -\delta k_t \, \mathrm{d}t + \mathrm{d}\mathcal{I}_t^+ - \mathrm{d}\mathcal{I}_t^-,$$

with the natural investment constraint that $k_t \geq 0$. The value function is a solution to

$$0 = \min\{rV_1 + \delta k - k^\alpha \mu, |V_1' - 1|\},$$

which is given by

$$V_1(k_0) = \frac{1-\alpha}{\alpha}\frac{\delta + r}{r}k^* + k_0 = \frac{\mu}{r}(1-\alpha)(k^*)^\alpha + k_0$$

with $k^* = \left(\frac{\mu\alpha}{\delta+r}\right)^{\frac{1}{1-\alpha}}$. In fact, whether originally above or below, the firm shifts its capital to the point $k^*$. In this sense, $k^*$ represents the ideal level of capital.

This solution thus illustrates that even in the absence of frictions, the firm has a sweet spot $k^*$ in terms of its size, which can be interpreted as the point $Z$ in our complete model.

**Liquidity risk** Without frictionless financing, the firm must manage its cash flows in order to mitigate the risk of unwanted ruin. For simplicity, consider a firm that does not have access to equity issuance and whose capital level must be maintained, i.e., $i = \delta k$.

[20] We omit the liquidation value, because it is always dominated by the frictionless disinvestment.

The firm's problem is then[21]

$$V(k,c) = \sup_D \mathbb{E}\left[\int_0^\tau e^{-rt}\,\mathrm{d}D_t\right],$$

where $\tau = \inf\{t > 0 : c_t < 0\}$ is the ruin time, $k_t \equiv k$, and

$$\mathrm{d}c_t = k^\alpha(\mu\,\mathrm{d}t + \sigma\,\mathrm{d}W_t) - \delta k\,\mathrm{d}t.$$

The value function $V$ can be found explicitly, and the optimal dividend payout policy is to pay dividends whenever cash levels exceed

$$\frac{\operatorname{atanh}\left(\frac{\mu(k)b(k)}{r+\mu(k)a(k)}\right)}{b(k)}, \tag{21}$$

where

$$\mu(k) = \max\{k^\alpha\mu - \delta k, 0\} \qquad a(k) = \frac{\mu(k)}{k^{2\alpha}\sigma^2}, \qquad b(k) = \frac{\sqrt{\mu(k)^2 + 2rk^{2\alpha}\sigma^2}}{k^{2\alpha}\sigma^2}.$$

This is the dashed line in Figure C.1 and illustrates the generally increasing need for cash buffers as capital grows.

**Investment frictions** In the preceding problem, the firm is required to maintain its capital level. We now introduce a one-off opportunity to adjust it:

$$\max_i V(k+i, c-i). \tag{22}$$

As we see in Figure C.1, this gives rise to a structure resembling that of the complete model. The dividend region, Region A, has a natural correspondence to the set of points where immediate dividend payouts are optimal, represented in light gray.[22] Moreover, the set of points where the optimizer in (22) is zero, naturally corresponds to and resembles the boundary between the net positive investment region B and the net negative investment region C.

[21] For simplicity, we leave out the liquidation value. With a liquidation value included, the optimal dividend payout boundary in Figure C.1 would have a more pronounced downward curve.

[22] Because the optimization is sequential—first investment then dividends—immediate dividends could occur post-investment. We thus define the region as points where either (i) there is no investment, and dividends are immediately paid out or (ii) there is investment and, post-investment, dividends are immediately paid out.

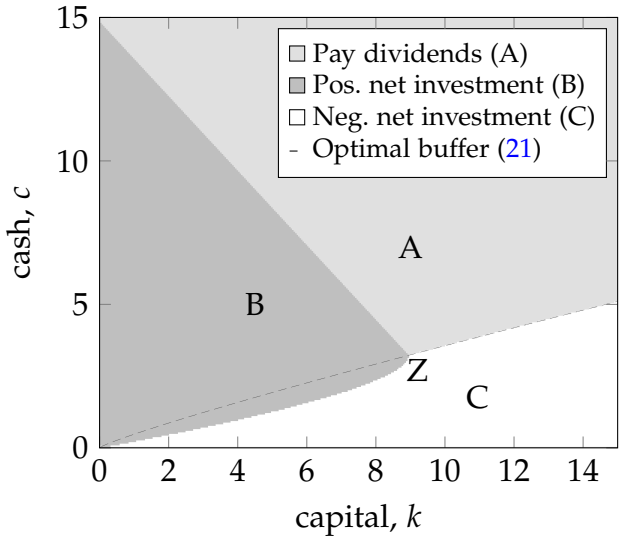



Figure C.1: Combined plot illustrating the cash buffer level (21) and the optimal policies for (22). The dashed line shows the dividend payout boundary (21) for a firm constrained to maintain its capital level and facing financing frictions. Pertaining to the optimal policies for (22), the light gray region consists of points where immediate dividend payout is optimal. The remaining space is split into the dark gray region consists of points where investment is optimal and the white region consists of points where disinvestment is optimal.

## C.2 Additional supporting figures

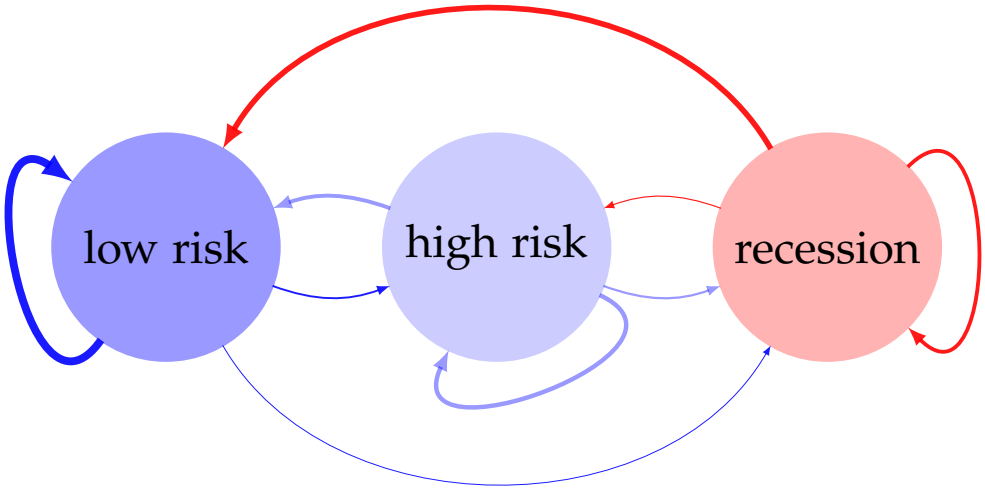



Figure C.2: **Transition probabilities diagram**
This figure shows the transition probabilities between the low-risk expansion ($l$), high-risk expansion ($m$), and recession ($h$) regimes. Thicker edges indicate higher transition probabilities (see Table 1).

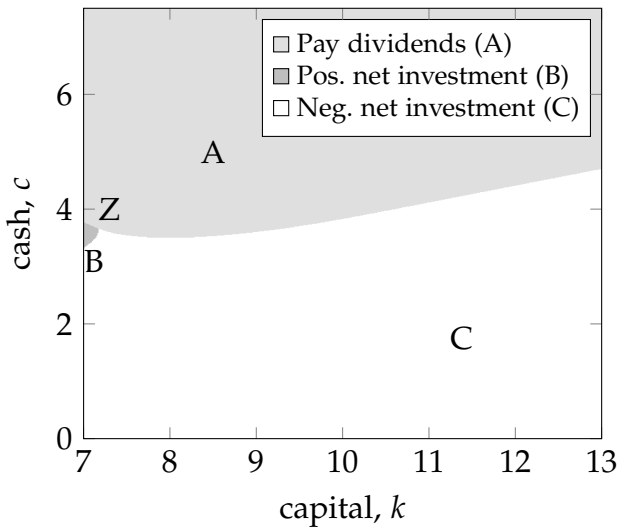
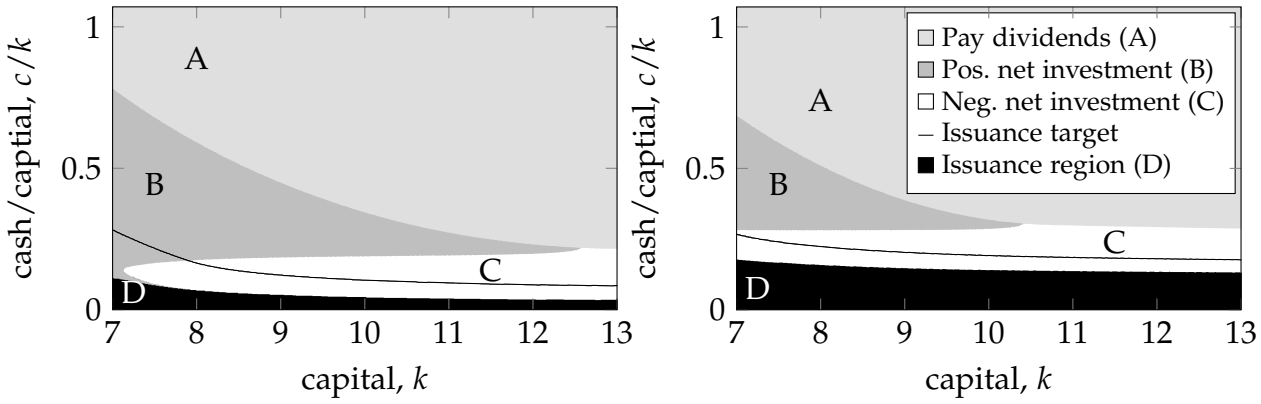
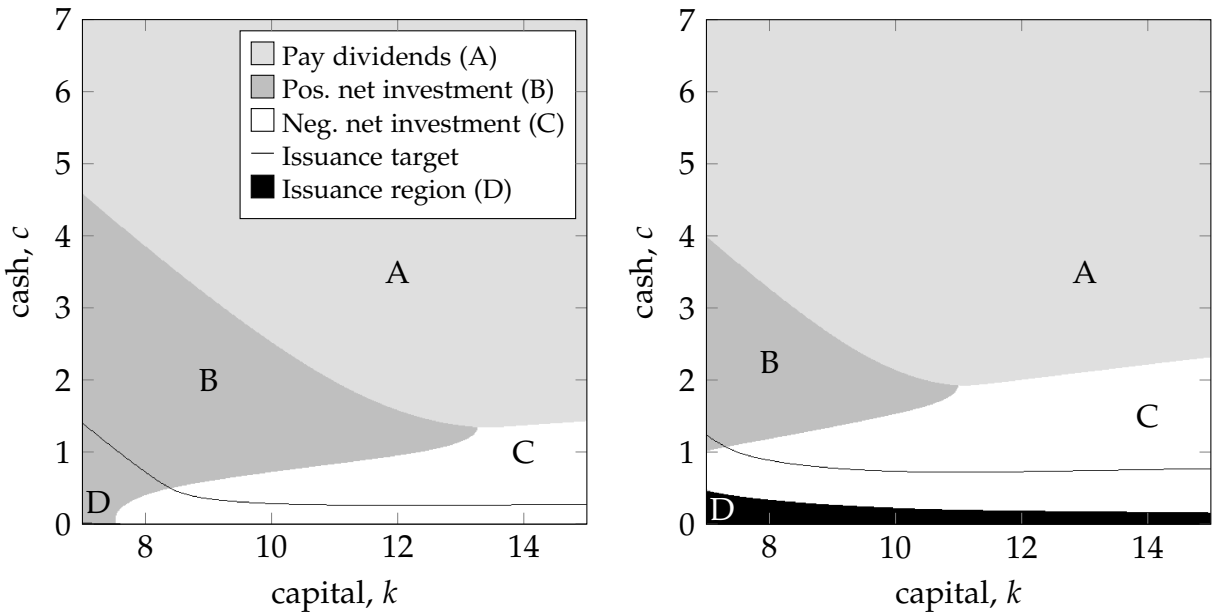



Figure C.3: **Policy diagram in the recession regime** $h$



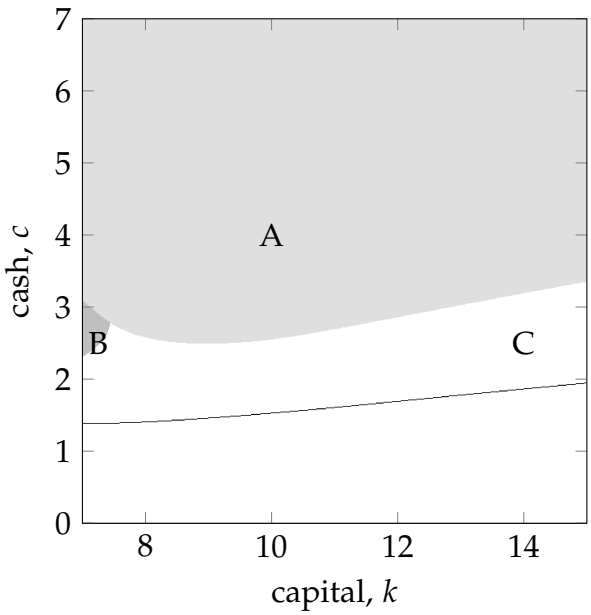

(a) **Expansion, Low Risk ($l$)** (b) **Expansion, High Risk ($m$)**

Figure C.4: **Optimal policies in $(k, c/k)$ state space.**
This figure shows the firm's optimal policies in the $(k, c/k)$ state space for low-risk expansion (panel a) and high-risk expansion (panel b). Parameters used are summarized in Table 2.




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

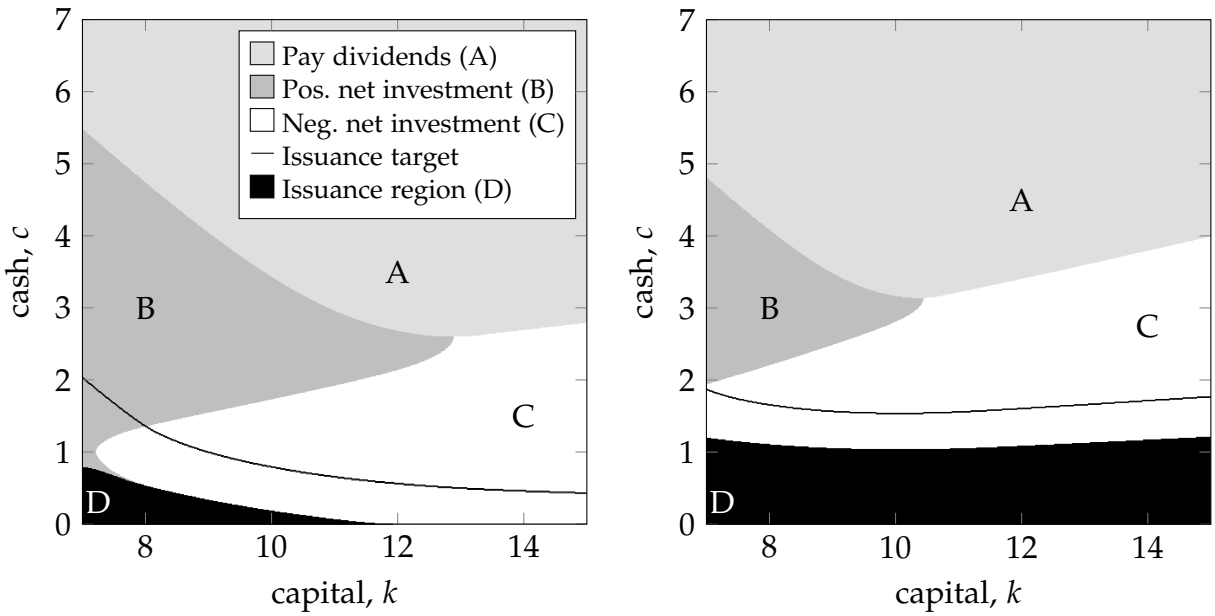
(b) **Expansion, High Risk ($m$)**




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

Figure C.5: **Optimal policies with equity issuance allowed in recession**

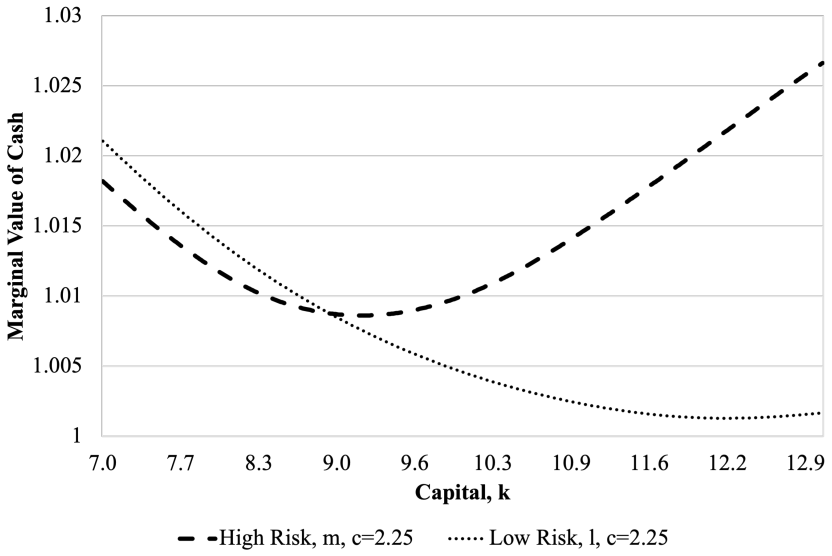
This figure shows the firm's optimal policies when issuance is allowed in the recession regime. Like in Bolton, Chen and Wang (2013), we increased the fixed component of issuance costs $\lambda_f$ to 0.5, or 100 times the expansion level of 0.005. The recession regime now shows an issuance target (black line) and an issuance boundary at $c = 0$. Parameters used are summarized in Table 2.



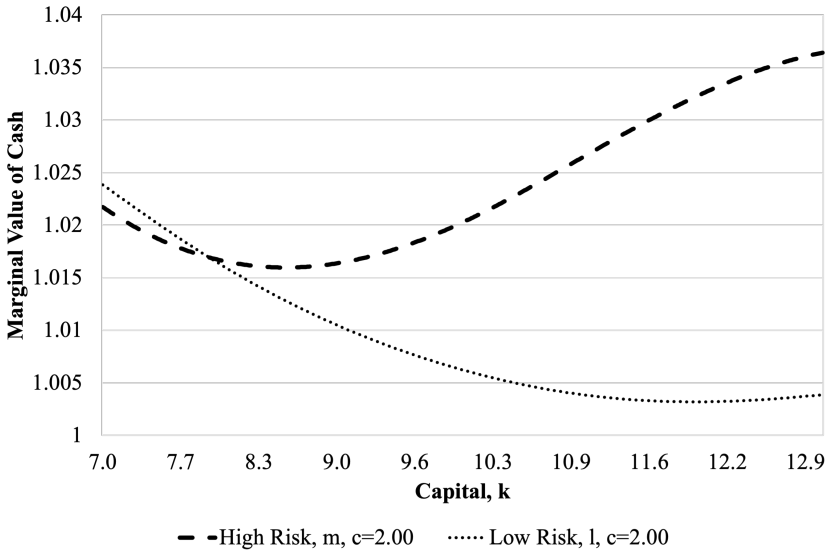

(a) **Expansion, Low Risk ($l$)** (b) **Expansion, High Risk ($m$)**

Figure C.6: **Optimal policies with disinvestment**

This figure shows the firm's optimal policies when disinvestment is permitted (investment is not irreversible) in the expansion regimes, recouping the full book value. The adjustment cost parameter for disinvestment is 0.04. The other parameters used are summarized in Table 2.




(a) Marginal Value of Cash (Y-axis) against size $k$ (X-axis) when $c = 2.25$ in low-risk expansion regime $\ell$ and high-risk expansion regime $m$.



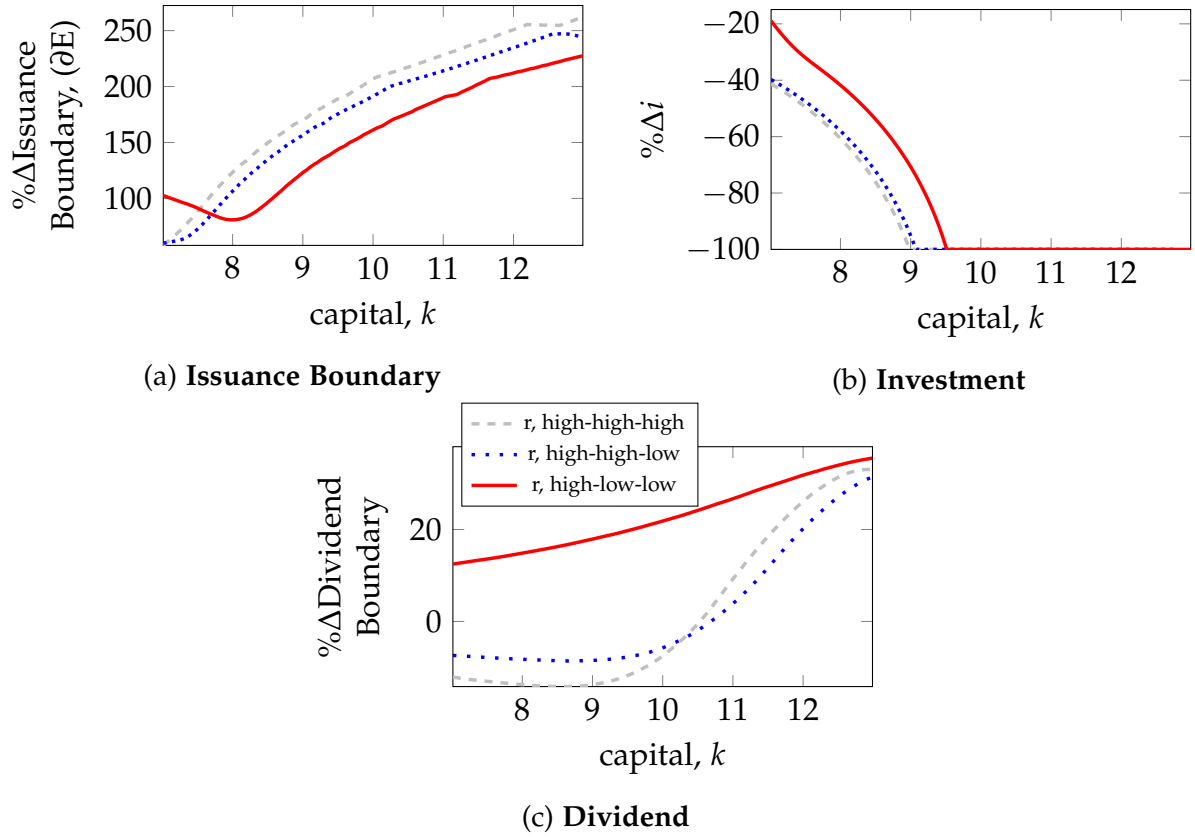

(b) Marginal Value of Cash (Y-axis) against size $k$ (X-axis) when $c = 2.00$ in low-risk expansion regime $\ell$ and high-risk expansion regime $m$.

Figure C.7: Marginal Value of Cash as a function of firm size $k$ across the low and high-risk expansion regimes with $c = 2.25$ or $c = 2.00$.

## C.3 Robustness: Cyclical discount rate $r$ & issuance costs $\lambda_f$

### C.3.1 Cyclical discount rate $r$

We examine how firm policies' sensitivity to recession risk changes with the risk-free rate. Initially, we kept $r$ fixed throughout the business cycle. The first scenario is that monetary policy lowers the discount rate during a recession ($h$). The second scenario is that monetary policy also lowers the discount rate when recession risk is high ($m$).




(a) **Issuance Boundary**

(b) **Investment**

(c) **Dividend**

Figure C.8: **Lower sensitivity to risk when $r$ decreases**

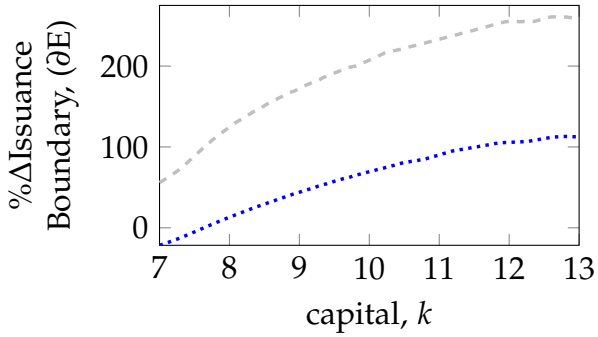
The horizontal axis represents the firm's capital stock $k$, while the vertical axis shows the percentage change between low-risk ($l$) and high-risk ($h$) regimes. *high-high-high* has $r = 6\%$ across all regimes ($l, m, h$, see Table 2). *high-high-low* has $r = 6\%$ in expansion ($r_l = r_m$) and $r = 5\%$ in recession ($r_h$). *high-low-low* has $r = 6\%$ in low-risk expansion regime ($l$) and $r = 5\%$ in high-risk expansion ($r_m$) and recession ($r_h$) regimes.

Figure C.8 shows the model's predictions remain robust across varying discount rate "r". The figure illustrates that firm policies—preemptive issuance, investment, and dividends—are less sensitive to recession risk changes when $r$ drops earlier in the business cycle. The dashed gray line represents the baseline case with a constant discount rate, comparing low-risk and high-risk expansion regimes. The blue dotted line and solid red line depict alternative scenarios. Lower $r$ leads to more forward-looking behavior,

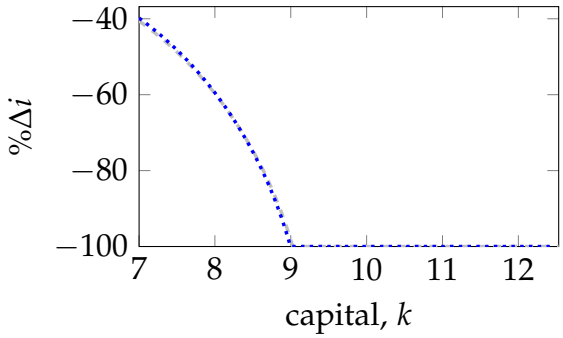
making distant recession effects more relevant today. Thus, if firms know that the Fed lowers rates when recession risk rises, firms become more forward-looking and take more preemptive actions even when recession risk is low. This behavior mitigates the impact of rising recession risk on firm decisions. However, such a policy also lowers investment when recession risk is low because firms put more weight on future recessions.

### C.3.2 Cyclical issuance costs $\lambda_f$

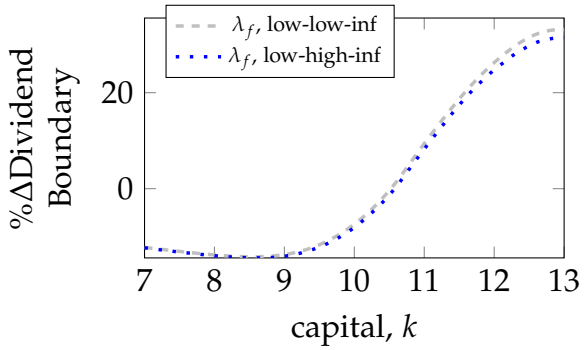
We allow investors to increase equity capital costs ($\lambda_f$) with rising recession risk. Figure C.9 shows that model predictions are stable despite cyclical issuance costs. Preemptive issuance policy sensitivity to recession risk is more affected by cyclical $\lambda_f$ than investment or payout policies. The dashed gray line is the baseline where issuance costs soar in recessions. The dotted blue line represents an alternative scenario where issuance costs increase tenfold in the high-risk regime $m$. When financing costs increase with recession risk—such as when no policy intervention occurs—firms respond by preparing more aggressively in low-risk periods, which makes them less sensitive to increases in risk later on. However, this results in future recessions exerting a stronger influence on firm investment even during low-risk periods. To mitigate the impact of recession risk on preemptive firm behavior during expansions, policymakers may aim to reduce the sensitivity of issuance costs to rising recession risk. For example, opening bond-purchase windows for large issuers once recession risk becomes acute, while providing earlier access to precautionary liquidity tools for small firms with limited cash reserves and high reinvestment needs, may help lower issuance costs and mitigate the preemptive effects of recession risk during low-risk periods. Relatedly, policymakers may want large systemic firms (e.g., financials) to be more preemptive to reduce bailout risks. Since large firms want to delay adjustment until risk is high, regulators may wish to tighten loan-to-value limits or release counter-cyclical capital buffers *earlier* for those institutions.




(a) **Issuance Boundary**




(b) **Investment**




(c) **Dividend**

Figure C.9: **Counterfactual when $\lambda_f$ increases in high-risk expansion regime**

The horizontal axis is the firm's capital stock $k$. The vertical axis shows the percentage change in the outcome variable between low-risk ($l$) and high-risk expansion ($m$) regimes. *low-low-inf* represents the benchmark model with fixed issuance costs in regimes $l$ and $m$, which increase to infinity in $h$. *low* means $\lambda_f = 0.005$ (benchmark value, see Table 2). *low-high-inf* means $\lambda_f$ increases tenfold in the high-risk regime.

# D Empirical Appendix

Table D.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 D.2: Issuances decline in recessions

The outcome is a firm-quarter issuance indicator equal to 100 if an issuance in a quarter exceeds a specified percentage of total assets less cash at the end of the prior quarter. The explanatory variable is one if quarter $t$ is an NBER recession. We control for a *Time Trend*, which accounts for any general increases in issuance frequency over the sample period. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

| | $\text{Issuance}_t$ | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| $\text{NBER Recession}_t$ | -1.530** | -0.899** | -0.639** | -0.302* |
| | (0.629) | (0.361) | (0.266) | (0.173) |
| Time Trend | 0.016*** | 0.005** | 0.003 | 0.003** |
| | (0.003) | (0.002) | (0.002) | (0.001) |
| Constant | 3.843*** | 2.768*** | 1.864*** | 0.644*** |
| | (0.621) | (0.423) | (0.338) | (0.233) |
| Issuance Threshold $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$ | 2% | 5% | 10% | 25% |
| % Adjusted $R^2$ | 0.10 | 0.03 | 0.02 | 0.02 |
| Observations | 411,195 | 411,195 | 411,195 | 411,195 |

Table D.3: 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 | -0.01 | 1.00 | | | | | | | |
| BC | 0.07 | 0.51 | 1.00 | | | | | | |
| CPSB | -0.10 | 0.29 | 0.44 | 1.00 | | | | | |
| XRI | 0.59 | 0.30 | 0.60 | -0.16 | 1.00 | | | | |
| XRI-2 | 0.35 | -0.27 | 0.73 | -0.41 | 0.66 | 1.00 | | | |
| S&P 500 | 0.03 | -0.41 | -0.14 | -0.21 | -0.07 | 0.05 | 1.00 | | |
| NYSE | 0.05 | -0.42 | -0.16 | -0.26 | -0.09 | 0.06 | 0.98 | 1.00 | |
| AI | 0.21 | 0.40 | 0.59 | 0.25 | 0.59 | 0.56 | -0.01 | -0.00 | 1.00 |

Table D.4: Quarterly Compustat Sample Selection

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

| Criteria | Obs. Lost | Obs. Remaining |
|---|---|---|
| COMPUSTAT, 1961Q1 – 2022Q4 | | 1,948,319 |
| Less: | | |
| Drop quarters before Great Moderation (1985Q1) | (280,090) | 1,668,229 |
| Pre-IPO Data | (111,509) | 1,556,720 |
| Firms headquartered outside of USA | (333,211) | 1,223,509 |
| Firms incorporated outside of USA | (22,121) | 1,201,388 |
| Financials (SIC-1=6) | (393,359) | 808,029 |
| Utilities (SIC-2=49) | (50,683) | 757,346 |
| Public Administration (SIC-1=9) | (17,878) | 739,468 |
| Missing or zero assets | (29,292) | 710,176 |
| Missing cash and cash equivalents | (1,179) | 708,997 |
| Drop gvkey-quarter duplicates | (1,298) | 707,699 |
| PP&E less than $5M or missing PP&E | (247,671) | 460,028 |
| Negative cash and cash equivalents | (219) | 459,809 |
| Less than $1M in sales | (12,641) | 447,168 |
| Singleton Firms | (376) | 446,792 |
| Drop quarters in NBER recessions | (45,837) | 400,955 |
| Final sample (11,926 firms, 1985Q1-2022Q4) | | 400,955 |

Table D.5: Empirical Regression Results (Using PP&E)
This table repeats Table 6 using net PP&E to proxy for the size of the capital stock rather than total assets less cash. Column (1) reports the effect on the probability of equity issuance, defined as a binary variable equal to 100 when issuance in quarter $t+1$ exceeds 50% of firm $i$'s size (net PP&E at the end of quarter $t$). Column (2) shows the issuance amount, conditional on issuing more than 50% of size in quarter $t+1$, standardized within firm. Column (3) reports firm cash holdings in quarter $t$, prior to issuance in $t+1$, also conditional on such issuance and standardized within firm. Column (4) examines the within-firm standardized percent change in payouts over the same horizon, including only firms with nonzero payouts in the prior year and some variation over time. Column (5) measures the within-firm standardized percent change in investment, comparing investment over the four future quarters ($t+1$ to $t+4$) to the four prior quarters ($t-3$ to $t$), to smooth seasonal effects. This column includes only firms with complete investment data for the full eight-quarter window. *Recession Probability*$_t$ is the quarter $t$ average log monthly probability of a recession occurring in quarter $t+4$, standardized within firm. $Size_{i,t}$ is the log of firm $i$'s net PP&E at the end of quarter $t$, standardized within firm. Standard errors are double-clustered by firm and quarter. *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively.

| | Issuance Propensity (1) | Issuance Amount (2) | Cash at Issuance (3) | Dividend Growth (4) | Investment Growth (5) |
|---|---|---|---|---|---|
| Recession Probability$_t$ | 0.090*** | 0.188** | 0.059* | -0.027** | -0.037*** |
| | (0.032) | (0.074) | (0.035) | (0.013) | (0.013) |
| Recession Probability$_t$ × PP&E$_{i,t}$ | -0.038 | 0.101*** | 0.065*** | -0.013* | -0.012* |
| | (0.032) | (0.035) | (0.025) | (0.007) | (0.007) |
| PP&E$_{i,t}$ | -0.459*** | -0.459*** | 0.312*** | -0.044*** | -0.251*** |
| | (0.035) | (0.034) | (0.024) | (0.009) | (0.010) |
| Intercept | 0.618*** | 2.769*** | -0.479*** | 0.001 | -0.000 |
| | (0.046) | (0.070) | (0.037) | (0.013) | (0.011) |
| Adjusted $R^2$ | 0.31 | 8.65 | 9.84 | 0.24 | 5.31 |
| $N$ | 361,673 | 2,241 | 2,256 | 140,916 | 231,696 |

Table D.6: Robustness for equity issuance propensity results in column (1) of Table 6.

This table presents the results for the issuance propensity regression reported in column (1) of Table 6, using alternative minimum issuance thresholds ranging from 2% to 50% of firm size, as well as various control specifications. *Recession Probability*$_t$ denotes the log probability in quarter $t$ of a recession occurring within one year, standardized within firm. *Size*$_{i,t}$ is the log of firm $i$'s total assets less cash holdings at the end of quarter $t$, standardized within each firm over the full sample. Business cycle controls include HP-filtered log real GDP in quarter $t$, the CRSP excess market return in quarter $t$, and the contemporaneous recession probability from Chauvet and Piger (2008). To allow for differential sensitivity to macroeconomic conditions by firm size, each control is interacted with *Size*$_{i,t}$. Standard errors are clustered at the quarter level. ** and *** indicate significance at the 5% and 1% level, respectively.

| | Issuance Propensity | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Recession Probability$_t$ | 0.255 | 0.164** | 0.139*** | 0.102*** | 0.116** |
| | (0.201) | (0.072) | (0.049) | (0.033) | (0.053) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.199 | -0.127 | -0.071 | -0.060 | -0.080** |
| | (0.163) | (0.069) | (0.048) | (0.035) | (0.037) |
| Size$_{i,t}$ | -2.475*** | -1.278*** | -0.864*** | -0.520*** | -0.531*** |
| | (0.167) | (0.071) | (0.052) | (0.038) | (0.036) |
| GDP$_t$ | | | | | -0.049 |
| | | | | | (0.073) |
| GDP$_t$ × Size$_{i,t}$ | | | | | 0.090** |
| | | | | | (0.042) |
| MKTRF$_t$ | | | | | 0.128*** |
| | | | | | (0.046) |
| MKTRF$_t$ × Size$_{i,t}$ | | | | | -0.079** |
| | | | | | (0.038) |
| Chauvet$_t$ | | | | | -0.006 |
| | | | | | (0.076) |
| Chauvet$_t$ × Size$_{i,t}$ | | | | | -0.100 |
| | | | | | (0.061) |
| Constant | 6.532*** | 2.347*** | 1.203*** | 0.619*** | 0.611*** |
| | (0.223) | (0.094) | (0.064) | (0.045) | (0.042) |
| Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$ | 2% | 10% | 25% | 50% | 50% |
| % Adjusted $R^2$ | 0.90 | 0.64 | 0.56 | 0.40 | 0.45 |
| Observations | 361,674 | 361,674 | 361,674 | 361,674 | 361,663 |

Table D.7: Robustness of issuance amount estimates in column (2) of Table 6 to alternative minimum issuance thresholds.

The sample includes firm-quarter observations in which the issuance amount, expressed as a share of the firm's total assets excluding cash, exceeds the specified thresholds, ranging from 2% to 50%. The outcome variable, Issuance Amount, is standardized within firm based on the full sample, including quarters without issuance. *Recession Probability*$_t$ is the log probability in quarter $t$ of a recession occurring within one year, standardized within firm. *Size*$_{i,t}$ denotes firm $i$'s total assets minus cash holdings at the end of quarter $t$, standardized within firm. Business cycle controls include HP-filtered log real GDP in quarter $t$, the CRSP excess market return in quarter $t$, and the contemporaneous recession probability from Chauvet and Piger (2008). Each of these controls is interacted with *Size*$_{i,t}$ to capture differential sensitivities of small and large firms to macroeconomic conditions. Column (6) includes year fixed effects to exploit within-year variation in recession risk. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

| | Issuance Amount/Size$_{i,t}$ | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Recession Probability$_t$ | -0.019 | 0.025 | 0.091 | 0.211*** | 0.172** | 0.360*** |
| | (0.034) | (0.048) | (0.062) | (0.078) | (0.077) | (0.090) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.001 | 0.019 | 0.054* | 0.116*** | 0.111** | 0.109** |
| | (0.019) | (0.023) | (0.029) | (0.040) | (0.043) | (0.044) |
| Size$_{i,t}$ | -0.289*** | -0.372*** | -0.433*** | -0.517*** | -0.511*** | -0.358*** |
| | (0.022) | (0.023) | (0.029) | (0.039) | (0.042) | (0.042) |
| GDP$_t$ | | | | | 0.092 | 0.180** |
| | | | | | (0.076) | (0.090) |
| GDP$_t$ × Size$_{i,t}$ | | | | | 0.011 | -0.022 |
| | | | | | (0.044) | (0.040) |
| MKTRF$_t$ | | | | | 0.081 | 0.064 |
| | | | | | (0.089) | (0.073) |
| MKTRF$_t$ × Size$_{i,t}$ | | | | | 0.019 | 0.026 |
| | | | | | (0.054) | (0.049) |
| Chauvet$_t$ | | | | | 0.054 | 0.046 |
| | | | | | (0.098) | (0.061) |
| Chauvet$_t$ × Size$_{i,t}$ | | | | | 0.085* | 0.060 |
| | | | | | (0.049) | (0.046) |
| Constant | 1.556*** | 2.595*** | 2.796*** | 2.682*** | 2.678*** | 2.805*** |
| | (0.034) | (0.046) | (0.062) | (0.073) | (0.077) | (0.052) |
| $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$ | 2% | 10% | 25% | 50% | 50% | 50% |
| Year FE | No | No | No | No | No | Yes |
| % Adjusted $R^2$ | 2.47 | 4.53 | 6.69 | 10.06 | 10.28 | 22.02 |
| Observations | 23,706 | 8,523 | 4,378 | 2,241 | 2,241 | 2,241 |

Table D.8: Robustness of cash at issuance estimates in column (3) of Table 6 to alternative minimum issuance thresholds and controls.

The sample consists of firm-quarter observations that immediately precede an equity issuance in quarter $t+1$ exceeding a threshold ranging from 2% to 50% of total assets less cash at the end of quarter $t$. The outcome variable, $Cash_{i,t}$, represents a firm's cash holdings at the end of quarter $t$, standardized within firm using the full sample (including quarters not preceding issuance). *Recession Probability*$_t$ is the log probability in quarter $t$ of a recession occurring within one year, standardized within firm. $Size_{i,t}$ is the log of firm $i$'s total assets less cash holdings at the end of quarter $t$, standardized within firm. Business cycle controls include HP-filtered log real GDP in quarter $t$, the CRSP excess market return in quarter $t$, and the contemporaneous recession probability from Chauvet and Piger (2008). Each of these controls is interacted with $Size_{i,t}$ to capture differential sensitivities of small and large firms to macroeconomic conditions. Column (6) includes year fixed effects to exploit within-year variation in recession risk. We cluster standard errors by quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

| | Cash at Issuance$_{i,t}$ | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Recession Probability$_t$ | -0.005 | 0.009 | 0.022 | 0.087** | 0.098** | 0.183*** |
| | (0.016) | (0.017) | (0.023) | (0.038) | (0.043) | (0.051) |
| Recession Probability$_t$ × Size$_{i,t}$ | 0.019* | 0.045*** | 0.061*** | 0.094*** | 0.093*** | 0.098*** |
| | (0.010) | (0.014) | (0.020) | (0.029) | (0.031) | (0.033) |
| Size$_{i,t}$ | 0.406*** | 0.348*** | 0.350*** | 0.356*** | 0.344*** | 0.295*** |
| | (0.009) | (0.012) | (0.018) | (0.026) | (0.026) | (0.026) |
| GDP$_t$ | | | | | -0.018 | -0.004 |
| | | | | | (0.037) | (0.049) |
| GDP$_t$ × Size$_{i,t}$ | | | | | 0.007 | 0.023 |
| | | | | | (0.028) | (0.028) |
| MKTRF$_t$ | | | | | 0.049 | 0.072* |
| | | | | | (0.051) | (0.043) |
| MKTRF$_t$ × Size$_{i,t}$ | | | | | 0.033 | 0.039 |
| | | | | | (0.033) | (0.030) |
| Chauvet$_t$ | | | | | -0.038 | -0.023 |
| | | | | | (0.036) | (0.036) |
| Chauvet$_t$ × Size$_{i,t}$ | | | | | -0.026 | -0.007 |
| | | | | | (0.030) | (0.031) |
| Constant | -0.040** | -0.274*** | -0.355*** | -0.419*** | -0.439*** | -0.484*** |
| | (0.016) | (0.018) | (0.022) | (0.037) | (0.037) | (0.030) |
| Issuance Sample $\left(\frac{\text{Issuance}_{i,t+1}}{\text{Assets-Cash}_{i,t}} > X\%\right)$ | 2% | 10% | 25% | 50% | 50% | 50% |
| Year FE | No | No | No | No | No | Yes |
| % Adjusted $R^2$ | 15.26 | 11.86 | 11.68 | 12.18 | 12.18 | 16.24 |
| Observations | 23,776 | 8,554 | 4,397 | 2,256 | 2,256 | 2,256 |

Table D.9: Robustness of payout growth estimates in column (4) of Table 6 to additional controls.

The outcome variable is the growth in dividends and share repurchases. 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. *Recession Probability*$_t$ is the quarter $t$ average monthly probability of a recession, standardized within firm. *Size*$_{i,t}$ is the log of firm $i$'s total assets less cash holdings at the end of quarter $t$, standardized within firm. Controls for the business cycle include HP filtered log real GDP 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 a firm when small and large to have different sensitivities to the business cycle. The sample only includes firms with payouts in the prior year and some variation in payouts. Column (3) includes year fixed effects to exploit within-year variation in recession risk. We double cluster standard errors by firm and quarter. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

| | (1) | $\left(\frac{\sum_{j=1}^{4}\text{Payouts}_{i,t+j}}{\sum_{j=-3}^{0}\text{Payouts}_{i,t+j}}-1\right)$ (2) | (3) |
|---|---|---|---|
| Recession Probability$_t$ | -0.026** | -0.020 | -0.038* |
| | (0.012) | (0.013) | (0.020) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.018** | -0.019** | -0.011 |
| | (0.007) | (0.008) | (0.007) |
| Size$_{i,t}$ | -0.039*** | -0.041*** | -0.030*** |
| | (0.009) | (0.009) | (0.006) |
| GDP$_t$ | | -0.022 | -0.004 |
| | | (0.016) | (0.023) |
| GDP$_t$ × Size$_{i,t}$ | | 0.012 | 0.015* |
| | | (0.008) | (0.008) |
| MKTRF$_t$ | | 0.027** | 0.022** |
| | | (0.013) | (0.011) |
| MKTRF$_t$ × Size$_{i,t}$ | | 0.006 | -0.002 |
| | | (0.007) | (0.005) |
| Chauvet$_t$ | | -0.004 | 0.012 |
| | | (0.032) | (0.013) |
| Chauvet$_t$ × Size$_{i,t}$ | | -0.007 | -0.004 |
| | | (0.014) | (0.009) |
| Constant | 0.002 | -0.002 | -0.000 |
| | (0.013) | (0.014) | (0.007) |
| Year FE | No | No | Yes |
| % Adjusted $R^2$ | 0.21 | 0.31 | 1.57 |
| Observations | 140,916 | 140,916 | 140,916 |

Table D.10: Robustness of investment growth estimates in column (5) of Table 6 to additional controls.

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. *Recession Probability*$_t$ is the quarter $t$ average monthly probability of a recession in twelve months, standardized within firm. *Size*$_{i,t}$ is the log of firm $i$'s total assets less cash holdings at the end of quarter $t$, standardized within firm. Controls for the business cycle include HP filtered log real GDP 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. Column (3) includes year fixed effects to exploit within-year variation in recession risk. 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) | (3) |
| Recession Probability$_t$ | -0.039*** | -0.037*** | -0.049*** |
| | (0.013) | (0.013) | (0.011) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.016** | -0.018** | -0.015*** |
| | (0.007) | (0.008) | (0.005) |
| Size$_{i,t}$ | -0.159*** | -0.160*** | -0.173*** |
| | (0.009) | (0.009) | (0.005) |
| GDP$_t$ | | 0.001 | -0.005 |
| | | (0.017) | (0.014) |
| GDP$_t$ × Size$_{i,t}$ | | 0.002 | -0.003 |
| | | (0.011) | (0.007) |
| MKTRF$_t$ | | 0.002 | 0.007 |
| | | (0.014) | (0.005) |
| MKTRF$_t$ × Size$_{i,t}$ | | 0.012 | 0.005* |
| | | (0.008) | (0.003) |
| Chauvet$_t$ | | -0.044* | -0.005 |
| | | (0.026) | (0.012) |
| Chauvet$_t$ × Size$_{i,t}$ | | 0.000 | 0.009 |
| | | (0.015) | (0.012) |
| Constant | 0.000 | -0.007 | -0.002 |
| | (0.011) | (0.013) | (0.004) |
| Year FE | No | No | Yes |
| % Adjusted $R^2$ | 2.30 | 2.34 | 3.64 |
| Observations | 231,696 | 231,696 | 231,696 |

Table D.11: Repeating Table 6: Are the Most Cyclical Firms Different?
We identify the 10% of firms in the sample that are the most cyclical. $\mathbb{1}$(Most Cyclical) is an indicator equal to one for these firms and zero otherwise. Cyclicality is measured by the correlation between HP-filtered log industry sales (by SIC-3) and HP-filtered log real GDP.

| | Issuance Propensity (1) | Issuance Amount (2) | Cash at Issuance (3) | Payout Growth (4) | Investment Growth (5) |
|---|---|---|---|---|---|
| Recession Probability$_t$ | 0.112*** | 0.203** | 0.084** | -0.037*** | -0.024* |
| | (0.036) | (0.080) | (0.039) | (0.012) | (0.013) |
| Recession Probability$_t$ $\times$ Size$_{i,t}$ | -0.077** | 0.105** | 0.087*** | -0.017** | -0.018** |
| | (0.038) | (0.042) | (0.029) | (0.007) | (0.008) |
| Recession Probability$_t$ $\times$ $\mathbb{1}$(Most Cyclical) | -0.101*** | 0.164 | 0.047 | -0.028* | -0.019 |
| | (0.034) | (0.201) | (0.140) | (0.015) | (0.017) |
| Recession Probability$_t$ $\times$ Size$_{i,t}$ $\times$ $\mathbb{1}$(Most Cyclical) | 0.186*** | 0.084 | 0.074 | 0.006 | -0.004 |
| | (0.060) | (0.106) | (0.114) | (0.014) | (0.017) |
| Size$_{i,t}$ | -0.533*** | -0.506*** | 0.360*** | -0.158*** | -0.043*** |
| | (0.041) | (0.041) | (0.025) | (0.009) | (0.010) |
| $\mathbb{1}$(Most Cyclical) | -0.367*** | 0.455* | 0.190 | -0.001 | -0.004 |
| | (0.059) | (0.247) | (0.155) | (0.007) | (0.006) |
| $\mathbb{1}$(Most Cyclical) $\times$ Size$_{i,t}$ | 0.148** | -0.002 | 0.037 | -0.013 | 0.042*** |
| | (0.068) | (0.136) | (0.138) | (0.013) | (0.014) |
| Intercept | 0.653*** | 2.669*** | -0.424*** | 0.000 | 0.002 |
| | (0.051) | (0.076) | (0.037) | (0.011) | (0.012) |
| Adjusted $R^2$ | 0.42 | 10.34 | 12.18 | 2.30 | 0.23 |
| $N$ | 361,668 | 2,241 | 2,256 | 231,696 | 140,916 |

Table D.12: Repeating Table 6: Are the Least Cyclical Firms Different?
We identify the 10% of the sample that is the least cyclical. 𝟙(Least Cyclical) is an indicator equal to one for such firms and zero otherwise. Specifically, we find the correlation of HP-filtered log aggregate industry sales by SIC-3 and correlate this with HP-filtered log GDP.

| | Issuance Propensity (1) | Issuance Amount (2) | Cash at Issuance (3) | Payout Growth (4) | Investment Growth (5) |
|---|---|---|---|---|---|
| Recession Probability$_t$ | 0.102*** | 0.232*** | 0.082** | -0.042*** | -0.030** |
| | (0.034) | (0.078) | (0.038) | (0.013) | (0.013) |
| Recession Probability$_t$ × Size$_{i,t}$ | -0.053 | 0.120*** | 0.092*** | -0.018*** | -0.024*** |
| | (0.037) | (0.041) | (0.029) | (0.007) | (0.009) |
| Recession Probability$_t$ × 𝟙(Least Cyclical) | 0.000 | -0.182 | 0.036 | 0.023 | 0.030* |
| | (0.038) | (0.151) | (0.099) | (0.015) | (0.016) |
| Recession Probability$_t$ × Size$_{i,t}$ × 𝟙(Least Cyclical) | -0.063 | -0.019 | 0.013 | 0.015 | 0.049*** |
| | (0.053) | (0.118) | (0.076) | (0.014) | (0.014) |
| Size$_{i,t}$ | -0.525*** | -0.528*** | 0.364*** | -0.159*** | -0.037*** |
| | (0.040) | (0.041) | (0.026) | (0.009) | (0.010) |
| 𝟙(Least Cyclical) | -0.057 | 0.302** | -0.111 | -0.001 | -0.001 |
| | (0.054) | (0.136) | (0.097) | (0.007) | (0.007) |
| 𝟙(Least Cyclical) × Size$_{i,t}$ | 0.043 | 0.087 | -0.067 | 0.005 | -0.012 |
| | (0.055) | (0.116) | (0.075) | (0.013) | (0.014) |
| Intercept | 0.626*** | 2.648*** | -0.407*** | 0.000 | 0.002 |
| | (0.048) | (0.072) | (0.037) | (0.011) | (0.013) |
| Adjusted $R^2$ | 0.40 | 10.24 | 12.09 | 2.30 | 0.24 |
| $N$ | 361,668 | 2,241 | 2,256 | 231,696 | 140,916 |