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Essays on Firm Dynamics and Taxation

Danilo Stojanović

Dissertation

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All remaining errors are my own.

Prague, Czech Republic Danilo Stojanović

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Abstract

In the first chapter, I show that the U.S. economy benefits from the 2003 tax cuts on dividends and capital gains. In my general equilibrium model, the tax reform reduces the costs of equity issuance, while dividend adjustment costs and a capital-adjusted limit on repurchases drive changes in dividends and repurchases. The tax reform stimulates small, productive firms to increase capital investment by borrowing more from shareholders. Large, less productive firms respond by reducing investment to finance increased payouts to shareholders. This capital reallocation increases aggregate productivity gains, with a part of increased payouts directed to consumption.

In the second chapter, we show that increased firm-specific profit uncertainty reduces capital investment. Quantile regressions reveal this effect is stronger at a higher level of investment for firms facing financing constraints compared to those with irreversible capital. Our general equilibrium model evaluates the impact of frictions and their role in transmitting the uncertainty shocks on real and financial outcomes. Firms reduce investment and increase cash holdings to avoid costly borrowing and irreversible capital adjustments.

In the third chapter, we study the influence of changes in firms' entry, exit and borrowing on the propagation of tax shocks in the U.S. economy. We apply a proxy-SVAR model to isolate exogenous variations in tax changes. The model indicates that corporate income tax cuts increase capital accumulation, which relaxes collateral constraints and provides firms with additional funds. These funds sustain initial tax stimulative effects on aggregate productivity and output growth.

Introduction

This thesis studies how different types of U.S. public firms respond to changes in government tax policy and uncertainty shocks, and their potential implications for aggregate productivity gains and social welfare. All three chapters highlight the role and impact of frictions in transmitting the tax and uncertainty shocks to macroeconomic aggregates and emphasize the importance of extensive margin effects of the shocks for aggregate responses.

The first chapter explores the hypothesis that the 2003 tax cuts on dividends and capital gains in the United States led to an increase in aggregate dividends and share repurchases. While the empirical evidence supports increased payouts to shareholders after 2003, theory predicts a drop in aggregate repurchases. This is because large firms cannot increase repurchase, while small firms increase new equity issuance. To rationalize empirical findings on complementary payouts, I develop a dynamic general equilibrium model with heterogeneous firms in which they face convex dividend adjustment costs and a capital-adjusted regulatory limit on repurchases. These frictions penalize large changes in dividends and allow larger firms to buy back more shares. I show that small (and productive) firms increase new equity issuance to finance higher capital investment, while large (and unproductive) firms finance increased dividends by reducing capital investment. Repurchases gradually increase as constraints are relaxed, supported by an increasing capital stock over time. Part of the increased payouts is reinvested in high-productivity firms through the stock market, leading to increased aggregate Total Factor Productivity (TFP). Another part of increased payouts is used for consumption, increasing social welfare in the economy.

The second chapter studies how firm-level profit volatility affects the investment and financial behaviour over four decades. Using Compustat data, we document that when idiosyncratic uncertainty increases: (1) high-investing firms cut their investment rate more sharply than other firms, reshaping the cross-sectional distribution of the investment rate; (2) extensive margin investment decision - whether to invest in new projects or not - accounts for 45% of the uncertainty effects; and (3) complementarity between idiosyncratic financial and real conditions largely affects constrained firms. We then develop a heterogeneous-firm model with both real and financial frictions to interpret these findings. Higher capital adjustment costs raise the investment inaction rate by 31%, while tighter collateral constraints reduce the investment spike rate by 46%. The interaction between partially irreversible capital and the collateral constraint reduces firms' debt capacity and liquid value of capital, leading to increased precautionary savings behavior. Specifically, increased volatility in firm-level productivity from the estimated value of 0.1915 to 0.2085 can capture around 5.9% of the decline in the average investment rate and 20% of the increase in cash holdings. Our findings also indicate a 2.2% reduction in the fraction of firms investing in new capital at the extensive margin, while investment in existing capital at the intensive margin decreases by 3.7%.

The third chapter analyzes the impact of firm dynamics and borrowing on the propagation of average corporate income tax shocks for the U.S. economy from 1993q2 to 2019q4. We study this transmission using a proxy-SVAR model, where the narrative measures of tax changes are used as instruments. We show that when there is increased net entry of firms and borrowing in the capital market, the average corporate income tax cuts lead to a temporary rise in aggregate TFP and real GDP. In addition, these expansionary effects persist only if firms can borrow additional external funds. The economic intuition is that tax cuts stimulate an increase in capital accumulation, which relaxes collateral constraints and provides firms with additional funds to sustain previously increased aggregate TFP and output growth.

1 The 2003 Tax Reform and Corporate Payout Policy in the U.S.

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1.1 Introduction

In 2003, the Bush administration authorized a fiscal stimulus package, which lowered dividend taxes sharply and capital gains taxes modestly such that the wedge between these taxes was eliminated.[1] The objective was to enhance long-term economic growth by reducing capital costs. Empirical evidence documents an increase in aggregate capital investment alongside aggregate payouts to shareholders following the tax reform. However, existing quantitative models overlook the positive responses of both share repurchases and dividends (e.g., Ábrahám et al., 2023; Anagnostopoulos et al., 2012; Gourio and Miao, 2011, 2010). The rise in dividend tax preference parameter after 2003 and a fixed limit on repurchases are the reasons that lie behind the strong substitution between aggregate dividends and repurchases.[2] This payout substitution can lead to weaker productivity gains and long-term social welfare.[3]

To address this gap, I extend Gourio and Miao (2011, 2010)'s general equilibrium model by incorporating a flexibility motive for repurchases along with the existing tax motive for dividends. This extension includes two payout frictions: quadratic adjustment costs on dividends and a capital-adjusted regulatory constraint on repurchases. Paying regular

[1]The Jobs and Growth Tax Relief Reconciliation Act of 2003 in the United States (JGTRRA) implemented tax cuts on dividends and capital gains. For taxpayers in the top four income tax brackets with marginal tax rates of 25%, 28%, 33%, or 35%, a new dividend tax rate of 15% was introduced. Additionally, the 2003 tax reform lowered the top capital gains tax rate from 20% to 15%.

[2]The 2003 tax reform reduces taxes on dividends relative to capital gains, increasing preferences for dividends while simultaneously reducing the cost of issuing new equity. At the same time, all firms face a fixed constraint on increasing repurchases. Hence, firms transiting to the regimes with new equity issues and dividends generate almost perfect substitution between aggregate dividends and repurchases.

[3]When the 2003 tax cuts increased aggregate dividends and decreased aggregate repurchases without changing total payouts, the overall capital available for circulation across firms would remain constant.

dividends commits firms to a specific payout level.[4] Deviating from this commitment is costly for firms, especially for those with limited excess cash. In contrast, Jagannathan et al. (2000) empirically show that share repurchases do not impose strict commitments as firms could announce repurchases without conducting them, allowing flexibility in varying returns over time. However, the Internal Revenue Service treats periodic repurchases as dividends, eliminating the pre-2003 tax advantage of repurchases, while the volume condition in SEC Rule 10b-18 limits share repurchases to prevent stock price manipulation. Hence, I set an upper bound on repurchases based on capital net of profit (or capital value). This constraint imposes a minimum repurchase commitment consistent with regulatory rules. The distribution of dividend changes in FFA data supports smooth adjustment costs, while SVAR estimates show a gradual increase in share repurchases after the tax cuts.

In this paper, the immediate responses of aggregate payouts to the 2003 tax cuts are twofold. First, dividends increase due to larger tax cuts on dividends, but this increase is twice as weak as in Gourio and Miao (2011) because of adjustment costs and an imposed zero dividend target.[5] Second, repurchases drop as the tax reform removes their advantage and lowers equity issuance costs, reducing the number of firms that buy back shares. High adjustment costs that prevent firms with a zero dividend target from initiating dividends, combined with short-run capital stickiness in the repurchase constraint, lead to a smaller drop in repurchases than in the benchmark model. Over time, the effects of adjustment costs intensify at high dividend levels due to convexity of the adjustment cost function, which stabilizes dividends and creates more flexibility in redirecting excess cash to recover repurchases. Furthermore, as capital investment relaxes the repurchase constraint, firms start increasing repurchases. The combined effect of payout frictions explains why repurchases

[4] In general, there are two types of dividends: regular and special. Special (one-time) dividend payments could be considered equivalent to share repurchases. Although special dividend payments recorded a significant rise after 2003, they accounted for less than 2.5% of total dividends on average following the 2003 tax reform, while regular dividends increased by 20% (see Chetty and Saez, 2006, 2005). Following the seminal survey study by Lintner (1956) on regular dividend payments, extensive empirical literature confirms that markets impose large costs on volatile dividends, inducing firms to commit to a targeted level of dividends.

[5] This study imposes a single dividend target that is exogenous and common to all firms. Otherwise, multiple dividend targets mitigate the role of adjustment costs on dividends that stabilize dividends.

initially drop and then recover and become positive in the long run.

Given that payout frictions have important implications for aggregate payout responses, I also address the following questions. How do exogenous changes in the parameter values of payout frictions affect aggregate payouts? Once the empirical rise in aggregate dividends and repurchases is captured by these frictions[6], I examine the model-implied allocation efficiency and welfare gains of the tax cuts. I also evaluate how the economic recovery from the 2001-2002 recession stimulated firms to distribute excess cash to shareholders.

This study presents the following quantitative results. First, the interplay of payout frictions and capital reallocation across firms within the dynamic general equilibrium model leads to a 1.14% rise in share repurchases and a 8.43% rise in dividends. Second, aggregate productivity gains, measured by Total Factor Productivity (TFP), increase by 0.27%. Welfare benefits, measured by increased consumption for fixed leisure, increase by 0.82%. Third, the tax effects on payouts are stronger for firms with lower dividend adjustment costs and more relaxed repurchase constraints. Fourth, the economic recovery from the 2001-2002 dot-com crisis slightly increases aggregate dividends and repurchases. Fifth, the drop in dividend taxes has larger aggregate, efficiency and welfare effects than the drop in capital gains taxes.

The main idea behind the aggregate results is that the tax reform reduces the costs of equity issuance, while payout frictions drive an increase in dividends and repurchases. The tax reform stimulates small, productive firms to increase capital investment by borrowing more from shareholders. Large, less productive firms respond by reducing investment to finance increased payouts to shareholders.[7] Positive payouts enable investors to transfer cash more efficiently to higher-productivity firms through stock market, contributing to a reduction in capital misallocation and an increase in aggregate productivity gains. Another part of the increase in payouts is directed to consumption, resulting in higher social welfare.

[6] A drop in dividend adjustment cost is expected for the post-2003 period due to the accounting scandals occurring in 2001-2002, which created distrust among shareholders, potentially stimulating shareholders to request large dividends even in the absence of the tax reform. In addition, 2003 regulatory changes by the SEC increased the volume limit on repurchases.

[7] Firms in my model can increase payouts to shareholders following the tax cuts only by reducing capital investment or imposing upward wage rigidity, *ceteris paribus*. Reduced investment diminishes future operating profit and increases uncertainty about maintaining long-term dividend commitments.

Upward wage rigidity is also examined to evaluate the general feedback effects of wage increases on firms' payout decisions. Firms with high investment opportunities reduce the demand for new expensive equity issues, retaining the number of firms engaged in repurchases. However, firms with low investment opportunities can finance the transition to a dividend regime. Sticky wages also mitigate the tax pressure on reducing investment by firms with low investment opportunities, increasing the intensive margin effects of the tax reform. With sticky wages, dividends and repurchases increase by around 7% and 14%, respectively. The aggregate TFP increases by 0.06%, while the welfare benefits increase by 2.44%.

Several key contributions to the literature on corporate tax changes are presented in this study. First, this research quantitatively captures the empirically documented rise in aggregate dividends, repurchases and capital investment. A model that more realistically captures aggregate responses to the tax reform can have higher effects on aggregate TFP and long-term consumption equivalent welfare of the household. Second, the traditional models typically connect investment responses to dividend tax changes with the marginal source and use of funds. This study reveals that investment responses also depend on the degree of the constraints on repurchases. Specifically, these constraints amplify the negative effects of dividend tax cuts on investment when capital is reallocated to dividend regime. Third, while existing empirical studies show a 20% increase in aggregate regular dividends (Chetty and Saez, 2006, 2005) and around 10% in capital investment (Campbell et al., 2013), this study applies a proxy-SVAR approach à la Mertens and Ravn (2013) to uncover a 7.5% increase in aggregate repurchases.

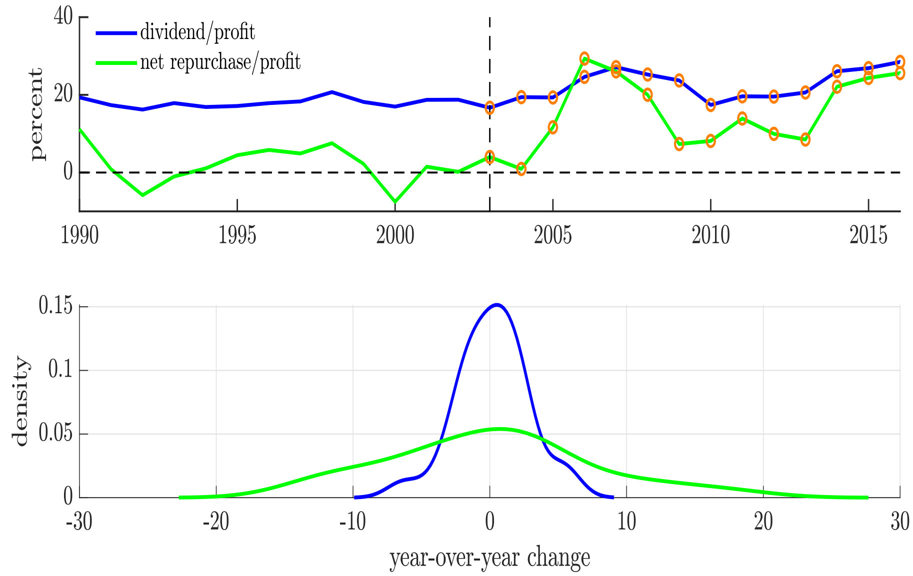
This chapter is structured as follows. Section 1.2 provides the rationale for incorporating the payout flexibility in the model as a motive for repurchases. Section 1.3 includes related literature. Section 1.4 describes the model. Section 1.5 explains finance regimes and capital reallocation. Section 1.6 discusses the calibration of the model and quantitative results. Section 1.7 concludes.

1.2 Empirical Evidence

This section provides data support for incorporating a specific functional form of payout frictions in the model economy: (i) convex and symmetric adjustment costs for dividends and (ii) a capital-adjusted constraint on repurchases.

Using aggregate data from the Federal Reserve Board's Flow of Funds Accounts (FFA)[8], Figure 1.1 provides several messages. First, corporate profits are not enough to explain all variations in aggregate payouts. Second, aggregate dividends are relatively stable, while aggregate net repurchases exhibit significantly higher volatility.[9] Third, repurchases initially fall due to the loss of tax advantage over dividends, but their subsequent rise suggests that non-tax factors drive repurchases. Fourth, dividends and net repurchases do not experience a decline just before 2003, implying that the 2003 tax reform was unanticipated.

Figure 1.1: Aggregate payout dynamics and their densities in FFA data



Note: Positive net repurchases indicate that repurchase exceeds equity issuance. The vertical dashed line refers to the implementation of the 2003 tax reform. A bottom panel shows a kernel density estimate of year-over-year payout changes across firms at the aggregate level.

[8]The construction of variables using the FFA data is explained in Appendix 1.8.A. Since firms can simultaneously issue new shares and buy back their old shares within a year, I focus on net repurchases.

[9]The lack of commitment is the main reason for repurchases having much larger volatility than dividends.

Strong persistence of dividend payments. Dividends may serve as an indicator of a firm's profitability, and thus any deviation from the dividend target induces costs by market participants (see Lintner, 1956). Negative deviations could imply a financial problem, while large positive dividends may indicate a lack of investment opportunities. This aversion to change dividends could explain low variability of dividends at the aggregate level.

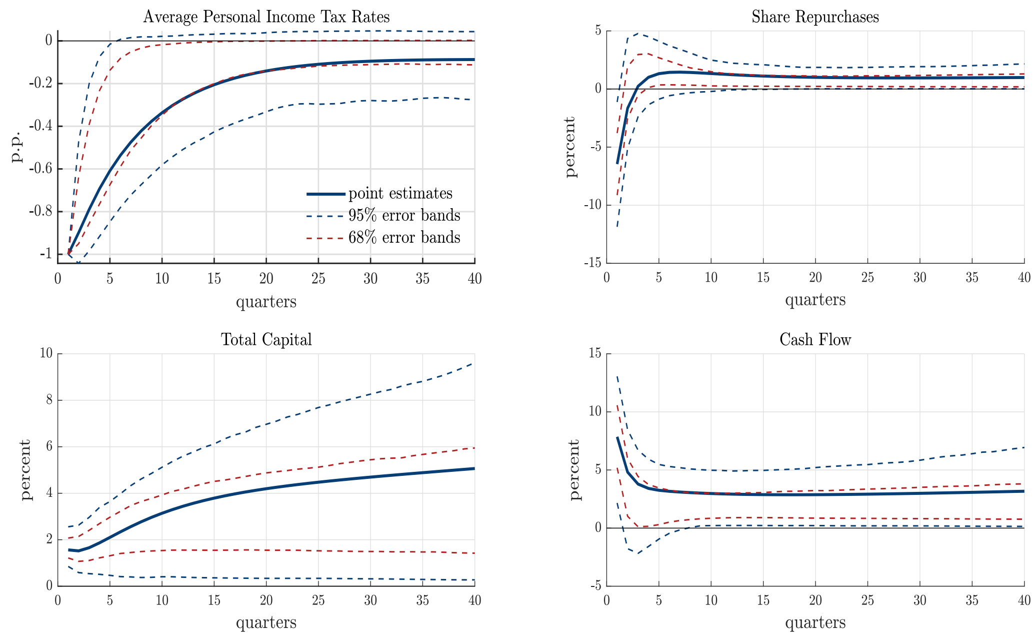
Figure 1.1 shows that the distribution of dividend changes is centered around zero, with relatively few extreme changes, supporting the use of convex and symmetric dividend adjustment costs in the model. This evidence is usually ignored in the general equilibrium analysis of tax reforms. Using firm-level Compustat data, Chetty and Saez (2006, 2005) provide a dif-and-dif evidence of a 20% rise in aggregate regular dividends after 2003, highlighting that firms commit to a higher level of dividends.

Financial flexibility of share repurchases. There is no obligation that commits firms to continue future repurchases, and thus firms could vary shareholder returns more easily. Figure 1.1 indicates that firms adjust repurchases more frequently and significantly than dividends relative to their profits. Firms view repurchases as a flexible alternative to dividends due to the high costs related to dividend volatility. The extensive literature confirms the importance of this flexibility of repurchases (see Ricardo, 2020; Farre-Mensa et al., 2014; Jermann and Quadrini, 2012; Brav et al., 2005; Fama and French, 2001; Jagannathan et al., 2000, among many others).

Using FFA data, we estimate the gradual increase of aggregate share repurchases following average personal income tax cuts. I follow the approach by Mertens and Ravn (2013) to isolate exogenous variation in taxes, combining a Structural Vector Autoregressive (SVAR) model with the narrative approach in estimating tax effects. Identification is obtained by imposing the restrictions that the narrative measures of tax changes are correlated with the structural tax shock but not correlated with other structural shocks. The narrative measures of tax changes used as instruments are identified by Romer and Romer (2010). The proxy SVAR does not require zero restrictions on the contemporaneous relationship among the variables in the VAR.

The baseline specification includes four variables: (1) average personal income tax rate (policy variable), (2) share repurchases, (3) cash flow, (4) fixed capital.

Figure 1.2: The effects of average personal income tax cuts



Note: Share repurchases refer to repurchases net of issuance as a fraction of operating profits. I use quarterly data from FFA from 1993q4 to 2006q4. The starting period for estimation is chosen to avoid interference from other tax reforms. Data construction and sensitivity analysis is provided in Appendix 1.8.A.

Figure 1.2 plots the impulse responses of selected variables to a one-percentage-point decrease in the average personal income tax rates (APITR). Repurchases initially fall but record persistent positive growth after five quarters. If aggregate repurchases increase by 1% in the long run (40 periods following the tax cuts) for a 1p.p. decrease in APITR, then the observed 7.5% increase in aggregate share repurchases corresponds to an average reduction in taxes on dividends and capital gains of 7.5p.p.[10] The subsequent analysis explores the role of payout friction in accounting for the dynamic responses of repurchases to the tax reform. The change in APITR loses statistical significance after 5 or 15 quarters (depending on the error bands), but point estimates do not return back to zero even after 40 quarters. Therefore, the estimated tax cuts are considered permanent. The permanent tax changes and

[10]Linear mapping between impulse responses of repurchases to the tax shocks between 1p.p. and 7p.p. is assumed for the purpose of comparing with the model-predicted increase in aggregate repurchases.

gradual responses in share repurchases are important implications of the empirical model for the later analysis in the quantitative model.

Although President Bush announced lower tax rates in January 2003 for the first time, the tax cuts were debated until May 2003. The tax reform narrowly passed the Senate with a 51-50 vote, clearly indicating how uncertain it was for the tax act to become law.[11]

1.3 Related Literature

This study is related to three strands of literature. The first strand is concerned with theoretical analysis of the effects of permanent dividend tax cuts on capital accumulation and payouts. Santoro and Wei (2011) and McGrattan and Prescott (2005) indicate that constant dividend taxes have no influence on capital investment and dividends in the model without heterogeneity.[12] Considering household heterogeneity and incomplete markets, Anagnostopoulos et al. (2012) find that dividend tax cuts negatively affect investment and positively impact dividends. In a general equilibrium model with heterogenous firms, Ábrahám et al. (2023) document negative effects of dividend tax cut on investment and dividends when uncertainty about the duration of the tax cut is increased. Further, Gourio and Miao (2011, 2010) show that if marginal source and use of funds are asymmetric across firms in two adjacent periods, dividend tax cuts have positive real effects.

My study shows that the dividend tax cut can have negative effects on capital investment if the marginal source of funds is retained earnings but returns on investment are used for repurchases in the next period. This is because the constraint on repurchases depends on capital stock. When a firm uses a dollar of internal funds for investment, a dividend tax cut raises the marginal cost of investment but does not change the marginal

[11] More information is available on `https://www.senate.gov/legislative/LIS/roll_call_lists/roll_call_vote_cfm.cfm?congress=108&session=1&vote=00196`

[12] According to the "new view", marginal incentives to invest of a firm that uses retained earnings are not changed after dividend tax changes. This is because the marginal unit of earnings faces the equal dividend tax burden, regardless of whether the firm pays dividends in the current period or invests and uses returns on investment for dividends in the future. Hence, the relative price of investment to dividends is not affected by dividend tax (see Auerbach, 1985 and Bradford, 1981). Under the "old view", a firm uses new equity to finance investment, and thus dividend taxes affect capital investment (see Poterba and Summers, 1984).

benefit if returns are used for repurchases in the following period.

The second strand of literature studies the role of frictions in firm dynamics. This study differs in three important dimensions. *The first dimension* is related to an upper bound on share repurchases. The literature typically ignores regulatory limits on share repurchases.[13] Even if an upper bound on repurchases is imposed, it is limited by a fixed number (see Gourio and Miao, 2011), and is independent of firm characteristics or government fiscal policies, resulting in a partial explanation for changes in payouts. In contrast, inspired by a gradual increase in repurchases following the tax cuts, this study incorporates a repurchase constraint that is a function of capital net of profits.

The second dimension is associated with frictions on dividends. In contrast to Ricardo (2020) but aligned with Jermann and Quadrini (2012), this study imposes symmetric and convex costs on long-term dividends rather than on past dividends. Dividend smoothing is consistent with the observation from Section 2 and with managers' preferences documented in surveys by Farre-Mensa et al. (2014) and Brav et al. (2005). However, Jermann and Quadrini (2012) treat dividends and repurchases as equivalent payouts. Consequently, their model cannot generate a realistic relationship between firm decisions and equity return, and thus suffers from meaningful predictions for equity transactions consistent with data. Moreover, they impose multiple dividend targets on each firm, potentially underestimating the role of dividend adjustment costs.[14] Instead, this study imposes a single dividend target on all firms in the spirit of Melcangi (2023).

The third strand of literature is related to empirical evidence on the 2003 tax reform. Using Compustat data, Campbell et al. (2013) document a rise of 10.2% in capital expenditure for public U.S. firms. Yagan (2015) shows that private U.S. firms do not change investment. However, many private firms do not have access to external funds via new equity issues. Given that equity issuing firms account for around 10% of aggregate investment, as reported

[13]Frequent realizations of share repurchases begin to be treated as dividends by the Internal Revenue Service in the US (see Hennessy and Whited, 2007; Gomes, 2001).

[14]Suppose that a firm is hit by a positive productivity shock. As a result, the firm is likely to increase its dividends over time. However, the shock also increases the dividend target, reducing the cost of deviation and leading to greater fluctuations in dividends. Consequently, the effectiveness of adjustment costs on dividends as a volatility stabilizer is diminished when multiple dividend targets are considered.

by Gourio and Miao (2010) in Compustat data, and new equity issues recorded a strong rise after 2003, Yagan (2015) may underestimate positive investment responses by considering private U.S. firms as a control group of firms in the dif-in-dif analysis.

Moreover, public firms from Compustat data increase dividend payments by 20% (see Chetty and Saez, 2005). The literature also reports a strong real annualized average growth rate of aggregate share repurchases in the two-year window around 2003 (see Floyd et al., 2015). Chetty and Saez (2006, 2005) focus on a subsample of firms and show that dividend-initiator firms increase both dividends and repurchases, leading the authors to conclude that there is no substitution between aggregate payouts after 2003. In addition, Floyd et al. (2015) and Edgerton (2013) document the absence of substitution between dividends and repurchases. Using a proxy-SVAR à la Mertens and Ravn (2013), this study isolates exogenous variation in the tax cuts and provides novel evidence of a positive response of aggregate repurchases to the 2003 tax cuts in FFA data. My quantitative model aligns with the empirical results regarding the absence of aggregate substitution between dividends and repurchases.

1.4 Model Economy

The model has two purposes: positive and normative. On the positive side, the model is necessary to explain why the 2003 tax cuts generate a rise in aggregate dividends and repurchases. The key puzzle is, why do firms buyback their shares if the 2003 tax reform generates a strong tax motive for dividends? Financial frictions, such as adjustment costs on dividends and an endogenous constraint on repurchases, help to explain why firms are reluctant to distribute all their excess cash to shareholders as dividends and use a portion for repurchases. The model also aims to show what would have occurred to firms' payouts in the counterfactual scenario with different non-tax experiments. On the normative side, the question is what are the efficiency and welfare effects of the 2003 tax cuts in the US? The reallocation of capital across firms has an important role in generating investment and payout dynamics documented in the empirical literature. This capital reallocation further affects output, wages and consumption.

I develop a dynamic general equilibrium model similar to the framework of Gourio and Miao (2011), incorporating dividend adjustment costs and a capital-adjusted limit on repurchases. I also exclude equity transaction costs, which tend to underestimate the fraction of equity issuing firms before and after the tax reform. This distorts the assessment of aggregate productivity gains. The model contains a representative household, heterogeneous firms and government. Time is discrete and the horizon is infinite.

1.4.1 Household

The infinitely-lived representative household maximizes the lifetime utility, which is the sum of current and present discounted future utility:

$$\max_{\{C_t, N_t, B_{t+1}, \theta_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - h \frac{N_t^{1+\varphi}}{1+\varphi} \right), \tag{1.1}$$

where $\beta \in (0,1)$ is the household's discount factor, C_t is consumption, N_t is labor supply, σ is the risk aversion parameter, h refers to disutility of labor, and φ is the inverse of Frisch labor supply elasticity.

At time t, the household earns labor income $w_t N_t$ in the competitive labor market and can receive income from savings in two financial assets: firm's shares θ_t and risk-free government bonds B_t.[15] A government bond costs one unit of goods at $t-1$ and pays $(1+r_t)$ units of goods at t, where r_t is a risk-free interest rate. Firm's shares cost P_{t-1} units of goods at $t-1$ and pay $d_t + P_t - s_t$ units of goods at t, where d_t is dividends. Throughout the text below, the market price of repurchased equity is denoted by $s_t < 0$, while $s_t \geq 0$ refers to the market price of new equity issue.

Note that the household is required to pay proportional taxes to the government: taxes on labor and bond returns τ_i, tax on dividends τ_d, and tax on capital gains τ_{cg}. Following the conventional approach used by Poterba and Summers (1984), capital gains are taxed on an accrual basis rather than upon realization. In addition, tax on capital gains is symmetric, which implies that capital losses are refunded. T_t is the lump-sum government transfer.

[15] The household owns all firms. There is a fixed continuum of firms $\ell \in [0,1]$, represented by the cross-sectional distribution of firms $\mu(k_t, z_t)$. Since firms are ex-ante identical, I drop the subscript ℓ for the rest of the analysis. Firms differ ex-post because of idiosyncratic productivity shocks and capital stocks.

The budget constraint of the household is

$$\begin{aligned} C_t + \int P_t \theta_{t+1} d\mu_t + B_{t+1} = \; & (1-\tau_i) w_t N_t + (1 + (1-\tau_i) r_t) B_t \; + \\ & + \int \Big((1-\tau_d) d_t + P_t - s_t - \tau_{cg}(P_t - s_t - P_{t-1}) \Big) \theta_t d\mu_t + T_t \; . \end{aligned}$$

The no-Ponzi game constraints on government bonds and firms' shares are considered to prevent the case of rolling over debt in infinity:

$$\lim_{T\to\infty} \prod_{t=0}^{T} \Big(1 + (1-\tau_i) r_t \Big)^{-1} B_{T+1} \geq 0 \; ,$$

$$\lim_{T\to\infty} \prod_{t=0}^{T} \Big(1 + (1-\tau_i) r_t \Big)^{-1} \theta_{T+1} \geq 0 \; .$$

The optimal conditions for households regarding consumption, labor supply, and equity decisions are derived in Appendix 1.8.B.1.

1.4.2 Firms

I assume that the household lends directly to firms, and thus the intermediation provided by banks is not necessary to provide funds to firms. Firms in the model economy are owned by the household (shareholder). The optimization problem of firms is consistent with the household's optimization problem, i.e. there is no agency problem.

Firms are heterogeneous in productivity and level of capital stock at any time t. The next period firm-level productivity shocks z_{t+1} are generated by a Markov process with transition function $Q(z_{t+1}, z_t)$. I assume that $Pr\{z_{t+1} = z_j | z_t = z_i\} = Q_{ij} \geq 0$ and $\sum_j Q_{ij} = 1$ for each $i = 1, \ldots, n_z$. The productivity process follows AR(1) process:

$$lnz_{t+1} = \rho \cdot lnz_t + \sigma_\epsilon \epsilon_{t+1}, \quad \epsilon_{t+1} \overset{iid}{\sim} \mathcal{N}(0,1) \tag{1.2}$$

where innovation ϵ_{t+1} has a normal distribution with mean zero and variance σ_ϵ^2. The persistence parameter satisfies $\rho \in (0,1)$. Firms are also subject to an exogenous aggregate TFP shock A_t, which is common to all firms. The sequence of aggregate productivity shocks is known with perfect foresight.[16]

[16]From now on, I assume that $A_t = 1$. When the counterfactual analysis of economic recovery is conducted, I consider the case with $A_t > 1$.

Firms use capital k_t and labor n_t to produce a single homogeneous output y_t. I assume a decreasing returns to scale (DRTS) production function $F_t(k_t, n_t; z_t)$ to ensure firm size matters, i.e. enable firm heterogeneity to exist in equilibrium. Consequently, the most productive firms will take control of the whole market. Since the competitive consumption goods market is considered, the price of output is the same for all firms and normalized to one. Operating profit function is defined as

$$\Pi_t(A_t, k_t, z_t; w_t) \coloneqq \max_{n_t \geq 0} \; A_t F(k_t, n_t; z_t) - w_t n_t(k_t, z_t) \tag{1.3}$$

The objective of managers is to maximize the sum of current and (present discounted) future net payments to shareholders from equation (1.13). Hence, the market value of the firm in period t is

$$V_t = \frac{1-\tau_d}{1-\tau_{cg}} d_t - s_t + P_t \tag{1.4}$$

The objective function of a firm is defined as

$$V_t(k_t, z_t) = \max_{\{k_{t+1}, i_t, d_t, s_t\}} \frac{1-\tau_d}{1-\tau_{cg}} d_t - s_t + \frac{1}{1+\frac{(1-\tau_i)r}{1-\tau_{cg}}} \mathbb{E}_t\left[V_{t+1}(k_{t+1}, z_{t+1}) \middle| z_t \right] \tag{1.5}$$

$$\text{s.t.} \quad d_t(k_t, z_t) + \phi_d(d_t - d^*)^2 + i_t + \frac{\psi}{2}\frac{i_t^2}{k_t} = (1-\tau_c)\Pi_t(A_t, k_t, z_t; w_t) + \tau_c \delta k_t + s_t(k_t, z_t) \tag{1.6}$$

$$q_t : \quad k_{t+1}(k_t, z_t) = (1-\delta)k_t + i_t(k_t, z_t), \quad k_0 > 0 \; given \tag{1.7}$$

$$\lambda_t^d : \quad d_t(k_t, z_t) \geq 0 \tag{1.8}$$

$$\lambda_t^s : \quad s_t(k_t, z_t) \geq -\eta(k_t - \Pi_t) \tag{1.9}$$

Flow of funds constraint (1.6) indicates that if internal funds (after-tax operating profit $(1-\tau_c)\Pi_t(A_t, k_t, z_t; w_t)$ and depreciation allowance $\tau_c \delta k_t$) are not sufficient to cover investment needs, $i_t + \psi i_t^2/(2k_t)$, a firm issues new shares $s_t \cdot \mathbb{1}_{s_t > 0}$. Otherwise, the firm distributes excess cash to shareholders as share repurchases $s_t \cdot \mathbb{1}_{s_t < 0}$ and dividends d_t.[17]

Distributing dividends triggers adjustment costs $\phi_d(d_t - d^*)^2$, where d^* is the targeted dividends. Following Jermann and Quadrini (2012), I introduce quadratic and symmetric adjustment costs to smooth dividend payments. Given the strong tax motive for dividends

[17] Notice that a firm does not have an option to retain excess cash.

after 2003, $\phi_d > 0$ implicitly imposes the bound on dividends. It also prevents payouts from offsetting each other proportionally in the budget constraint. For simplicity, I set the dividend target to zero, as in Melcangi (2023).

Capital accumulation constraint (1.7) indicates that investment in capital stock extends capital stock in the next period k_{t+1}. The depreciation rate is $\delta \in (0, 1)$. The Lagrange multiplier associated with equation (1.7) is the shadow price of capital, and is denoted by q_t.

Lagrange multipliers associated with the financial constraints (1.8) and (1.9) are λ_t^d and λ_t^s. Constraint (1.8) implies that a firm cannot reduce dividends without limits. Otherwise, costless external finance will make a financial problem of the firm negligible. I introduce an upper bound on repurchases that is contingent on the capital stock and profit, as indicated in equation (1.9). This constraint on repurchases ensures that low profitable capital is distributed and leads to a gradual increase in repurchases. Quantitative results are robust to using a constraint on repurchases based on the value of capital, as $s_t(k_t, z_t) \geq -\eta \cdot q_t \cdot k_t$.

1.4.3 Government

Government collects revenue from taxing the household's incomes (labor income, interest income, dividends, capital gains) and taxing firms' income. Since the government rebates these tax revenues to the household in a lump-sum transfer, this study does not consider the redistributive effects of the tax reform but rather focuses on the reallocation effects of the tax reform. The budget constraint of government is

$$\begin{aligned} T_t = \tau_i w_t N_t + \tau_c \int \left(\Pi(A_t, k_t, z_t; w_t) - \delta k_t\right) \mu_t(dk, dz) + \tau_d \int d_t(k_t, z_t) \mu_t(dk, dz) \\ - \tau_{cg} \int s_t(k_t, z_t) \mu_t(dk, dz) \end{aligned} \tag{1.10}$$

1.5 Finance Regimes and Mechanisms

This section highlights the role of financial frictions in payout and investment responses to tax cuts.

1.5.1 Finance Regimes

Adjustment costs on dividends play multiple roles in the model: they determine optimal financial policy after tax cuts, affect investment through capital reallocation across firms, reduce volatility in dividends, and prevent dividends and repurchases from offsetting each other proportionally in the budget constraint.

To illustrate the role of adjustment costs on dividends in defining finance regimes, I consider three counterfactual cases:

Case 1. Miller and Modigliani (1961) theorem of financial policy irrelevance. Suppose that $(1-\tau_d)/(1-\tau_{cg}) = 1$ and $\phi_d = 0$. Optimal financial policy of firms, as shown in equation (1.14) in Appendix 1.8.B.2, implies that $\lambda_t^d = \lambda_t^s = 0$. In this case, financial policy becomes irrelevant to firm value and investment, or simply remains indeterminate in equilibrium. That is, \$1 raised through new equity issuance or \$1 of internal funds has the same cost to the firm at margin. Hence, firms are indifferent between financing investment with internal or external funds.

Case 2. Introduce tax wedge between dividends and capital gains in the model. This includes $\tau_d > \tau_{cg}$ with $\phi_d = 0$. Optimal financial policy of firms (1.14) indicates that one of the constraints on either dividends (1.8) or repurchases (1.9), or both constraints must be binding. This implies that firms do not simultaneously issue new equity and pay dividends at optimum. Consequently, firms could be in one of the finance regimes (see below). However, the tax wedge becomes eliminated after the 2003 tax cuts, $(1-\tau_d)/(1-\tau_{cg}) = 1$, and thus some other financial frictions must be incorporated in the model to activate finance regimes. Otherwise, dividends and equity transactions are indeterminate after 2003.

Case 3. Introduce the tax wedge between dividends and capital gains, and adjustment costs on dividends in the model. These frictions, $\tau_d > \tau_{cg}$, $\phi_d > 0$, feature the pre-tax reform period. The 2003 tax cuts eliminate the tax wedge $\tau_d = \tau_{cg}$, but finance regimes exist due to dividend adjustment costs.[18] Importantly, the finance regimes change over time depending on idiosyncratic productivity and investment policy. At any time t firms may appear in one of the four regimes depending on their marginal source of finance:

- External growth regime (regime 1): $s_t > 0$ and $d_t = 0$. Firms have a low capital stock but high marginal product of capital. Since these firms do not have sufficient internal funds to finance their high investment needs, they have to issue new equities and do not distribute profits to shareholders.

- Share repurchase regime (regime 2): $s_t > -\eta(k_t - \Pi_t)$ and $d_t = 0$. Firms finance their growth potential with internal funds and start buying back their existing shares, but set dividends to zero.

- Dividend-constrained regime (regime 3): $s_t = -\eta(k_t - \Pi_t)$ and $d_t = 0$. Firms still do not pay dividends, but buy back their existing shares up to their upper limits. These firms do not need to issue new equity because the marginal return on investment may not be sufficient to cover lower firm value caused by share dilution.

- Payout regime (regime 4): $s_t = -\eta(k_t - \Pi_t)$ and $d_t > 0$. Firms buy back their existing shares up to their upper boundaries, and distribute the rest of excess cash to shareholders in a form of dividends.

Firms in regimes 3 and 4 prioritize repurchases, while only remaining profits are distributed as dividends. This structure reflects firms' preferences given the relative tax advantages of repurchases over dividends before 2003 and the additional costs of dividends.

1.5.2 Mechanisms

This section explains the channels through which tax cuts and financial frictions impact investment decisions of a *transiting* firm from regime 3. For that purpose, I exploit the user cost of capital framework, whose derivation is shown in Appendix 1.8.E.

[18]Appendix 1.8.H shows the role of adjustment costs of dividends in determining financial policy of a firm in equilibrium.

Dividend tax changes affect the current capital investment of a non-dividend firm only if it pays dividends in the following period, activating the reallocation channel. Changes in tax on capital gains affect the user cost of capital of the non-dividend firm at both extensive and intensive margins through the capital reallocation and after-tax return to equity.

Using equation (1.22) from Appendix 1.8.E shows that if a firm initiates dividends in the following period, the repurchase constraint has a positive impact on current capital investment, while the dividend adjustment costs negatively affect investment. That is, both financial frictions have effects on investment (and payouts) only at an extensive margin, *ceteris paribus*. In addition, the repurchase constraint mitigates positive effects of the dividend tax cut (or the 2003 tax reform) on investment through the reallocation channel.

Compared to the literature, this study shows that the capital reallocation of transiting firms is a necessary but not sufficient condition for dividend tax cuts to have a positive impact on investment. Dividend tax cuts may have negative effects on capital investment if returns on investment are used for repurchases in the next period. This is because a repurchase constraint depends on capital stock. Using a dollar of internal funds for investment increases its marginal costs, but dividend tax cuts do not affect its marginal benefit if the returns are allocated for repurchases in the next period.

1.6 Calibration and Quantitative Results

1.6.1 Calibration

The model calibration aims to capture key aspects of the payout and investment behaviour of firms at the aggregate level, including dividend smoothing, capital profitability, lagged investment effects and lumpy investment. Accordingly, key moments from the FFA and NIPA data are the autocorrelation of dividend-capital ratio, the mean of the profit-capital ratio, and the autocorrelation of the investment rate, respectively. Estimated lumpy investment comes from Cooper and Haltiwanger (2006). The model also aligns with changes in distribution of firms across finance regimes. The calibration period, 1988q1-2002q4, is selected for comparability with existing literature. I assume that the model reaches its initial steady state before 2003, allowing for the study of the long-run effects of the 2003 tax cuts. As the model lacks a closed-form solution for the stationary equilibrium, a numerical method is employed to approximate it.[19] Both households and firms operate under myopic expectations, where shocks are both unexpected and permanent.

The model has 17 parameters:

$$\Lambda = \Big\{\beta, \delta, d^*, h, \psi, \alpha_k, \alpha_n, \sigma_\epsilon, \rho, \sigma, \varphi, \eta, \phi_d, \tau_d, \tau_{cg}, \tau_i, \tau_c\Big\}.$$

Parameters are divided into two groups: internally and externally calibrated. The first group of parameters is determined in the stochastic environment, while the second group of parameters is set fixed in accordance with the estimates from the literature. The set of internally calibrated parameters includes

$$\omega = \{h, \psi, \eta\}.$$

The goal is to determine the value of the set of parameters $\hat{\omega}$ such that the model moments $\hat{m}(\omega)$ matches the data moments m. If the model permitted an analytic solution, we could directly compute model-generated moments from the system of equations. Since the model economy does not have a closed-form solution, the indirect inference is used for the estimation. The indirect inference proceeds in the following way: (1) for a set of parameters (externally calibrated and guessed internally calibrated), solve the dynamic problem of firms by the Value Function Iteration on a grid (2) compute stationary distribution of firms, (3) calculate model moments; (4) given a guess for ω, compute the difference between the model moments and data moments such that

$$g_i(\omega) = m_i - \hat{m}_i(\omega),$$

$$g(\omega) = (g_1(\omega), \dots, g_n(\omega)),$$

where $n = 3$ is the number of the data moments, (5) update the guess for ω using `fminsearch`, (6) continue the procedure until the difference between the model moments and data moments is minimized. The estimator is

$$\hat{\omega} = arg \min_{\omega} \ g(\omega)'\mathcal{W}g(\omega),$$

[19]Appendix 1.8.F provides the procedure for solving the model numerically.

where $\mathcal{W}$ is the optimal weighting matrix. In the model, $\mathcal{W}$ is set to the identity matrix. Estimated parameters are those that minimize the squared distance between model moments and data moments. Despite all the moments are jointly determined inside the model, some parameters are more suitable for matching certain moments. Table 1.1 shows obtained values for internally calibrated parameters, while Table 1.2 indicates values for externally calibrated parameters.

Tax system. I assume constant and proportional rates in the model. Shareholder income tax rates, including tax rates on dividends, capital gains and personal income, depend on the income tax bracket the shareholder belongs to. I assume that the representative household (shareholder) has an average income in the US, which belongs to the lowest category of the top four income tax brackets. Therefore, I set the dividend tax $\tau_d = 0.25$, the capital gains tax $\tau_{cg} = 0.20$, and the personal income tax $\tau_i = 0.25$. Operating profit of a firm is taxed at $\tau_c = 0.34$. These parameter values are typical in the literature (see, e.g., Ábrahám et al., 2023; Anagnostopoulos et al., 2012; Gourio and Miao, 2011, 2010).

Household preferences. The household rate of time preferences β is set to 0.971 such that average annualized nominal interest rate r equals 0.04, which corresponds to the after-tax risk free (3-month T-bill) interest rate in the US over the sample period.[20] The parameter h, which denotes the preferences for leisure, is set to 6.584 such that the aggregate labor supply equals 0.3 in equilibrium. Risk aversion parameter $\sigma = 1$ implies that the household has log utility of consumption. The inverse of Frisch labor elasticity is set to $\varphi = 1$, as suggested by Chang et al. (2019) for the representative household model.

Production technology. Using Tauchen and Hussey (1991), the continuous productivity process from (1.2) is discretized. I borrow the (non-structural) estimated production parameters from Gourio and Miao (2011, 2010) such that the capital share in production function $\alpha_k = 0.311$, the labor share in production function $\alpha_n = 0.650$, persistence of the productivity shock $\rho = 0.767$ and the standard deviation of the productivity shock $\sigma_\epsilon = 0.211$. The depreciation rate $\delta = 0.095$ is disciplined by the aggregate investment rate observed in NIPA. Convex adjustment costs of capital are incorporated in the model to prevent firms from quick responses to productivity shocks. The parameter $\psi = 0.650$ is set to match the

[20]In equilibrium, the discount factor of the household corresponds to $\beta = 1/(1 + (1 - \tau_i)r)$.

cross-sectional volatility of the investment rate observed in NIPA.

Table 1.1: Internally calibrated parameters, general equilibrium model

Description	Parameter	Value	Target	Source
discount factor	β	0.971	r=0.04	typical in literature
depreciation rate	δ	0.095	I/K=0.095	NIPA
weight on leisure	h	6.5843	N^s=0.3	typical in literature
convex inv adj cost	ψ	0.6505	$sd(I/K)$=0.156	NIPA
repurchase constraint	η	0.0026	$Sneg/(K-\Pi)$=0.0279	FFA

Note: Sneg refers to repurchases.

I choose the single target for dividends that is common to all firms in order to allow the dividend adjustment costs to reduce volatility in dividends.[21] The main drawback with the formulation of dividend adjustment costs is that the parameter d^* is exogenous, and thus a change in d^* triggers different dividends for reasons that are not necessary related to the 2003 tax cuts. The parameter $\phi_d = 0.373$ is determined as the mean of parameter estimates (0.1460 and 0.60) from Jermann and Quadrini (2012) and Melcangi (2023), respectively. The repurchase constraint parameter is set to 0.0026 to capture repurchases/(capital-profit) of 0.0278 in FFA data. Sensitivity analysis of different values for ϕ_d and η is conducted in Appendix 1.8.J.

1.6.2 Model Validation

Table 1.3 reports that the general equilibrium model (GE) matches targeted moments observed in the FFA data: investment rate, dividends and repurchases. As for non-targeted moments, the model moments are close to the data moments. Strong dividend smoothing is reflected in high autocorrelation of dividends-to-capital and dividends-to-earnings ratios. Eberly et al. (2012) claim that the best predictor of the future investment rate is the current investment

[21] Suppose that a firm is hit by a positive productivity shock. The firm will pay more dividends over time. However, the shock will also increase the dividend target, reducing the cost of deviation and increasing dividend volatility. Consequently, the role of the adjustment costs on dividends as a volatility stabilizer is mitigated with multiple dividend targets.

Table 1.2: Externally calibrated parameters, general equilibrium model

Description	Parameter	Value	Source
exponent on capital	α_k	0.311	GM(2010,2011)
exponent on labor	α_n	0.650	GM(2010,2011)
stand deviation of shock	σ_ϵ	0.211	GM(2010,2011)
persistance of shock	ρ	0.767	GM(2010,2011)
risk aversion	σ	1	typical in literature
inverse Frisch labor elasticity	φ	1	CKKR(2019)
tax on dividends	τ_d	0.25	typical in literature
tax on capital gains	τ_{cg}	0.20	typical in literature
tax on personal income	τ_i	0.25	typical in literature
tax on operating profit	τ_c	0.34	typical in literature
dividend target	d^*	0	Melcangi (2023)
dividend adj cost	ϕ_d	0.373	M(2023), JQ(2012)

Notes: GM(2010) and GM(2011) refer to the benchmark papers written by Gourio and Miao (2010) and Gourio and Miao (2011), CKKR(2019) is Chang et al. (2019), M(2023) is Melcangi (2023), JQ(2012) is Jermann and Quadrini (2012).

rate. Accordingly, I expect a strong autocorrelation of the investment rate in data and model. Capital profitability is assessed through the mean of the profit-capital ratio, a measure that closely matches empirical data. However, the model has lower volatility of repurchases than dividends, suggesting that there are shocks to profits other than firm-level productivity shocks important for model fit. Table 1.4 shows that the model also captures lumpy behaviour of investment.

Table 1.5 shows the relative percentage change in the fraction of firms between two periods. Compared with the pre-tax period, the after-tax period features a substantial drop in the transiting regime, leading to a rise in the number of firms within the external-growth regime and payout regime. This capital reallocation exerts a large extensive effect of the tax reform on reducing equity repurchases and increasing both new equity issuance and dividends. This study has a better model fit with Compustat data than the benchmark paper, based on

Table 1.3: Model fit of General Equilibrium model

	Data			Model		
Ratios	Mean	SD	AC(1)	Mean	SD	AC(1)
I/K	0.09	0.16	0.60	0.09	0.16	0.62
E/K	0.38	0.03	0.93	0.22	0.19	0.66
D/K	0.08	0.01	0.78	0.08	0.06	0.70
Sneg/K	0.03	0.04	0.37	0.01	0.01	0.63
D/E	0.21	0.02	0.54	0.33	0.03	0.55
Sneg/E	0.07	0.11	0.40	0.01	0.04	0.63

Notes: Variable Spos is equity issue, Sneg is repurchases, E is earnings. Investment is from NIPA data, others come from FFA data.

relative percentage changes. In addition, the mean absolute error between this study and Compustat data for relative changes in distribution of firms is 2.68. This statistics is much lower than that of the benchmark model. In contrast, the benchmark paper overestimates a fraction of firms in the transiting regime mainly because of equity transaction costs.

Table 1.4: Model fit of investment rate distribution

	Data	Model
Inactive ($\|i/k\| < 0.01$)	0.08	0.05
Positive ($i/k \geq 0.01$)	0.82	0.73
Negative ($i/k \leq -0.01$)	0.10	0.22
Positive spikes ($i/k \geq 0.2$)	0.19	0.19
Negative spikes ($i/k \leq -0.2$)	0.02	0.00

Note: Empirical moments are borrowed from Cooper and Haltiwanger (2006).

Table 1.5: Distribution of firms across the finance regimes

	Relative Percentage Change (%)		
	external-growth	transiting	payout
Compustat data	17.4	-33.3	12.8
This study	20.8	-37.9	12.8
Gourio and Miao (2011)	21.4	-24.0	27.3

Notes: In Compustat data, a relative percentage change in the fraction of firms within finance regimes is computed between the pre-tax period (1988-2002) and the post-tax period (2004-2006). The aggregated Compustat data are borrowed from Gourio and Miao (2010). For a comparability reason, this study groups firms from both share-repurchases and dividend-constrained regimes in a transiting regime.

1.6.3 Quantitative Results

1.6.3.1 Aggregate Responses and Sticky Wages After 2003

Could the historical reductions in taxes on dividends and capital gains (the JGTRRA reform) lead to substantial payouts to shareholders and increased capital investment after 2003? Table 1.6 shows that the 2003 tax cuts ($\tau_d = 0.15, \tau_{cg} = 0.15$) in the general equilibrium model (GE) trigger positive responses in long-run aggregate dividends, repurchases, and investment of 8.43% and 1.14% and 3.62%, respectively. Compared to the literature, Anagnostopoulos et al. (2012) predict a strong rise in dividends and a drop in investment after the 2003 permanent tax reform, while Gourio and Miao (2011) show the opposite responses as firms increase their new share issues and after-tax profits. Ábrahám et al. (2023) document an increase in dividends and a reduction in capital investment due to increased uncertainty about the duration of tax cuts and the opposite patterns when the reform is permanent.

Share repurchases are limited to experience a stronger increase, implying that the payout flexibility of repurchases was not sufficiently activated to generate the data-observed positive responses in aggregate repurchases to the tax reform. This is due to extensive margin

Table 1.6: Long-run aggregate effects of tax experiments

	% Change in aggregates (GE)			% Change in aggregates ($\widetilde{GE}$)		
	dividends	repurchases	investment	dividends	repurchases	investment
Empirical estimates	20.00	7.5	10.20			
Gourio and Miao (2011)	15.33	-13.60	4.04	25.78	-11.07	11.72
(0) τ_d=0.25, τ_{cg}=0.20						
Tax reforms:						
(1) τ_d=0.20, τ_{cg}=0.20	8.59	-2.61	0.25			
(2) τ_d=0.20, τ_{cg}=0.15	-0.05	3.73	3.39			
(3) τ_d=0.15, τ_{cg}=0.15	8.43	1.14	3.62	13.98	6.89	9.24

Table 1.6 shows percent changes in *aggregate* variables for the post-2003 period relative to the 1988q1-2002q4 calibration period. The taxes on dividends (τ_d) and capital gains (τ_{cg}) are set to 0.25 and 0.20 in the initial steady state. The 2003 tax reform includes $\tau_d = 0.15$ and $\tau_{cg} = 0.15$. GE indicates the general equilibrium setting, and $\widetilde{GE}$ is the general equilibrium model with sticky wages ($\rho_w = 0.65$). Empirical estimates of repurchases come from Section 1.2. Chetty and Saez (2006, 2005) document a rise in dividends, and Campbell et al. (2013) report a rise in investment.

decisions of transiting firms to reallocate capital to a regime with new equity issues.[22] In addition, wage feedback effects mitigate the importance of payout frictions observed in the post-2003 period. Incorporating the upward wage rigidity in the general equilibrium model ($\widetilde{GE}$) provides firms with excess cash after the tax cuts, leading to an increase in repurchases by 6.89% and dividends by 13.98%.[23] These aggregate tax effects are consistent across various counterfactual experiments (see Appendix 1.8.J for details). The benchmark paper, denoted by GM(2011) in Table 1.6, confirms the importance of the payout flexibility of repurchases because, under their implied setting with sticky wages, the 2003 tax reform would not be

[22]Large extensive margin effects of the tax reform are observed in Table 1.5. Transiting firms in the model economy are those with positive repurchases but without equity issues and dividends.

[23]The upward wage rigidity in the model mitigates the feedback effects of the wage growth after the tax reform, which generates excess cash available for payouts and capital investment. Appendix 1.8.G provides more information of the formulation of sticky wages in the model.

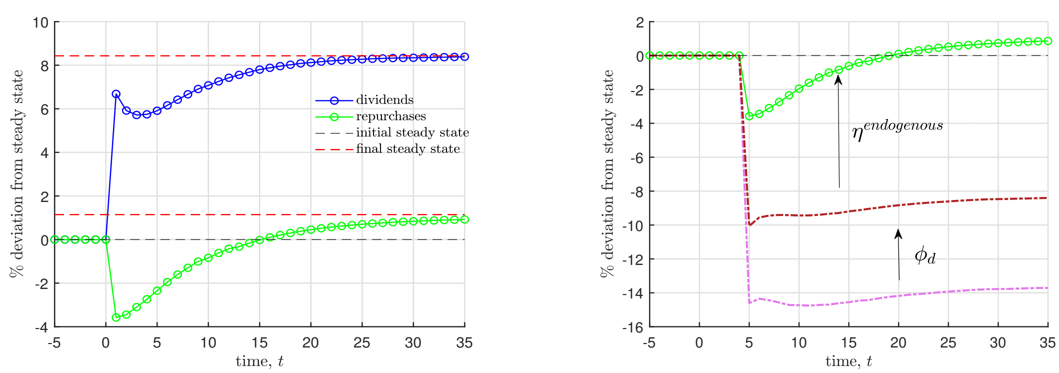
able to generate positive aggregate repurchases.

The findings about the absence of substitution between aggregate dividends and repurchases after 2003 are consistent with observation in the empirical literature (see Floyd et al., 2015; Edgerton, 2013; and Chetty and Saez, 2005).

Table 1.6 contains tax experiments that disentangle effects of dividend tax cuts from effects of capital gains tax cuts on payouts and capital investment. It shows that firms change optimal decisions considering a favorable type of tax cut. For example, compared to tax reform (1), tax reform (2) reduces the tax preference for dividends, leading to a decrease in dividends and an increase in repurchases.

Finally, Figure 1.3, panel (a) presents transitional dynamics of aggregate dividends and share repurchases in the general equilibrium. It shows that both dividends and repurchases increase gradually. The dividend pattern is consistent with the prediction of Poterba (2004), while I show in Figure 1.4 that the model-implied dynamics of repurchases is consistent with the empirical estimates from Section 1.2. Panel (b) shows the influence of both payout frictions in shaping repurchase responses over time.

Figure 1.3: Transitional dynamics of payouts in the US



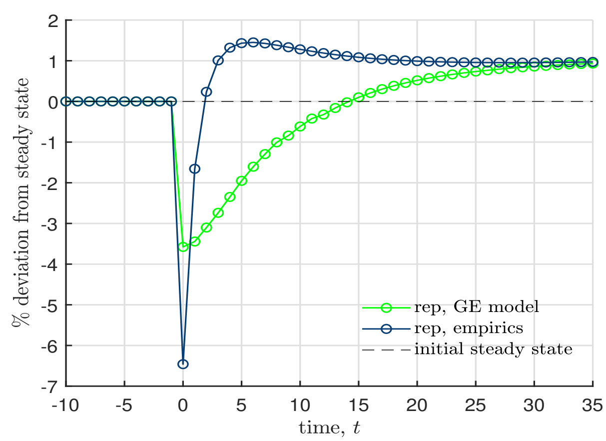
(a) payouts (b) repurchases

Notes: Panel (b) presents different repurchase responses depending on financial frictions. Purple line refers to the benchmark model of Gourio and Miao (2011), characterized by equity costs ($\lambda > 0$), no dividend adjustment costs ($\phi_d = 0$), a fixed repurchase constraint ($\eta > 0$). Red line is the counterfactual model with ($\lambda = 0$), ($\phi_d > 0$), and fixed ($\eta > 0$). Green line presents repurchases in my GE model with ($\lambda = 0$), ($\phi_d > 0$), and endogenous ($\eta > 0$).

In this paper, the immediate responses of aggregate payouts to the 2003 tax cuts are twofold. First, dividends increase due to larger tax cuts on dividends, but this increase is twice as weak as in Gourio and Miao (2011) because of adjustment costs and an imposed zero dividend target. Second, repurchases drop as the tax reform removes their advantage and lowers equity issuance costs, reducing a number of firms that buys back shares. High adjustment costs that prevent firms with a zero dividend target from initiating dividends, combined with short-run capital stickiness in the repurchase constraint, lead to a smaller drop in repurchases than in the benchmark model. The impact of both financial frictions is particularly pronounced for low-profitable firms.

Over time, the effects of adjustment costs intensify at high dividend levels due to convexity of the adjustment cost function, which stabilizes dividends and creates more flexibility in redirecting excess cash to recover repurchases. Furthermore, as capital investment relaxes the repurchase constraint, firms start increasing repurchases. The combined effect of payout frictions explains why repurchases initially drop and then recover and become positive in the long run.

Figure 1.4: Empirical estimates vs. model-implied repurchases



Notes: Blue dashed line indicates responses of aggregate repurchases to the tax 2003 reform generated by the proxy-SVAR model. Net repurchases to operating profit ratio is used as the measure of repurchases in the empirical model. Green line refers to the responses of aggregate repurchases generated in the general equilibrium model. Data source: Flow of Funds Accounts.

While dividend adjustment costs diminish the positive impact of the dividend tax reform on capital investment, the repurchase constraint amplifies its real effects. The intuition is that when a firm can use the investment returns for share repurchases instead of dividends, whose volatility is costly, the benefits of investment tend to increase. The impact of dividend adjustment costs and share repurchase constraint on optimal financial and investment policy is detailed in Appendix 1.8.B.2. I also show numerically that when more costly dividends are added on top of the 2003 tax reform, aggregate dividends reduce, while aggregate share repurchases increase. In contrast, tightening the repurchase constraint has the opposite effect on aggregate payouts. These numerical analyses are presented in Appendix 1.8.J.

1.6.3.2 Allocation and Welfare Effects

This subsection shows that complementarity between aggregate dividends and share repurchases is an important determinant of the allocation and welfare effects of the tax reform. There is robust empirical support for heterogeneous responses of firms to the 2003 tax reform (see, e.g., Campbell et al., 2013; Gourio and Miao, 2010; Chetty and Saez, 2006).

One of the primary arguments for implementing tax cuts on dividends and capital gains was to address the shortage of available cash for financing productive investment opportunities. Increased cash payouts to shareholders through tax cuts could circulate in capital markets to fuel investment. This study predicts a 0.27% increase in Total Factor Productivity (TFP) and a 0.82% rise in consumption-equivalent welfare in general equilibrium. Studying the dividend and capital gains taxes in a general equilibrium model with incomplete markets and heterogeneous shareholders, Anagnostopoulos et al. (2012) show welfare reduction. Ábrahám et al. (2023) document weakly positive responses of aggregate TFP and welfare gains of the representative household. Gourio and Miao (2011) report slightly higher productivity and welfare gains than this study despite lower aggregate total payouts. This is because a greater number of transiting firms in the pre-tax period magnifies the role of a reallocation channel after the 2003 tax reform.

Allocation Efficiency

Figure 1.5 shows that high-productive firms increase capital investment, while low-productive firms decrease investment after the tax cuts. Since Table 1.6 displays that aggregate investment rises, the rise in investment of high-productive firms is higher than the drop in investment of low-productive firms. Larger capital leads to higher output and labor demand over time. Considering that the rise in aggregate output is driven by high-productive firms, aggregate output increases more than the rise in aggregate capital and employment. Consequently, productivity gains, measured by aggregate TFP, become larger with the higher participation of the most productive firms in producing aggregate output.

Figure 1.5 depicts changes in aggregate capital across different productivity levels before and after 2003. The dividend tax cut (blue line) decreases capital among unproductive firms and increases capital among productive firms, implying that the dividend tax cut drives the reallocation of capital from unproductive to productive firms. The capital gains tax cut (red line) does the opposite thing. The impact of the capital gains tax cut on capital reallocation is less pronounced compared to the effects of the dividend tax cut. In the general equilibrium model with fully flexible wages, excess cash from reduced capital among less productive firms is directed to payouts, while high productive firms increase their capital investment through increased new equity issues.

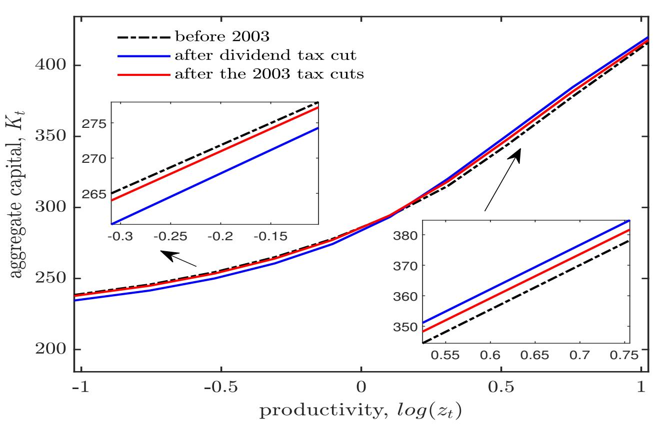


Figure 1.5: Capital reallocation in general equilibrium

Welfare Effects

Since payouts are conducted in compliance with the long-term balance strategy of firms, their rise is followed by a rise in capital investment, job creation (employment), higher wages, and higher consumption (see Table 1.7).

Table 1.7: Real effects of tax changes

	% Change in aggregates						
	investment	output	employment	wage	firm value	TFP	welfare
GE	3.62	1.58	0.29	1.29	9.42	0.27	0.82
$\widetilde{GE}$	9.24	7.47	7.00	0.45	17.40	0.05	2.44

Notes: Total Factor Productivity: $TFP = Y/(K^{\alpha_k} N^{\alpha_n})$. Welfare is expressed in consumption equivalent units. The 2003 tax reform: $\tau_d = 0.15, \tau_{cg} = 0.15$. Table 1.9 shows percent changes in aggregate variables for the post-tax period relative to the pre-tax period. $\widetilde{GE}$ is the general equilibrium setting with the sticky wages.

In this section, I compare the long-term welfare in the two tax regime economies, before and after the tax cuts.[24] The representative agent's welfare under the pre-tax policy regime in steady state is

$$W^A \equiv U(C^A) + V^h(N^A) = \frac{(C^A)^{1-\sigma}}{1-\sigma} - h\frac{(N^A)^{1+\varphi}}{1+\varphi}$$

Similarly, define the agent's welfare under the post-tax policy regime in steady state

$$W^B \equiv U(C^B) + V^h(N^B) = \frac{(C^B)^{1-\sigma}}{1-\sigma} - h\frac{(N^B)^{1+\varphi}}{1+\varphi}$$

I define Δ_{ev} as the percentage change in consumption that makes the agent indifferent between the two economies:

$$U((1+\Delta_{ev}) \cdot C^A) + V^h(N^A) = W^B$$

Given that $U(C) = ln(C)$ for $\sigma = 1$, the equivalent variation as a fraction of tax regime A's consumption to move from economy A to B is

$$\Delta_{ev} = exp(W^B - W^A) - 1$$

[24]Note that this comparison ignores transition effects, and thus Table 1.7 does not present the full welfare effects of the tax cuts. Given the significant difference between the welfare impacts across different models conditional of sticky wages, the welfare analysis remains important.

Table 1.7 shows that welfare increases by 0.82% in GE and by 2.44% in $\widetilde{GE}$. The tax cuts improve long-term welfare gains of the representative household through the increase in firm profits. This is because investors could more easily transfer cash to more productive firms using share repurchases, which reduces capital misallocation and increases return on investment. The size of the welfare gains depends on financial frictions in the model, including the tax wedge between dividends and capital gains, adjustment costs of dividends, constraint on repurchases and wage rigidity.

1.7 Conclusion

In the last two decades, the United States has intensively used corporate tax cuts as a strategy to stimulate economic growth. This study investigates the relationship between the tax 2003 reform and aggregate payouts to shareholders. I document a positive relationship between the tax cuts and repurchases in aggregate FFA data, while Chetty and Saez (2006, 2005) support a positive relationship between the tax cuts and dividends using firm-level Compustat data. These empirical findings contrast with the corporate finance literature, which highlights the substitution between aggregate dividends and repurchases following the tax reform. Subsequently, I develop a dynamic general equilibrium model with heterogeneous firms to rationalize these empirical findings and study their implications on aggregate productivity gains and social welfare.

The model in this paper incorporates financial flexibility of repurchases in the tax framework through two payout frictions, including dividend adjustment costs and a capital-adjusted regulatory constraint on repurchase. In the presence of additional costs on dividends, potential dividend-initiator firms use repurchases to avoid a long-term commitment to dividend payments. Similarly, dividend-paying firms tend to use repurchases to avoid a large deviation from a dividend target. The endogenous constraint on repurchases allows capital expenditure to create space for increasing repurchases over time, which reduces costly volatility in dividends. This study also considers sticky wages, which generates an approximately 14% increase in aggregate dividends and a 7.5% increase in repurchases, responses that are close to empirical evidence. Then, I investigate the policy implications of the positive relationship between aggregate payouts and the tax reform of 2003. A model that captures more realistically aggregate payout responses to the tax reform may imply a higher aggregate TFP and a long-term consumption equivalent welfare.

1.8 Appendix

1.8.A Data Construction and Identification of fiscal policy shocks

The aggregate data for the empirical investigation involves the Flow of Funds Accounts of the United States (Board of Governors of the Federal Reserve System). I construct cash-flow, net dividends, repurchases, new equity issues, operating profits, depreciation, taxes on corporate income from Table F.102: Nonfarm Nonfinancial Corporate Business. Book value of liabilities, market value of assets, real estate, equipment, intellectual property are obtained from Table B.102: Balance Sheet of Nonfarm Nonfinancial Corporate Business. The baseline sample period is from 1993q4 to 2006q4.

Cash-flow, operating and financial profits, and capital are calculated as

$$\text{Cash flow} = \text{operating profits} + \text{financial profits},$$

$$\text{Operating profits} = \text{operating income} + \text{depreciation - taxes on corporate income},$$

$$\text{Financial profits} = \text{property income received - property income paid},$$

$$\text{Total capital} = \text{real estate} + \text{equipment} + \text{intellectual property},$$

$$\text{Fixed capital} = \text{equipment}.$$

This appendix provides additional information on methodology related to empirical results from Section 1.2. I apply a proxy SVAR in the spirit of Mertens and Ravn (2013) to estimate the influence of the 2003 tax reform on aggregate share repurchases. The starting point in estimation is a standard reduced-form VAR model of order one:

$$y_t = Ay_{t-1} + B\nu_t, \quad \nu_t \overset{iid}{\sim} \mathcal{N}(0, I_4),$$

where y_t be a (4×1) vector of economic variables, including a constant term observed at time t, average personal income tax rates, repurchases, fixed capital and cash-flow. A is (4×4) dynamic matrix of coefficients and B is (4×4) impact matrix of coeficients, ν_t is an (4×1) vector of unobservable structural shocks with zero mean and unit variance. The problem with the structural shocks ν_t is that they are unobserved. In order to estimate B, we can bundle structural shocks into a single object:

$$y_t = Ay_{t-1} + u_t, \quad \text{where } u_t = B\nu_t.$$

Under the assumption that the VAR is invertible, the innovations u_t are written as linear combinations of the structural shocks ν_t with the standard covariance restrictions $Var(u_t) \equiv \Sigma_u = BB'$. The identification problem is to find a B matrix that satisfies $\Sigma_u = BB'$. To focus exclusively on identifying impulse responses to tax shocks, rather than other shocks, our task is limited to identifying the elements found in the first column of the matrix B. For that purpose, the narratively identified measures of exogenous shocks to average tax rates by Romer and Romer (2010) are used as an external instrument m_t. For m_t to qualify as a valid instrument, it must meet two conditions:

$$E[m_t \nu'_{1t}] = c \neq 0, \text{ relevance condition}$$

$$E[m_t \nu'_{2t}] = 0, \text{ exogeneity condition.}$$

For the sensitivity analysis to our baseline result from Section 1.2, I consider the longer time sample, starting from 1951q1 to 2006q4. The estimated results are shown in Figure 1.6.

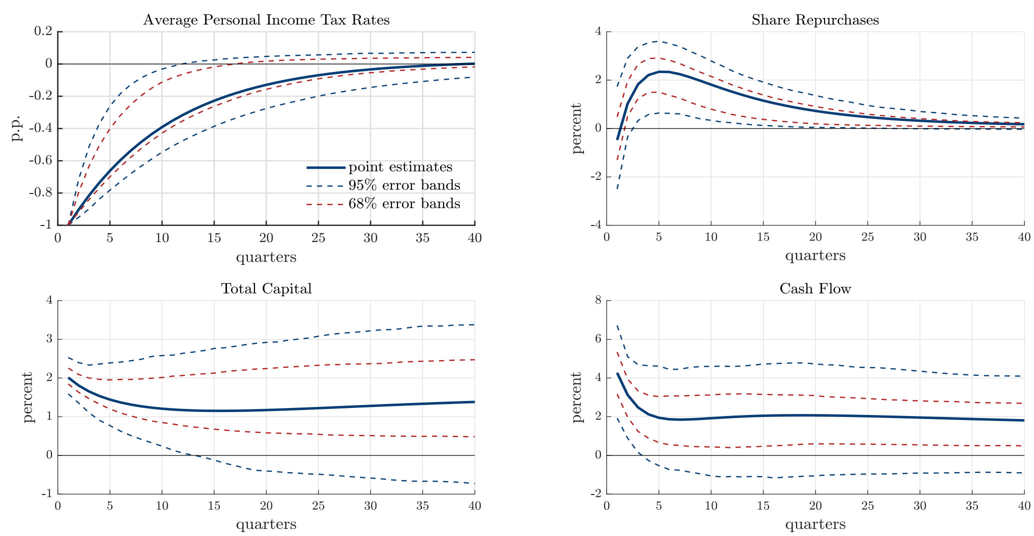


Figure 1.6: Responses of share repurchases to the shocks to personal tax rates

1.8.B Optimal Conditions for Household and Firms

1.8.B.1 Household

The optimal conditions for households with respect to consumption, labor supply and equity decisions are derived by maximizing utility subject to budget constraint:

$$C_t: \ \lambda_t = C_t^{-\sigma}$$

$$N_t: \ h \cdot N_t^{\varphi} = \lambda_t (1-\tau_i) w_t$$

$$B_{t+1}: \ \lambda_t = \beta \cdot \mathbb{E}_t \Big[\lambda_{t+1} \Big(1 + (1-\tau_i) r_{t+1} \Big) \Big]$$

$$\theta_{t+1}: \ \lambda_t = \frac{1}{P_t} \beta \cdot \mathbb{E}_t \Big[\lambda_{t+1} \Big((1-\tau_d) d_{t+1} + P_{t+1} - s_{t+1} - \tau_{cg}(P_{t+1} - s_{t+1} - P_t) \Big) \Big],$$

where λ_t is the Lagrange multiplier on the household's budget constraint. From optimal condition with respect to government bonds B_{t+1}, the household's discount factor is $\beta = \frac{1}{1+(1-\tau_i)r}$ in steady state equilibrium.

Combining the optimal conditions for B_{t+1} and θ_{t+1} leads to the no-arbitrage equation between firm shares and government bonds:

$$\underbrace{(1-\tau_i) r_{t+1}}_{r^b_{t+1}} = \underbrace{\frac{1}{P_t} \cdot \mathbb{E}_t \Big[(1-\tau_d) d_{t+1} + (1-\tau_{cg})(P_{t+1} - s_{t+1} - P_t) \Big]}_{r^s_{t+1}} \tag{1.11}$$

Since I assume that there is no aggregate uncertainty, the investment wedge between firm shares and government bonds does not exist. Equation (1.11) indicates that the household invests in firm shares until their expected returns equal returns on government bonds, i.e. there is no risk premium for share: $r^b_{t+1} = r^s_{t+1}$.

Rewrite equation (1.11) such that

$$(1-\tau_{cg}) + (1+\tau_i) r_{t+1} = \frac{1}{P_t} \cdot \mathbb{E}_t \Big[(1-\tau_d) d_{t+1} + (1-\tau_{cg})(P_{t+1} - s_{t+1}) \Big],$$

and divide the above expression by $(1-\tau_{cg})$ to obtain the ex-dividend price of shares

$$P_t = \frac{1}{1 + \frac{(1-\tau_i) r_{t+1}}{1-\tau_{cg}}} \mathbb{E}_t \underbrace{\left[\frac{1-\tau_d}{1-\tau_{cg}} d_{t+1} - s_{t+1} + P_{t+1} \right]}_{V_{t+1}}, \tag{1.12}$$

where V_{t+1} is the cum-dividend equity value of a firm. For $\tau_{cg} > 0$, managers of a firm anticipate future tax liability (deduction) on capital gain (loss). The transversality condition on equity prices is also imposed,

$$\lim_{T\to\infty} \prod_{t=0}^{T} \left(1 + \frac{(1-\tau_i)r_t}{1-\tau_{cg}}\right)^{-1} P_{T+1} = 0$$

Under the assumptions of no-aggregate uncertainty and no-bubbles, and iterating forward the price from equation (1.12), one can express the ex-dividend price as the present discounted sum of tax-adjusted payouts

$$P_t = \mathbb{E}_t \sum_{j=1}^{\infty} \left(\prod_{m=0}^{j-1} \frac{1}{1 + \frac{(1-\tau_i)r_{t+1+m}}{1-\tau_{cg}}} \right)^{j} \cdot \left(\frac{1-\tau_d}{1-\tau_{cg}} d_{t+j} - s_{t+j} \right) \tag{1.13}$$

The formulation of the firm's price (1.13) is consistent with Anagnostopoulos et al. (2022, 2012), Gourio and Miao (2011, 2010), Poterba and Summers (1984), among many others.

In equilibrium, $\theta_{t+1} = \theta_t = 1$ because all households are identical, which further implies that the household obtains all proceeds from share repurchases and provides all new equity issues. Risk-free bond holdings equal net debt of firms in equilibrium, $B_t = 0$.

1.8.B.2 Firms

Solutions to *static* problem of firms from (1.3) provide optimal labor demand, output and profit. Suppose that $y_t(k_t, z_t) \coloneqq A_t F_t(k_t, n_t; z_t) = A_t z_t k_t^{\alpha_k} n_t^{\alpha_n}$ where $0 < \alpha_k + \alpha_n < 1$. For a given capital stock, a firm decides optimally about the current level of labor demand after the realization of the productivity shock:

$$n_t : \; n_t(k_t, z_t) = (A_t z_t k_t^{\alpha_k})^{\frac{1}{1-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{1}{1-\alpha_n}}$$

Optimal output is

$$y_t(k_t, z_t) = (A_t z_t)^{\frac{1}{1-\alpha_n}} k_t^{\frac{\alpha_k}{1-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{\alpha_n}{1-\alpha_n}}$$

Optimal profit is

$$\Pi_t(A_t, k_t, z_t; w_t) = A_t^{\frac{1}{1-\alpha_n}} \underbrace{z_t k_t^{\alpha_k} (z_t k_t^{\alpha_k})^{\frac{\alpha_n}{1-\alpha_n}}}_{=(z_t k_t^{\alpha_k})^{\frac{1}{1-\alpha_n}}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{\alpha_n}{1-\alpha_n}} - w_t (z_t k_t^{\alpha_k})^{\frac{1}{1-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{1}{1-\alpha_n}}$$

$$\Leftrightarrow \ \Pi_t(A_t, k_t, z_t; w_t) = (A_t z_t k_t^{\alpha_k})^{\frac{1}{1-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{\alpha_n}{1-\alpha_n}} (1-\alpha_n)$$

Optimal Financial Policy

The optimal financial decisions of a firm are determined by

$$s_t: \quad \left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d\right) \cdot \frac{1}{1+2\phi_d d_t} + \lambda_t^s = 1 \tag{1.14}$$

Holding investment policy fixed, a firm's financial policy can be interpreted as follows. If a firm issues a dollar of new equity, it results in a capital loss for the shareholder. Hence, the RHS of (1.14) is the marginal costs of an additional unit of new equity issue to the shareholder at time t. At margin, if the firm distributes the raised dollar to the shareholder as dividends, then the shareholder receives $\$(1-\tau_d)/(1-\tau_{cg})$, adjusted for dividend costs $\$(1+2\phi_d d_t)$. In addition, issuing new equity and distributing dividends relax payout constraints by $\$\lambda_t^d$ and $\$\lambda_t^s$. Therefore, the LHS of (1.14) is the marginal benefits to the shareholder at time t. At optimum, equation (1.14) implies that the additional external finance is used to pay dividends until the RHS equals the LHS.

A higher ϕ_d reduces the marginal benefit of dividends, *ceteris paribus*. It also mitigates the positive impact of the tax 2003 reform on dividends. Consequently, a dividend paying firm does not have an incentive to pay large extra dividends, and similarly a non-dividend paying firm is discouraged to initiate dividends. Instead, firms can avoid more expensive dividends by repurchasing shares.

Before the tax reform, the tax wedge between dividends and capital gains is $\tau_d > \tau_{cg}$ or $(1-\tau_d)/(1-\tau_{cg}) < 1$. Since the tax wedge reduces the value of dividends, one can claim that the tax wedge makes new equity issue more costly than internal funds. Therefore, the tax wedge acts as a financial friction in the allocation of capital across firms. The 2003 tax reform eliminates the tax wedge $\tau_d = \tau_{cg}$, and thus makes borrowing cheaper.

Optimal Investment Policy

Optimal investment policy of a firm is determined using the equations (1.15) and (1.16):

$$i_t: \; q_t = \left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d\right) \cdot \frac{1}{1+2\phi_d d_t} \cdot \left(1 + \psi \frac{i_t}{k_t}\right), \tag{1.15}$$

$$\begin{aligned} k_{t+1}: \; q_t =& \frac{1}{1+\frac{(1-\tau_i)r}{1-\tau_{cg}}} \mathbb{E}_t \Bigg[\lambda_{t+1}^s \eta (1-\Pi_{k,t+1}) + q_{t+1}(1-\delta) + \\ & + \left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_{t+1}^d\right) \cdot \left((1-\tau_c)\Pi_{k,t+1} + \tau_c \delta + \frac{\psi}{2}\left(\frac{i_{t+1}}{k_{t+1}}\right)^2 \right) \Bigg], \\ \Leftrightarrow \; q_t =& \frac{1}{1+\frac{(1-\tau_i)r}{1-\tau_{cg}}} \mathbb{E}_t \left[\frac{\partial V_{t+1}(k_{t+1}, z_{t+1})}{\partial k_{t+1}} \right]. \end{aligned} \tag{1.16}$$

Combination of (1.15) and (1.16) gives

$$\left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d\right) \cdot \frac{1}{1+2\phi_d d_t} \cdot \left(1 + \psi \frac{i_t}{k_t}\right) = \frac{1}{1+\frac{(1-\tau_i)r}{1-\tau_{cg}}} \mathbb{E}_t \left[\frac{\partial V_{t+1}(k_{t+1}, z_{t+1})}{\partial k_{t+1}} \right]. \tag{1.17}$$

The LHS of (1.17) is the marginal costs of increasing the capital stock at time t, such as the opportunity costs that leave less money for dividends and the adjustment costs. The RHS of (1.17) represents the expected marginal discounted Tobin's q. Expected benefits come from a relaxed constraint on repurchases, the reselling value of capital and after-tax cash flow in the next period. At optimum, the firm invests in physical capital until the marginal costs equal the marginal benefits.

Equation (1.17) shows that dividend adjustment costs ϕ_d diminish the positive impact of dividend tax reform on capital investment, while the repurchase constraint η amplifies its real effects. The intuition is that when a firm can use investment returns to repurchase shares instead of paying dividends, whose volatility is costly, the benefits of investing in capital tend to rise.

Equation (1.15) implies that optimal investment is

$$i_t = \left(q_t \cdot \left(\frac{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d}{1+2\phi_d d_t} \right)^{-1} - 1 \right) \cdot \frac{k_t}{\psi}$$

When the marginal source of financing investment is a new equity issue, then $s_t > 0$ and $d_t = 0$ for all time t. By complementary slackness conditions, $\lambda_t^s = 0$. These firms invest until $q_t = 1$, when at margin they become indifferent between using an additional dollar of either external or internal funds to finance capital expenditure:

$$i_t = (q_t - 1) \cdot \frac{k_t}{\psi}$$

When the marginal source of finance is internal funds, investment policy is an increasing function of capital stock as long as firms reach their desired level of capital. Firms start to reduce investment at the point where they are indifferent between using an additional dollar of internal funds for either paying dividends or capital expenditure:

$$i_t = \left(q_t \cdot \left(\frac{\frac{1-\tau_d}{1-\tau_{cg}}}{1 + 2\phi_d d_t} \right)^{-1} - 1 \right) \cdot \frac{k_t}{\psi}$$

The above equation implies that the threshold level of investment for firms that pay dividends depends on taxes and adjustment costs on dividends.

1.8.C Stationary Distribution and Aggregation

Since there is no aggregate uncertainty, aggregate variables are constant in the long run, and thus a firm's choices are a function of individual state variables. The labor demand $n_t(k_t, z_t)$ is a static choice of a firm. The firm demands labor until the marginal product of labor equals (competitive) wage. The policy functions from (1.5)

$$k_{t+1} = g(k_t, z_t; w_t), \; i_t = i(k_t, z_t; w_t), \; d_t = d(k_t, z_t; w_t), \; s_t = s(k_t, z_t; w_t).$$

For a given wage, the policy functions map the firm's state variables (k_t, z_t) into the firm's current choices (k_{t+1}, i_t, d_t, s_t). Denote $\mathbb{B}$ as the Borel σ algebra. For a set $B \in \mathbb{B}$, $\mu_t(B)$ is the cross-sectional distribution of firms over capital and productivity that lie in set B. The transition function $\Gamma((k_t, z_t), B)$ denotes the probability that a firm with a state (k_t, z_t) will have a state that lies in the set B in the next period. Denote the vector of state variables as $a = (k_t, z_t)$, which lies in $\mathbb{A} \times \mathbb{Z}$, where $\mathbb{Z}$ is the set of (discretized) productivity shocks. Defining each set B as the Cartesian product $B_k \times B_z$, the transition function

$\Gamma : \mathbb{A} \times \mathbb{B} \rightarrow [0,1]$ can be represented as

$$\Gamma(a, B_k \times B_z) = \begin{cases} \sum\limits_{z_{t+1} \in B_z} Q(z_t, z_{t+1}) & \text{if} \;\; g(k_t, z_t; w_t) \in B_k \\ 0 & otherwise \end{cases}$$

Given the transition function, the law of motion for the firm distribution is given by

$$\mu_{t+1}(B) = \int_{\mathbb{A}} \Gamma(a, B) \mu_t(da) \tag{1.18}$$

When the stationary distribution is obtained $\mu_{t+1} = \mu_t = \mu^*$, one can compute the aggregate variables:

- Aggregate labor demand:

$$N_t^d(\mu^*; w_t) = \int_{\mathbb{A}} n_t(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate output:

$$Y_t(\mu^*; w_t) = \int_{\mathbb{A}} y_t(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate investment:

$$I_t(\mu^*; w_t) = \int_{\mathbb{A}} i_t(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate capital:

$$K_{t+1}(\mu^*; w_t) = \int_{\mathbb{A}} k_{t+1}(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate operating profit:

$$\Pi_t(\mu^*; w_t) = \int_{\mathbb{A}} \Pi_t(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate dividends:

$$D_t(\mu^*; w_t) = \int_{\mathbb{A}} d_t(k_t, z_t; w_t) \mu^*(dk, dz)$$

- Aggregate new equity issues:

$$S_t(\mu^*; w_t) = \int_{\mathbb{A}} s_t(k_t, z_t; w_t) \cdot \mathbb{1}_{s_t > 0} \; \mu^*(dk, dz)$$

- Aggregate share repurchases:

$$\tilde{S}_t(\mu^*; w_t) = \int_{\mathbb{A}} s_t(k_t, z_t; w_t) \cdot \mathbb{1}_{s_t<0}\ \mu^*(dk, dz)$$

- Aggregate adjustment costs on investment:

$$ACI_t(\mu^*; w_t) = \int_{\mathbb{A}} \left(\psi \frac{i_t(k_t, z_t; w_t)^2}{2k_t}\right) \mu^*(dk, dz)$$

- Aggregate adjustment costs on dividends:

$$ACD_t(\mu^*; w_t) = \int_{\mathbb{A}} \phi_d \cdot d_t(k_t, z_t; w_t)^2 \mu^*(dk, dz)$$

1.8.D Stationary Competitive Equilibrium

Given the government policy $\{\tau_c, \tau_d, \tau_{cg}, \tau_i, T\}$, a stationary competitive equilibrium is a sequence of allocations $\{C, N^s, B, \theta(k_t, z_t), g(k_t, z_t), d(k_t, z_t), s(k_t, z_t), i(k_t, z_t), n(k_t, z_t)\}$, prices $\{w, r, P(k_t, z_t)\}$, equity value $V(k_t, z_t) : \mathbb{A} \to \mathbb{R}$, and stationary distribution of firms $\mu^* : \mathbb{A} \to [0, 1]^{\mathbb{A}}$, such that:

- The allocations $\{C, N^s, B, \theta(k_t, z_t)\}$ solve the household's maximization problem (1.1).
- The allocations $\{g(k_t, z_t), d(k_t, z_t), s(k_t, z_t), i(k_t, z_t)\}$ solve the dynamic problem of firms (1.5), and $n(k_t, z_t)$ solves the static problem of firms (1.13).
- The government budget balances consistently with equation (1.10).
- The stationary distribution of firms μ^* satisfies (1.18).
- All markets simultaneously clear:
  - asset market: $\theta = 1$
  - bond market: $B = 0$
  - labor market: $N^s(\mu^*; w) = N^d(\mu^*; w)$
  - goods market: $Y(\mu^*; w) = C(\mu^*; w) + I(\mu^*; w) + ACI(\mu^*; w) + ACD(\mu^*; w)$

Equity prices $P(k_t, z_t)$, dividends and equity transactions are consistent with the non-arbitrage condition in equation (1.11). Factor prices (r, w) are determined by the Euler equation and the household's optimality condition with respect to labor supply, respectively:

$$r = \frac{1}{1-\tau_i}(\frac{1}{\beta} - 1), \quad w = -\frac{U_2(C, N^s)}{U_1(C, N^s)} \quad \Rightarrow \quad (1-\tau_i)w = h\frac{(N^s)^\varphi}{C^{-\sigma}}$$

1.8.E User Cost of Capital

The user cost of capital[25], which is a price of capital stock, equals the after-tax marginal cash flow corrected for the adjustment cost of investment

$$uc_t = (1-\tau_c)\Pi_{k,t+1}(A, k, z) + \frac{\psi}{2}\Big(\frac{i_{t+1}}{k_{t+1}}\Big)^2 \tag{1.19}$$

Equation (1.16) implies

$$q_t = \frac{1}{1 + \frac{(1-\tau_i)r}{1-\tau_{cg}}}\mathbb{E}_t\left[\lambda^s_{t+1}\eta(1-\Pi_{k,t+1}) + q_{t+1}(1-\delta) + \left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_{t+1}\right)\cdot\left((1-\tau_c)\Pi_{k,t+1} + \tau_c\delta + \frac{\psi}{2}\Big(\frac{i_{t+1}}{k_{t+1}}\Big)^2\right)\right]$$

Assuming a deterministic case of (1.16) and plugging (1.19) in (1.16) yields

$$uc_t = \left[q_t\Big(1 + \frac{r(1-\tau_i)}{1-\tau_{cg}}\Big) - \lambda^s_{t+1}\eta(1-\Pi_{k,t+1}) - q_{t+1}(1-\delta) - q_t(1-\delta) + q_t(1-\delta)\right]\cdot\Big(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_{t+1}\Big)^{-1} - \tau_c\delta$$

After rearranging the above expression, one can define the user cost of capital

$$uc_t = \left[q_t\Big(\frac{r(1-\tau_i)}{1-\tau_{cg}} + \delta\Big) - \lambda^s_{t+1}\eta(1-\Pi_{k,t+1}) - (q_{t+1} - q_t)\cdot(1-\delta)\right]\cdot\Big(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_{t+1}\Big)^{-1} - \tau_c\delta \tag{1.20}$$

Equation (1.15) implies

$$q_t = \left(\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_t\right)\cdot\frac{1}{1+2\phi_d d_t}\cdot\Big(1 + \psi\frac{i_t}{k_t}\Big)$$

Plugging equation (1.15) in (1.20) gives the expression for the user cost of capital:

$$uc_t = -\frac{\Psi_{i,t+1}(i,k)}{\Phi_{d,t+1}(d,d^*)}\cdot(1-\delta) - \tau_c\delta + \frac{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_t}{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_{t+1}}\cdot\frac{\Psi_{i,t}(i,k)}{\Phi_{d,t}(d,d^*)}\cdot\Big(\frac{r(1-\tau_i)}{1-\tau_{cg}} + 1\Big) - \frac{\lambda^s_{t+1}\eta(1-\Pi_{k,t+1})}{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda^d_{t+1}} \tag{1.21}$$

where $\Psi_{i,t} = 1 + \psi\frac{i_t}{k_t}$ and $\Phi_{d,t} = 1 + 2\phi_d d_t$. To specify the influence of financial frictions

[25] This framework provides equivalent results to those in equation (1.17).

on investment through reallocation decisions of transiting firms, as an illustrative example, consider three possible cases for a firm that is in the dividend-constrained regime at t:

Case 1. Switching to the payout regime at $t+1$:

$$s_t = -\eta(k_t - \Pi_t),\ d_t = 0 \ \text{ while } \ s_{t+1} = -\eta(k_{t+1} - \Pi_{t+1}), \quad d_{t+1} > 0$$

$$uc_t^1 = -\frac{\Psi_{i,t+1}(i,k)}{\Phi_{d,t+1}(d,d^*)} \cdot (1-\delta) - \tau_c\delta + \frac{(1-\lambda_t^s)}{\frac{1-\tau_d}{1-\tau_{cg}}} \cdot \Psi_{i,t}(i,k) \cdot \left(\frac{r(1-\tau_i)}{1-\tau_{cg}} + 1\right) - \frac{\lambda_{t+1}^s \eta(1-\Pi_{k,t+1})}{\frac{1-\tau_d}{1-\tau_{cg}}} \tag{1.22}$$

Case 2. Switching to the external growth regime at $t+1$:

$$s_t = -\eta(k_t - \Pi_t),\ d_t = 0 \ \text{ while } \ s_{t+1} > 0, \quad d_{t+1} = 0$$

$$uc_t^2 = -\Psi_{i,t+1}(i,k) \cdot (1-\delta) - \tau_c\delta + (1-\lambda_t^s) \cdot \Psi_{i,t}(i,k) \cdot \left(\frac{r(1-\tau_i)}{1-\tau_{cg}} + 1\right) \tag{1.23}$$

Case 3. Remaining in the dividend-constrained regime at $t+1$:

$$s_t = -\eta(k_t - \Pi_t),\ d_t = 0 \ \text{ while } \ s_{t+1} > -\eta(k_{t+1} - \Pi_{t+1}), \quad d_{t+1} = 0$$

$$uc_t^3 = -\Psi_{i,t+1}(i,k) \cdot (1-\delta) - \tau_c\delta + (1-\lambda_t^s) \cdot \Psi_{i,t}(i,k) \cdot \left(\frac{r(1-\tau_i)}{1-\tau_{cg}} + 1\right) \tag{1.24}$$

1.8.F Numerical Algorithm

Since there is no analytical solution to the dynamic problem of the model economy, I solve the model numerically. The procedure for solving the model consists of five steps:

1. *Given a guess of wage rate w_0, compute value function $V(k_t, z_t)$ and optimal decision rules $(g(k_t, z_t), d(k_t, z_t), s(k_t, z_t), i(k_t, z_t), n(k_t, z_t))$ for a firm by a value function iteration on a grid.* I assume that the constraint on share repurchases is always binding, suggesting that firms have to exploit all opportunities for repurchases due to tax and flexibility motives before starting to pay dividends. I set 600 grid points for capital stock and 10 grid points for productivity. The grid is finer for lower levels of capital stock. The lower bound for capital is $\underline{k} = 1e-3$, while the upper bound for capital is

set at the level to bind with small probability $\bar{k} = 3 \cdot k^*$. A targeted level of capital k^* is computed in the following manner. From (1.21), the firm's user cost of capital is:

$$uc_t = -\frac{\Psi_{i,t+1}(i,k)}{\Phi_{d,t+1}(d,d^*)} \cdot (1-\delta) - \tau_c \delta + \frac{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d}{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_{t+1}^d} \cdot \frac{\Psi_{i,t}(i,k)}{\Phi_{d,t}(d,d^*)} \cdot \left(\frac{r(1-\tau_i)}{1-\tau_{cg}} + 1 \right) - \frac{\lambda_{t+1}^s \eta}{\frac{1-\tau_d}{1-\tau_{cg}} + \lambda_{t+1}^d}$$

where $\Psi_{i,t} = 1 + \psi \frac{i_t}{k_t}$ and $\Phi_{d,t} = 1 + 2\phi_d(d_t - d^*)$. Targeted dividends d^* are set to zero in the baseline model for simplicity. In the absence of real and financial frictions, the firm always invests in physical capital to hit some targeted capital. This targeted capital is determined by production technology, interest rate, and depreciation of capital. Hence, we have the user-cost of capital: $uc_t = r + \delta$. To determine the upper bound of capital stock, I set the marginal product of capital $F_{k,t} = uc_t$ such that in the equilibrium $\alpha_k (k^*)^{\alpha_k - 1} (n^*)^{\alpha_n} = r + \delta$. From the last expression, one can determine $k^* = (n^*)^{\frac{\alpha_n}{1-\alpha_k}} (\frac{\alpha_k}{r+\delta})^{\frac{1}{1-\alpha_k}}$. After setting grid points for capital and productivity, iterate on value function to solve the dynamic problem of firms (equation 1.8).

2. *Compute the stationary distribution* $\mu^*(k_t, z_t; w_t)$. Iterate on the law of motion for the firm distribution (equation 1.18), initiating from a uniform distribution over (k_t, z_t).

3. *Given* μ^*, *compute aggregate quantities* such as labor demand, output, investment, capital, profit, dividends, equity issues, share repurchases $(N^d, Y, I, K, \Pi, D, S, \tilde{S})$, respectively.

4. Once the aggregate labor demand is computed, check whether the labor market clears: $(1 - \tau_i)w = h\frac{(N^s)^\varphi}{C^{-\sigma}}$, where C is computed from the resource constraint. If the labor market condition is not satisfied, then use the bisection method to update wage guess.

5. Repeat the above steps n times until the labor market clears. This delivers the market-clearing wage w_n^*.

1.8.G Wage Rigidity

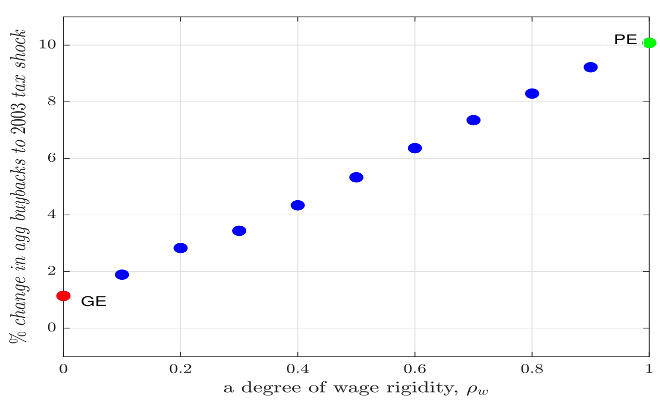
Following Blanchard and Galí (2007), I impose *ad hoc* wage rigidity:

$$\text{initial steady-state}: \;\; w_0 = w_n^{*,pre}$$

$$\text{final steady-state}: \;\; w_1 = (w_0)^{\rho_w} \cdot (w_n^{*,post})^{1-\rho_w}$$

where $\rho_w \in [0, 1]$ measures persistence of wage rigidity. Parameter $\rho_w = 0$ stands for the general equilibrium setting with fully-flexible wage that clears the labor market (red dot in Figure 1.7). I use the bisection method to clear excess aggregate demand in the labor market, i.e. after n steps one needs to determine wage that clears the labor market in the pre-tax period $w_n^{*,pre}$ and wage that clears the market in the post-tax period $w_n^{*,post}$. Figure 1.7 shows responses of aggregate repurchases to the tax reform of 2003 for different degrees of wage rigidity. The green dot implies that the wage is fixed at the level from its initial steady state. That is, labor demand determines aggregate employment in the model economy, while the labor market-clearing condition is ignored.[26] Values for the degree of wage rigidity range usually from 0.5 to 1 in the literature. Following Duval and Vogel (2012), I set $\rho_w = 0.65$. The wage rigidity reveals that the wage feedback effects do not play an important role in explaining the responses in aggregate repurchases to the tax reform.

Figure 1.7: Aggregate repurchases and wage rigidity



[26]Similar analysis with wage rigidity is conducted by Di Nola et al. (2021) and Hong and Moon (2019) among many others.

1.8.H Dynamic Problem of Firm

$$V_t(k,t) = \min_{\{\mu_t,q_t,\lambda_t^d,\lambda_t^s\}} \max_{\{k_{t+1},i_t,d_t,s_t\}} \frac{1-\tau_d}{1-\tau_{cg}} d_t + \lambda_t^d d_t - s_t + \lambda_t^s (s_t + \eta(k_t - \Pi_t)) - q_t(k_{t+1} - (1-\delta)k_t - i_t)$$

$$- \mu_t \Big(d_t + \phi_d (d_t - d^*)^2 + i_t + \frac{\psi}{2}\frac{i_t^2}{k_t} - (1-\tau_c)\Pi_t(A_t, k_t, z_t; w_t) - \tau_c \delta k_t - s_t \Big) + \beta \mathbb{E}_t \Big[V_{t+1}(k_{t+1}, z_{t+1}) \Big| z_t \Big] \tag{1.25}$$

$$d_t: \ \frac{1-\tau_d}{1-\tau_{cg}} + \lambda_t^d - \mu_t \cdot (1 + 2\phi_d(d_t - d^*)) = 0 \tag{1.26}$$

$$s_t: \ -1 + \lambda_t^s + \mu_t = 0 \tag{1.27}$$

$$k_{t+1}: \ -q_t + \beta \mathbb{E}_t \Big[\frac{\partial V_{t+1}(k_{t+1}, z_{t+1})}{\partial k_{t+1}} \Big| z_t \Big] = 0 \tag{1.28}$$

$$i_t: \ q_t - \mu_t (1 + \psi \frac{i_t}{k_t}) = 0 \tag{1.29}$$

$$EC[k_t]: \ \frac{\partial V_t(k_t, z_t)}{\partial k_t} = \lambda_t^s \eta (1 - \frac{\partial \Pi_t(k_t, z_t)}{\partial k_t}) + q_t(1-\delta) - \mu_t \left(\frac{\psi}{2} \Big(\frac{i_t}{k_t}\Big)^2 - (1-\tau_c)\frac{\partial \Pi_t(k_t, z_t)}{\partial k_t} - \tau_c \delta \right) \tag{1.30}$$

$$KT_1: \ \lambda_t^d \geq 0, \ d_t \geq 0, \ \lambda_t^d \cdot d_t = 0 \tag{1.31}$$

$$KT_2: \ \lambda_t^s \geq 0, \ s_t \geq -\eta(k_t - \Pi_t), \ \lambda_t^s \cdot (s_t + \eta(k_t - \Pi_t)) = 0 \tag{1.32}$$

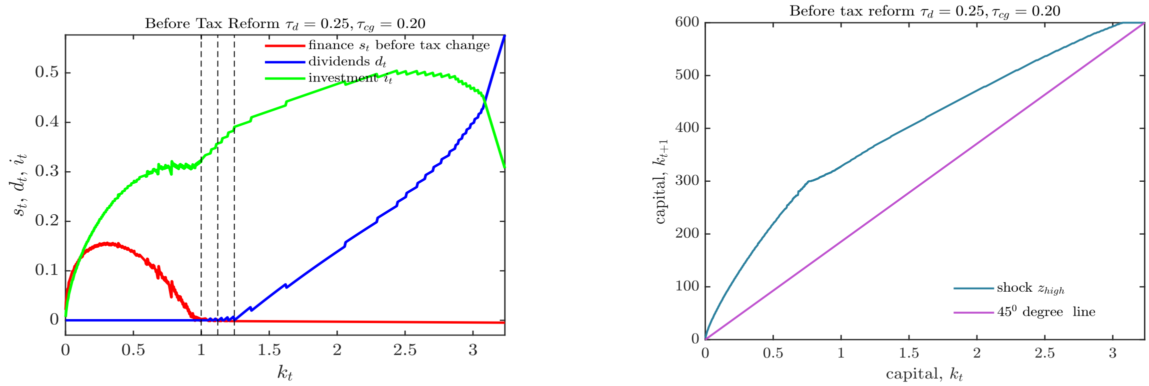
where the complementary slackness conditions from Kuhn-Tucker are given by KT_1 and KT_2. The shadow value of funds is denoted by μ_t. Note that the shadow value of funds determines financial policy of a firm (or the position of the firm in the finance regime). Equations (28) and (33) indicate that μ_t is bounded above by $\frac{1-\tau_d}{1-\tau_{cg}} \cdot (1 + 2\phi_d(d_t - d^*))^{-1} = 0$ (when $d_t > 0, \ \lambda_t^d = 0$, and marginal source of finance is retained earnings), while equations (29) and (34) indicate that μ_t is bounded below by 1 (when $s_t > -\eta(k_t - \Pi_t), \ \lambda_t^s = 0$, and marginal source of finance is new equity issue). Therefore, tax wedge and adjustment costs on dividends together determine the lower bound of μ_t, while the upper bound of μ_t is exogenous. Considering that there is no kink in equity value, there is no inaction region with firms that do not either issue new equity (buy back their shares) or pay dividends. If there are no financial frictions in the model economy, $\tau_d = \tau_{cg} = 1$ and $\phi_d = 0$, then the wedge between the two bounds no longer exits, i.e. financial policy of heterogeneous firms becomes indeterminate. Therefore, $\mu_t \in \left[\frac{1-\tau_d}{1-\tau_{cg}} \cdot (1 + 2\phi_d(d_t - d^*))^{-1},\ 1\right]$.

1.8.I Responses of Firms in the pre-2003 Period

Figure 1.8 plots optimal financial and investment responses of firms obtained for the calibration period. Panel (a) shows three decision rules, including equity finance, dividends and investment, for a *medium* level of positive productivity and different levels of capital stock. Depending on the initial capital stock, firms are located in one of the four finance regimes. The finance regimes are separated by the vertical lines. Firms with low capital and high marginal product of capital need to borrow from their shareholders to finance their investment needs. Firms with moderate capital finance investment and repurchases with internal funds. Finally, firms in the payout regime initiate dividends along with repurchases. Once firms reach the targeted level of capital stock, capital investment remains relatively constant, while dividends start to rise. Panel (b) shows the dynamics of capital stock.

Figure 1.8 plots the inverted U-shape relation between new equity issue and capital for a medium productivity, which could be explained by two opposing forces. On the one hand, greater external financing at time t increases investment, generating expected operating profit in $t + 1$. On the other hand, higher external financing induces costs related to the tax wedge between dividends and capital gains. When capital is low, its rise increases future profits more than the costs related to new equity issue under the DRTS technology, and thus increases the demand for external finance. On the contrary, when capital is high, the expected increase in profitability is smaller than the costs related to external funds, reducing new equity issue. Additionally, larger capital expenditure increases capital adjustment costs[27], which exerts pressure on a demand for equity issuance at lower levels of capital.

[27]Convex capital adjustment costs contain disruption costs during installation of new capital, costs related to learning production structure, etc.



(a) policy responses

(b) capital dynamics

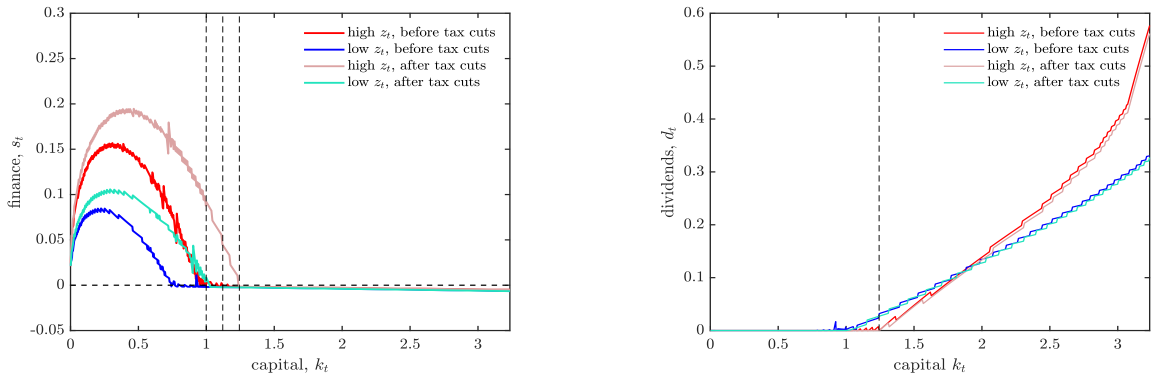
Figure 1.8: Optimal decisions of firms in general equilibrium, before tax cuts

For a given level of capital stock k_t and fixed government fiscal policy, Figure 1.9 panel (a) plots changes in finance regimes and heterogeneous equity responses of firms to higher positive productivity shock (compare dark blue with dark red lines). Notice that the (intensive margin) effects of higher productivity are much stronger for firms with smaller capital. Moreover, the capital thresholds, which separate finance regimes, are an increasing function of productivity. These shifts of the capital threshold lines are the largest for firms within regimes 1 and 4.

Figure 1.9 panel (a) shows that firms in regime 1 respond by issuing more new equities $s_t > 0$. In addition, there is a large increase in the fraction of firms in this regime. There are large extensive and intensive margin effects on equity decisions, induced by higher productivity.

Firms in regime 2 increase equity repurchases, while firms in regime 3 do not issue new equities because such equity transaction reduces the market value of shares that could not be covered by returns on investment under the DRTS technology. Instead, firms with low investment opportunities use excess cash for initiating dividend payments. Finally, higher positive productivity does not affect equity issues of firms in regime 4.

Figure 1.9 panel (b) illustrates that a positive productivity shock has asymmetric effects on dividends, conditional on a level of capital. At a low capital stock and fixed fiscal policy, a firm that is hit by a higher positive productivity shock responds by delaying



(a) finance (b) dividends

Figure 1.9: Optimal equity and dividend responses of firms in general equilibrium

dividends in order to exploit larger investment opportunities (compare dark red with dark blue lines). Moreover, the slope of the capital threshold for initiating dividends becomes steeper with the higher positive productivity shock. Greater capital investment generates internal funds that can be used for fututure dividends, and increases the space for repurchases by relaxing its constraint. Panel (b) also depicts that firms with a quite large capital stock increase dividends, suggesting that positive productivity shocks increase internal funds more than they raise investment needs.

Financial Responses of Firms in the post-2003 Period

Figure 1.9 shows heterogeneous responses of firms in equity transactions and dividends to the 2003 tax cuts.[28] Dividends become relatively more tax preferable than repurchases, but repurchases still keep the flexibility motive due to costly upward adjustments in dividends. In addition, the tax reform stimulates new equity issues via the elimination of the tax wedge between dividends and capital gains. Lastly, the tax cuts lead to larger capital investment through the reduced user cost of capital and cheaper external funds.

Holding capital stock and positive productivity fixed, Figure 1.9 panel (a) shows that the 2003 tax reform has large intensive and extensive margin effects on equity decisions.

[28]The model economy has 10 grid points for productivity. High positive productivity refers to the 8th grid point, while low positive productivity indicates the 7th grid point.

Comparing dark red line with light red line, firms in regimes 1 and 2 respond by issuing more new equities. Panel (b) indicates that the tax reform generates asymmetric dividend responses for different levels of productivity. Comparing light red line with light blue line, the effects are stronger at higher capital stock.

1.8.J Sensitivity Analysis

This section conducts sensitivity analyses as the post-2003 period was also characterized by economic recovery, distrust among shareholders from the 2001-2002 dot-com crisis and regulatory changes in volume limit on repurchases by the US Securities and Exchange Commission (SEC).

Table 1.8 has results from the baseline model (Column 2) and counterfactual experiments (other Columns) that quantify a relative contribution of wages, a rise in aggregate productivity, and targeted dividends to aggregates. In Column 4, analysis of the economic recovery from the 2001-2002 recession beginning in early 2003 is conducted. Aggregate productivity recorded an increase of 0.18% from 2003q1 to 2019q4 compared with 1988q1-2002q4 in the data, indicating $A_t = 1.0018$ in the final steady state.[29] The economy is initially in steady state, and then it is hit by the permanent positive productivity shock at the top of the tax shock in the general equilibrium. In Column 5, we observe that increasing dividend target from zero to 0.0561, which is the mean of dividends to earnings for the 1988-2006 period, leads to higher aggregate payouts.

I recalibrate the models with different parameter values of the adjustment costs ϕ_d to quantify the contribution of changes in preferences of shareholders for dividends to changes in aggregate payouts. A drop in ϕ_d is expected for the post-2003 period because of the accounting scandals occurring in 2001-2002, which created distrust among shareholders and potentially stimulating shareholders to request large dividends even in the absence of the tax reform. I also checked what would occur to aggregate payouts to shareholders if ϕ_d increased.

[29] The rise in Total Factor Productivity is measured by using the San Francisco Federal Reserve's database. See https://www.frbsf.org/economic-research/indicators-data/total-factor-productivity-tfp/

Table 1.8: Aggregate responses

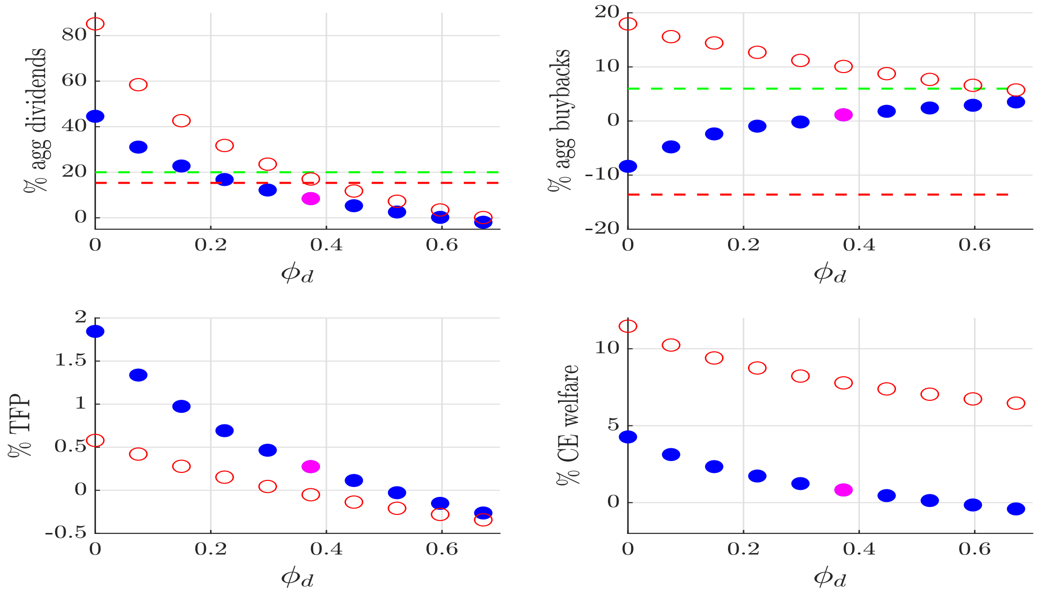
Aggregate	GE	PE	ER	DT
Capital	3.62	12.30	3.88	3.88
Equity issues	77.17	79.83	77.24	73.59
Output	1.58	10.69	1.84	1.68
Employment	0.29	10.69	0.29	0.30
Dividends	8.43	17.04	8.65	9.79
Repurchases	1.14	10.08	1.45	6.95
Wage	1.29	0.00	1.55	1.38
TFP	0.27	-0.05	0.45	0.29

Notes: Table 1.8 shows percent changes in aggregate variables for the post-2003 period relative to the 1988q1-2002q4 calibration period. ER refers to economic recovery from the 2001-2002 crisis. GE stands for the general equilibrium, PE refers to the partial equilibrium. DT contains a change in dividend target.

Figure 1.10 shows three important messages. First, the changes in ϕ_d induce a substitution between aggregate dividends and share repurchases in the general equilibrium setting with fully flexible wages (blue circles) and a complementarity with fully rigid wages (red circles). However, the expected drop in adjustment costs on dividends cannot explain an empirically observed increase in aggregate repurchases (dotted green line). Second, the impact of the wage rigidity on aggregates is stronger at lower adjustment costs of dividends. Third, TFP and welfare benefits move in the opposite directions when the wage rigidity is incorporated.

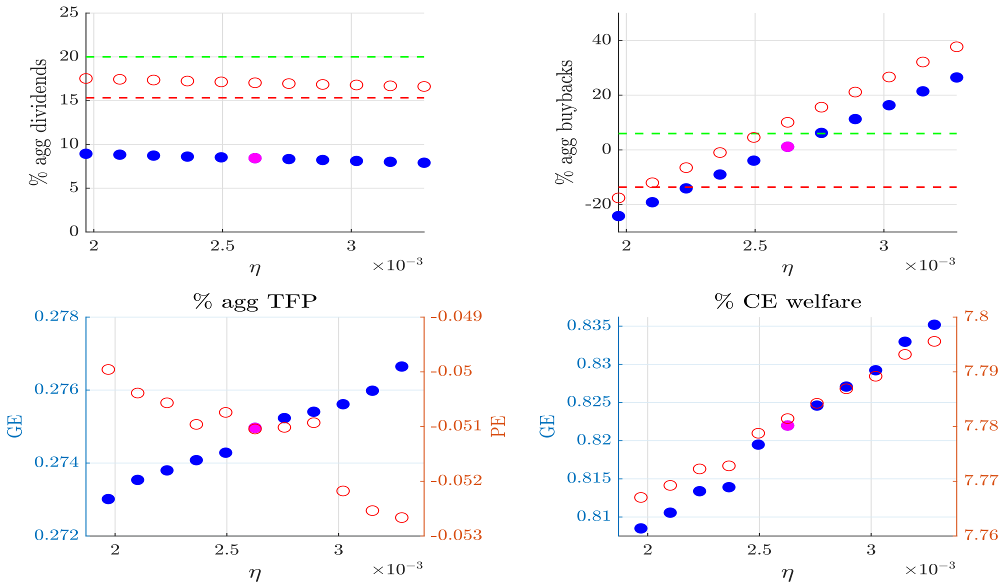
We could also expect a more relaxed constraint on repurchases because the SEC extended the limit for repurchases in 2003. Figure 1.11 shows that the expected rise in η induces a negative correlation between aggregate dividends and repurchases, while TFP and welfare recorded a rise in GE.

Figure 1.10: Long-run aggregate effects of dividend adjustment costs



Notes: Purple dots refer to aggregate responses to the 2003 tax cuts for the calibrated ϕ_d. Blue dots indicate counterfactual experiments under which changes in ϕ_d are added to the tax cuts in the general equilibrium (GE) setting, while the value of other parameters are kept fixed at their values in the initial steady state. Similar experiments are conducted in the partial equilibrium setting (red circles). For each value of ϕ_d, I solve GE and compute aggregates. Red dashed lines are model-generated aggregate responses by the benchmark paper Gourio and Miao (2011). Green dashed lines are estimated aggregate responses to the 2003 tax cuts by the literature. Holding leisure fixed at its initial level, changes in consumption are taken as a measure for welfare effects.

Figure 1.11: Long-run aggregate effects of the share repurchase constraint



Notes: Purple dots refer to aggregate responses to the 2003 tax cuts for the calibrated η. Blue dots indicate counterfactual experiments under which changes in η are added to the tax cuts in the general equilibrium setting, while the value of other parameters are kept fixed at their values in the initial steady state. Similar experiments are conducted in the partial equilibrium setting (red circles). For each value of η, I solve the *GE* model and compute aggregates. Red dashed lines are model-generated aggregate responses by Gourio and Miao (2011). Green dashed lines are estimated aggregate responses to the 2003 tax cuts by the literature. Holding leisure fixed at its initial level, changes in consumption are taken as a measure for welfare effects.

2 Firm-level Uncertainty and Frictions: Implications for Capital and Financial Decisions in the US

Co-authored with Veljko Bojović (Berlin School of Economics)

2.1 Introduction

Over the past four decades, the U.S. corporate sector has experienced a large decline in the average investment rate, dropping from 10.49% in 1980 to 4.80% in 2018. During the same period, average uncertainty regarding the profit growth rate increased from 0.43% to 0.78%.[30] These trends raise the question of the extent to which idiosyncratic profit volatility affects the investment rate. The novelty of this study is to explain the negative relationship between the investment rate and idiosyncratic uncertainty through the interaction of financial and real frictions, whose impact increases as the investment rate rises. During periods of heightened uncertainty, high-investing firms decrease their investment rate and increase cash holdings.

Recent progress has been made in explaining the investment-uncertainty relationship by incorporating new measures of real frictions (see, e.g., Kermani and Ma, 2023; Kim and Kung, 2017; Chirinko and Schaller, 2009) and measures of financial frictions (Alfaro et al., 2024; Almeida et al., 2004) into investment models. However, these frictions have been mostly studied separately, leaving their possible interactions and implications unexplored. Importantly, the impact of frictions varies with the investment rates in Compustat data. In addition, the literature focuses on *average* effects on the investment rate. It is unclear from the literature whether the estimated average effects imply that all firms decrease their investment rates by the same average amount or a few firms decrease investment rates by a large amount. Hence, our study aims to bridge these gaps by empirically and quantitatively

[30]We use the U.S. Compustat Annual data for the analysis, excluding financial companies and utilities. The investment rate is defined as gross capital expenditure (`capx`, item 128) to the lagged book value of total assets (`at`, item 6). Volatility of a firm is computed as the standard deviation of the profit growth rate (`oibdp`, item 13) in the current and previous four years. The aggregate measure of the typical firm volatility in a given year is obtained by taking the mean across all sample firms in a year. The Pearson correlation coefficient of -0.5669 between the investment rate and uncertainty is statistically significant at 1%.

exploring the interactions between financial and real frictions, and to estimate the effects of profit volatility on different quantiles of the investment rate distribution. Addressing these research gaps is important for defining and implementing targeted policies, as the distributional analysis of uncertainty effects identifies the firms most sensitive to uncertainty shocks, while the complementarity between frictions suggests that mitigating the negative effects of one friction can help alleviate the negative effects of another.

We characterize the empirical relationship between fixed capital investment and firm-specific uncertainty about the future profit growth rate using annual data from Compustat for the 1980-2018 period, and find that a one-standard deviation increase in the profit uncertainty leads to a drop in the mean annual investment rate by 0.59%, which is in line with the literature's findings that range between 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996).[31] Relative to the unconditional mean investment rate of 7%, this is a decline of 6.2% per year. Consistent with the empirical literature, we find that the average effect of uncertainty on the investment rate increases in the presence of capital irreversibility or financial constraints.[32]

We document several novel empirical findings. First, firms from the right tail of the investment rate distribution decrease their investment rates much more strongly than other firms, suggesting that the extensive margin decision of whether to invest or not is important to understand the effects of profit volatility on the average investment rate. The drop in the positive investment spike and the rise in the inaction rate additionally support the importance of the extensive margin effects of uncertainty.[33] Second, the extensive margin investment decisions account for almost half of the decline in the annual investment rate.[34] Third, by estimating quantile regressions, the individual influence of both financial and real frictions on

[31] Our OLS regression results closely align with the IV estimates, which utilize a one-year lagged uncertainty measure as an instrumental variable.

[32] We follow the literature in using the crude measures for financial and real frictions. If less than 20% of profits is set aside for dividends, then a firm is financially constrained. If the fixed capital stock to total asset ratio exceeds its medium level in industry, a firm has irreversible capital.

[33] The positive investment spike involves the fraction of firms with an annual investment rate larger than 20%. The inaction rate refers to the fraction of firms with an annual investment rate smaller that 1% in absolute value.

[34] Change in the spike rate is our proxy for the extensive margin investment responses.

the investment-uncertainty relationship becomes stronger at a higher investment rate. While the response of investment to increased uncertainty along the extensive margin is mostly driven by financial frictions, real frictions have a stronger effect on the inaction rate. Fourth, when considering the interaction between frictions, the financial friction amplifies the negative effects of uncertainty on firms with irreversible investment.[35]

Motivated by our empirical evidence, we extend a standard heterogeneous-firm model with additional frictions to evaluate which frictions explain investment behaviour in the last four decades and to understand the role of interconnecting frictions in investment decisions under uncertainty.[36] First, we incorporate capital irreversibility and fixed capital adjustment costs, together with convex costs. This comprehensive capital cost structure reduces the liquidity value of capital and helps to generate observed capital adjustments along extensive and intensive margins. Second, similar to Melcangi (2024), we combine collateral constraint with partially irreversible capital to affect the collateral value of capital. The combination of frictions makes it more difficult to finance lumpy investment and stimulates a reallocation of resources from capital to cash. This is consistent with a precautionary savings channel.

The main findings of our model are as follows. The model accounts for 33% of the decrease in the investment rate and around 80% of the increase in cash holdings. Increased volatility in firm-level productivity from the estimated value of 0.1915 to 0.2085 can capture around 5.9% of the decline in investment rate and 20% of the increase in cash holding. Our findings indicate a 2.2% reduction in the fraction of firms investing in new capital at the extensive margin, while investment in existing capital at the intensive margin decreases by 3.7%. An investment decline at the extensive margin is more sensitive to tighten collateral constraint and costly equity issuance, while more costly capital adjustments have a greater impact on the rise in the inaction rate. Finally, the irreversible costs have the role of amplifying the impact of uncertainty by increasing investment inaction observed in the late period. This is probably due to reduced liquidity and collateral value of capital.

The general intuition behind the role of frictions in transmitting the negative effect of uncertainty on investment is the following. As profit volatility rises, firms are more likely to face

[35] All our empirical findings are robust to various measures of the investment rate, uncertainty, and frictions.

[36] Uncertainty shocks are introduced in the model as changes in the variance of firm-specific profit shocks.

shortfalls in internal funds. In the fear of running out of internal funds, financially constrained firms reduce the investment rate and increase a precautionary demand for cash holdings to limit their exposure to financial losses and avoid costly borrowing. Conversely, financially unconstrained firms could absorb increased volatility by reducing either accumulated cash holdings or dividends, without sacrificing investment.[37] Irreversible investment implies that all firms face additional costs when adjusting capital stock, inducing larger investment that occurs less frequently.[38] Firms with irreversible capital delay investment in new capital or switch to zero investment to avoid committing to projects with potentially more costly capital adjustments in an uncertain environment. Finally, fully reversible assets allow financially constrained firms to mitigate the impact of costly external funds. Without financial frictions, firms could more easily finance lumpy investment. In other words, a separate investigation of the frictions masks the overall effects of profit volatility on investment rate.

This chapter is organized as follows. Section 2.2 presents the related literature. Section 2.3 documents the negative relationship between firm-specific uncertainty and investment. Section 2.4 develops a quantitative model. Section 2.5 concludes. The appendix contains information on data sources and robustness checks on empirical evidence.

2.2 Related Literature

This study is related to two stands of the literature. The first strand investigates the relationship between firm-level uncertainty and fixed capital investment. Theory identifies several channels through which uncertainty impacts investment, including costly external funds arising from information asymmetry (Myers and Majluf, 1984), irreversibility of investment caused by sunk costs (Dixit and Pindyck, 1994), and the convexity of the marginal product of capital in output prices induced by assumptions of perfect competition, constant returns to scale, and absent irreversibility (Abel, 1983). While the first two channels predict a negative

[37] If a firm has sufficient internal funds to finance desired investment, regardless of the profit shock realization, then the firm is classified as financially unconstrained.

[38] Investment irreversibility induces a reluctance to invest because forward-looking firms do not like to increase investment today if it seems likely they will have to reduce it later (Chirinko and Schaller, 2009). To minimize fixed costs, firms tend to adjust their capital stock only for large profit shocks and remain investment inactive otherwise.

relationship, the third channel suggests a positive correlation. Empirical studies generally confirm a negative relationship between firm-level uncertainty and the investment rate for publicly traded firms in the US (see e.g., Alfaro et al., 2024; Kermani and Ma, 2023; Liu and Wang, 2021; Gilchrist et al., 2014; Panousi and Papanikolaou, 2012; Baum et al., 2008; Almeida and Campello, 2007; Bulan, 2005; Minton and Schrand, 1999) and for firms in the UK (Bloom et al., 2007).[39] However, it remains ambiguous from the literature whether the observed *average* decline in the investment rates is driven by a large number of firms or just a few firms. We also emphasize the importance of interconnecting financial and real frictions in the transmission of profit volatility to capital expenditure as the impact of both frictions varies across the investment rate distribution. Almeida and Campello (2007) show that investment–cash flow sensitivity increases in the tangibility of firms' assets only for financially constrained firms. Instead, we propose the quantile regression to determine the importance of the extensive margin investment decisions for investment-uncertainty sensitivity. While this model is implemented in exploring pay-performance sensitivity (Hallock et al., 2010) and pecking order theory (Chay et al., 2015), the analysis of the investment-uncertainty relationship across the investment rates remains unexplored.

The second strand of literature explores the financial implications of the negative investment-uncertainty relationship. While the recent explanation for the investment decline, provided by Alfaro et al. (2024) for example, predicts positive cash holdings, their model generates almost zero change in positive net dividends. In contrast, the combination of collateral constraints and irreversible investment in our model, as suggested by Melcangi (2024), reduces the liquidity and collateral value of capital, resulting in a reallocation of resources from capital to cash. The rise in cash holdings exceeds the decline in dividends net of equity issuance, leading to positive net dividends. In contrast to Falato et al. (2022), which document that the largest part of a rise in cash holdings could be explained by a rise in intangible capital, we show that firm-specific profit uncertainty is also an important factor.

[39] Leahy and Whited (1996) find that the impact of stock price uncertainty on capital investment disappear once average Tobin's Q is considered in the regression model. In contrast, Boyle and Guthrie (2003) document that a firm is more likely to increase investment when cash-flow volatility increases due to future shortage of internal funds. Kim and Kung (2017) show that firms with more redeployable assets increase investment when facing increased uncertainty.

2.3 Empirical Evidence

This part of our study focuses on answering interconnected questions: What is the impact of profit volatility on the distribution of the investment rate? How do interactions between financial and real frictions influence firms' investment decisions?

Important factors affect the investment-uncertainty relationship over the long-time horizon, including investment opportunity and internal funds. That is, weak investment opportunity and a lack of internal funds may lead to a drop in investment, regardless of the impact of the uncertainty measure. We partial out the impact of such confounding factors and pay attention to a precautionary savings channel through which uncertainty affects investment.[40] We focus on the following three empirically testable predictions:

- Prediction 1: Extensive margin investment decision is important for the average effects of profit volatility.

- Prediction 2: Individual influence of both financial and real frictions on the investment-uncertainty relationship becomes stronger at larger investment rates.

- Prediction 3: The impact of profit volatility on irreversible assets increases in the presence of financial constraint.

2.3.1 Summary Statistics

Using Compustat data, we study decisions of the U.S. firms. The sample period is annual from 1980 to 2018, covering the period of the "Great Moderation" of the 1980s. The starting year of the sample is chosen to be comparable with the literature. We focus on firms' decisions at an annual level because firms generally set their budgets on capital expenditure annually during the budgeting process.

Table 2.1 presents descriptive statistics for firm-specific variables. It reports the mean, median, minimum, maximum, standard deviation, and number of observations. Our main variables of interest are the investment rate and profit volatility. The summary statistics

[40] In Appendix B and Appendix C, we confirm that there persists a long-run negative relationship between the investment rate and uncertainty measures after controlling for the impacts of confounding factors.

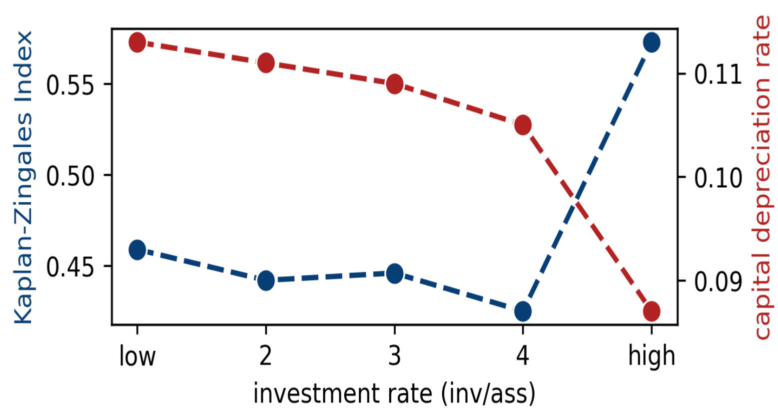
Table 2.1: Summary statistics

Variable	Mean	Std. dev.	Min	Max	Median	Obs.
investment/assets	0.0707	0.0646	0.0079	0.2618	0.0491	91371
vol(profit)	0.8692	1.3565	0.0476	5.3654	0.3084	85100
mkt/book	2.2886	1.6764	0.5202	6.8799	1.7550	81100
sales/assets	1.2506	0.6714	0.3049	2.8195	1.1461	81100
cash/assets	0.1293	0.1397	0.0038	0.4895	0.0728	81100
r10yTCMR	8.9263	6.4569	1.7493	26.9135	7.4282	91400
RGDPgrowth	-0.0019	0.0229	-0.0750	0.0289	0.0037	81100
size	5.9467	1.7494	3.1777	9.3738	5.7934	81100
age	1.9737	0.9737	0.0000	3.4012	2.0794	81100

Table 2.1 presents summary statistics for variables used in regression equation (1). The sample includes Compustat firms from 1980 to 2018. All variables are winsorized. A detailed description of variables is provided in Appendix A.

show that the average firm holds 7% of their assets in investment. Profit volatility, is on average, 0.87, which is rather close to Liu and Wang (2021). On average, sampled firms have good growth prospects in the sample period. More specifically, average Tobin's Q is 2.29 and the sales-to-asset ratio is 1.25, which are slightly above those in Liu and Wang (2021).

Figure 2.1: Financial and real conditions of firms across investment quintiles



Data source: Compustat (1980-2018). corr(KZindex,dep) = -0.11

Figure 2.1 shows that the impact of financial and real conditions of firms (blue and red dots) varies across the investment rate distribution; they are stronger for high-investing firms. This simple univariate analysis motivates us to study uncertainty effects beyond the average investment rate. In addition, the opposing patterns in conditions, especially moving to a high investment group, suggests that ignoring their complementarity underestimates the true effects of idiosyncratic uncertainty. The increase in average Kaplan-Zingales index within the Q5 investment group indicates that some high-investing firms heavily rely on external funds in financing their high growth opportunities, pushing up the average index. At the same time, high-investing firms suffer from higher capital adjustment costs as the low depreciation rate means that it is more expensive to adjust capital quickly.

2.3.2 Empirical Setting

Similar to Gilchrist et al. (2014) and Panousi and Papanikolaou (2012), we estimate the investment-uncertainty relationship using the following reduced-form investment equation:

$$\frac{inv_{i,t}}{ass_{i,t-1}} = \beta_0 + \beta_1 \cdot \sigma_{i,t-1} + \beta_2' \cdot X_{i,t-1} + \eta_t + \gamma_i + \epsilon_{i,t} \tag{2.1}$$

Equation (2.1) is our baseline specification. Investment in property, plant and equipment (PPE) of firm i in year t, $inv_{i,t}/ass_{i,t-1}$, is scaled by the beginning-of-period total assets $ass_{i,t-1}$ to control for large cross-sectional differences in assets. This scaling makes the investment of firms comparable.[41] Profit volatility is measured as the standard deviation of the firm's profit growth over the recent five years, i.e. the lagged uncertainty variable refers to a realized shock before making investment decisions.[42] We consider lagged profit volatility $\sigma_{i,t-1}$ to alleviate concerns about a reverse impact of investment on the uncertainty measure. There are two main differences relative to Gilchrist et al. (2014) and Panousi and Papanikolaou (2012). First, we do not consider the log specification of variables in order to capture the possibility of a non-linear relationship between investment and uncertainty variables. Second, they construct a metric of idiosyncratic volatility using data on stock

[41]Larger firms tend to have a proportionally larger investment than smaller firms.

[42]The lagged volatility is supported by the high persistence of the volatility series (see Figure 2.20 in Appendix J).

returns. There is a potential concern about variability in stock returns that captures the noise unrelated to fundamentals (see Bloom et al., 2007 for more details).

$$X_{i,t-1} \in \left\{ \frac{mkt_{i,t-1}}{book_{i,t-1}},\ \frac{sale_{i,t-1}}{ass_{i,t-1}}, \frac{cash_{i,t-1}}{ass_{i,t-1}},\ log(asset_{i,t-1}),\ log(age_{i,t-1}) \right\}.$$

$X_{i,t-1}$ controls for firm-specific investment opportunities, financial condition and demographic characteristics of firms. Specifically, $X_{i,t-1}$ contains average Tobin's Q, real sales growth rate, cash, size and age of firm i. Profit volatility may capture the effects of poor investment opportunities that are missed by the average Tobin's Q. To address this omitted variable bias, we consider the sales-to-asset ratio as an additional control variable. Firm age refers to number of years since a firm enters the sample, while firm size is measured by total assets.

Firm fixed-effects γ_i control for systematic differences in the average investment rates across firms but remaining constant over time. Time fixed-effects η_t capture the impacts of macro factors that are common across firms but vary over time. With time fixed effects, we effectively demean each observation by its time average. Hence, we cannot include macro factors together with time FE in the regression, such as real output growth and real risk-free interest rate. That is, aggregate time-series variables have no explanatory power in regressions that include time fixed effects. All control variables are measured as of $t-1$ to mitigate concerns regarding endogeneity. Time lags between the investment rate and explanatory variables are also needed to enable lags in investment implementation. Equation (2.1) is annually estimated using ordinary least squares.

2.3.3 Regression Results

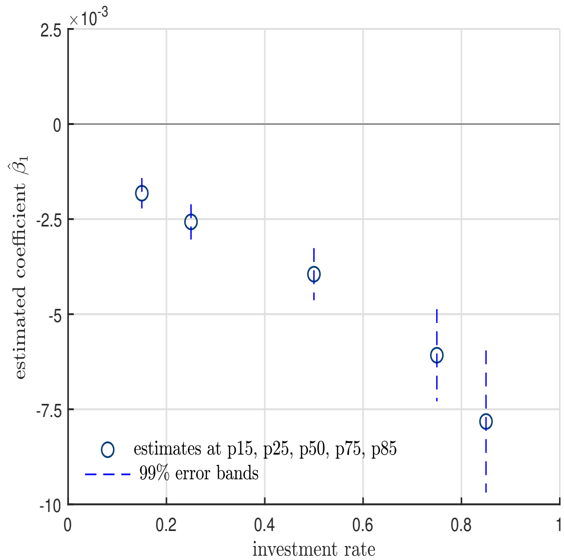
Impact of Profit Volatility

The literature focuses on the *average* effects of uncertainty on the investment rate, estimating that a one-standard deviation increase in firm-level uncertainty leads to a drop in the mean annual investment rate in the range between 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996). Our estimates of the baseline equation (2.1) of -0.0044 suggest that uncertainty reduces the mean investment rate by 0.59%.[43] It remains unclear from the literature whether the

[43] In Appendix D we provide a detailed regression analysis of the average investment responses.

estimated average effects imply that all firms decrease the investment rates by the same average amount or a few firms decrease the investment rates by a large amount. From a policy perspective, conducting distributional analysis is important for defining and implementing targeted policies as it identifies firms that are most sensitive to uncertainty shocks.

Figure 2.2: Estimated impact of uncertainty across investment levels



dependent var = inv/ass
impact of $\sigma = -0.0044^{***}$

dependent var = frac(|inv/cap| < 0.01)
impact of $\sigma = 0.005^{***}$

dependent var = frac(inv/cap ≥ 0.2)
impact of $\sigma = -0.018^{***}$

Figure 2.2 shows that firms from the right tail of the investment rate distribution (75th and 85th percentiles) decrease the investment rates much more strongly than firms from the left tail (25th and 15th percentiles), implying that the extensive margin decision of whether to invest or not is important to understand the average response of the investment rate. The drop in the positive investment spike rate and the rise in the inaction rate additionally support the importance of the extensive margin investment decision for the average effects of profit volatility.[44] The empirical literature does not distinguish investment responses along intensive and extensive margins.

To determine the importance of the extensive margin (whether to invest) relative to the intensive margin (how much to invest), we perform the following exercise. The average investment rate in period t is represented as the weighted average of spike and non-spike

[44]The spike rate involves the fraction of firms with an annual investment rate larger than 20%. The inaction rate refers to the fraction of firms with an annual investment rate smaller than 1% in absolute value.

investment rates:

$$i_t = \gamma_t \cdot i_t^s + (1-\gamma_t) \cdot i_t^{ns},$$

where i_t^s and i_t^{ns} is the investment rate conditional on spike and nonspike, respectively; γ_t is the fraction of firms with a positive investment spike. The impact of uncertainty on the average investment rate is[45]

$$\frac{\partial E(i_t)}{\partial \sigma_t} = \underbrace{E(\gamma_t)\frac{\partial E(i_t^s)}{\partial \sigma_t} \;+\; (1-E(\gamma_t)) \cdot \frac{\partial E(i_t^{ns})}{\partial \sigma_t}}_{\text{intensive margin}} \;+\; \underbrace{\frac{\partial E(\gamma_t)}{\partial \sigma_t}\Big(E(i_t^s) - E(i_t^{ns})\Big)}_{\text{extensive margin}}$$

The intensive margin captures how uncertainty affects the *magnitude* of the investment rate within two groups of firms: those with an investment spike and nonspike. The corresponding investment responses are then weighted by the average fraction of firms that belongs to each group of firms. The extensive margin captures how uncertainty affects the *composition* of firms, i.e. the fraction of firms with the spike rate. The uncertainty effects along the extensive margin are adjusted by the investment gap between firms engaging in spike investment and those in non-spike states. In Compustat data, this investment gap is positive and large, indicating that high-investing firms contribute significantly more to overall capital accumulation than other firms in the economy. Overall, we find that the extensive margin component accounts for 45% of the average annual decline in the investment rate.

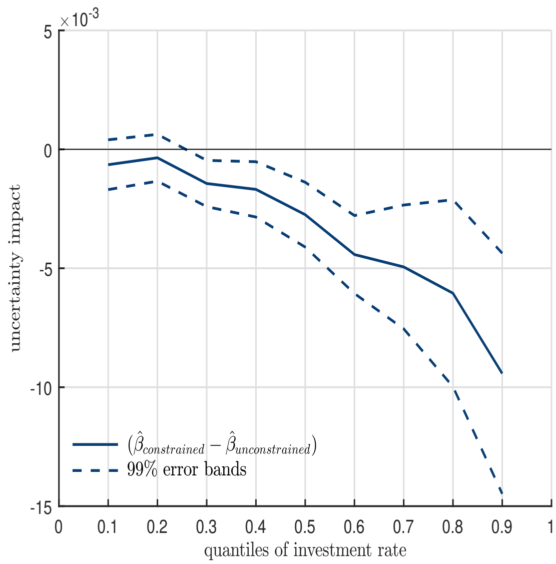
Heterogeneous Impact of Profit Volatility

Our next step is to compute the heterogeneous impact of profit volatility on the investment rates across different groups of firms: constrained and unconstrained. To do so, we perform two steps. First, every year, firms are divided into a *financially* constrained (unconstrained) group on the basis of the exogenous threshold of a dividend-to-profit ratio. If a firm spends less than 20% of its operating profit on dividends, then it is located in the financially constrained group, and vice-versa. Second, within each (un)constrained group, firms are sorted into ten equal-sized groups on the basis of their investment rate. Our results are robust to alternative

[45] The decomposition of the extensive and intensive margin components of the uncertainty impact on the average investment rate is provided in Appendix D.

proxies for financial constraints, including Kaplan-Zingales index, Whited-Wu index, assets, and cash holdings (see Appendix E). A similar procedure is conducted for analyzing real friction. We sort firms with irreversible investment if their capital intensity ratio exceeds a median level of the two-digit NAICS industry.[46]

Figure 2.3: Investment heterogeneity under uncertainty: Impact of financial constraints



Responses within *constrained* firms:

dependent var = frac($|inv/cap| < 0.01$)

impact of σ = 0.0046***

dependent var = frac($inv/cap \geq 0.2$)

impact of σ = -0.0153***

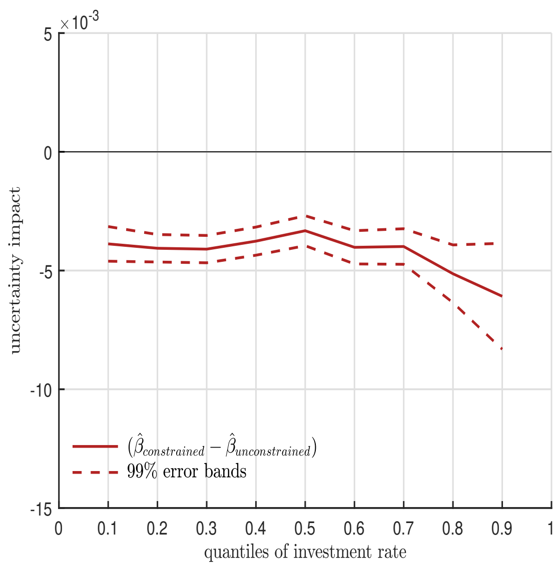
Notes: The blue solid line shows the difference between investment responses to uncertainty between constrained and unconstrained firms across different levels of investment. The dashed lines refer to the 99% confidence intervals generated using robust standard errors.

The empirical literature extensively explores the role of frictions on transmitting the effects of uncertainty on the *average* investment rate. Consistent with the literature, Figure 2.3 indicates that, on average, financially constrained firms reduce the investment rate more than unconstrained firms. This difference in average effects between firms is statistically significant. The intuition is that ex-ante financially constrained firms have limited access to external funds, and thus they heavily depend on internal funds to finance their investment. In the fear of running out of internal funds when profit volatility increases, they reduce the investment rate and increase a precautionary demand for cash holdings to limit their exposure to financial losses and avoid costly borrowing. Conversely, unconstrained firms can increase borrowing or decrease dividends to smooth their investments.

[46]In Appendix A, we consider the low depreciation rate as an alternative measure of investment irreversibility.

The novel evidence from Figure 2.3 shows that financially constrained firms with the high investment rates respond more strongly to uncertainty than other firms in the sample. This is because firms with the high investment rates have more to lose when future profits are lower than expected.[47] A significant drop in the investment spike rate and a rise in zero investment additionally support the significance of the extensive margin investment decision within financially constrained firms for the average investment decline.

Figure 2.4: Real frictions and investment rate distribution



Responses within *constrained* firms:

dependent var = frac($|inv/cap| < 0.01$)

impact of σ = 0.0055^{***}

dependent var = frac($inv/cap \geq 0.2$)

impact of σ = -0.0038^{***}

Notes: The red solid line shows the difference between investment responses to uncertainty between capital adjustment constrained and unconstrained firms across different levels of investment. The dashed lines refer to the 99% confidence intervals generated using robust standard errors.

Figure 2.4 indicates that, on average, constrained firms delay irreversible investments or switch to zero investment more than unconstrained firms in order to avoid committing to projects with potentially more costly capital adjustments if profit conditions worsen. The difference in responses is larger at higher quantiles of the investment rate distribution.

In summary, quantile regression estimates reveal that the influence of both frictions on the investment-uncertainty relationship is stronger at higher levels of investment. While the investment response of constrained firms to increased uncertainty along the extensive

[47]The theoretical argument for the stronger impact of the financial friction at higher quantiles of the investment rate distribution is that the costs of cutting investment in terms of foregone returns become lower than the costs of external funds.

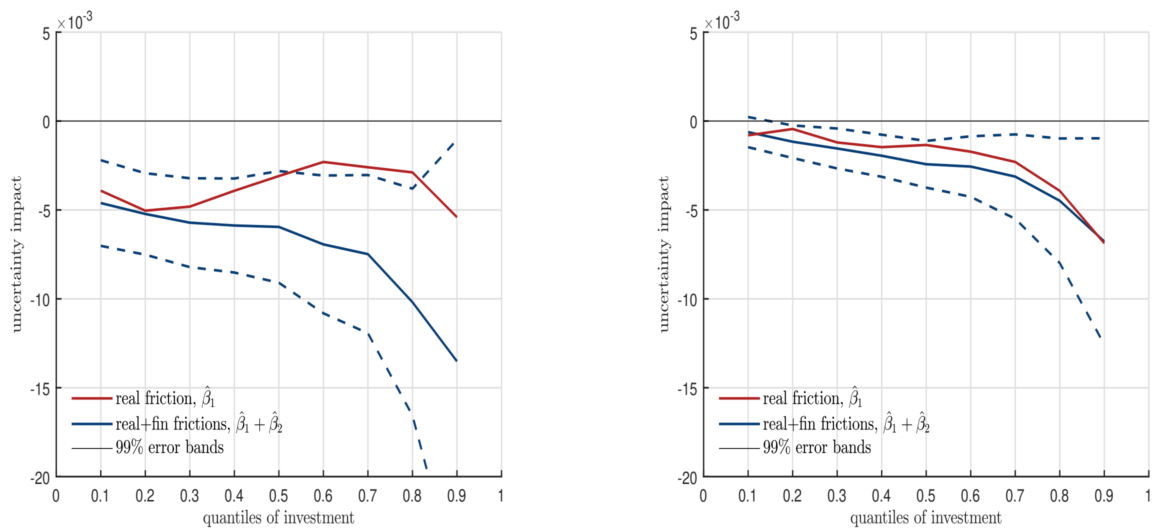
margin is mostly driven by financial frictions, real frictions have a stronger effect on the inaction rate. Financial frictions lead to a stronger change in the shape of the investment rate distribution than real frictions.

Interaction Between Financial and Real Frictions

To quantify the impact of the interaction between frictions, we first sort firms into capital adjustment constrained and *un*constrained groups on the basis of the *capital intensity ratio* (real friction) and then estimate the impact of uncertainty on the investment rate conditional on the *dividend constraint* (financial friction):

$$\frac{inv_{i,t}}{ass_{i,t-1}} = \beta_0 + \beta_1\sigma_{i,t-1} + \Big(\beta_2\sigma_{i,t-1} + \beta_3\Big) \cdot \mathbb{1}\left(\frac{div_{i,t}}{ear_{i,t}} \leq 0.20\right) + \beta_3' X_{i,t-1} + \gamma_i + \eta_t + \epsilon_{i,t} \quad \text{if } cir \in \{1, 0\}$$

Figure 2.5: Effects of financial and real frictions on the investment-uncertainty relationship



(a) **ir**reversible investment ($cir = 1$)

(b) reversible investment ($cir = 0$)

In Figure 2.5, the interaction between the two frictions shows that the impact of uncertainty on investment remains relatively stronger for firms with irreversible assets. Within capital adjustment constrained firms, our estimates indicate that the financial constraint amplifies the negative impact of profit volatility on irreversible assets. Conversely, this impact is negligible for firms with fully reversible assets. This is because the reversible assets increase the firms' ability to obtain external funds, allowing them to absorb uncertainty shocks.

Constrained firms with high investment rates show significantly stronger investment responses than other firms. Ignoring the interaction between the financial and the real conditions of firms underestimates the true effects of uncertainty. In addition, complementarity between conditions is important for defining a targeted policy, as addressing the negative effects of the financial condition alleviates the negative effects of the real condition.

Robustness Checks and Endogeneity Issues

We perform several robustness checks of our baseline regression results obtained in Figure 2.2 and we obtain quantitatively similar results. For instance, Table 2.13 (part K in the Appendix) explores alternative measures of the investment rate, investment opportunity, and a financial position of a firm. In Table 2.14, we investigate the influence of different time windows of profit volatility. Risky projects with a shorter horizon have stronger negative effects on the investment rate. Additionally, profit volatility is replaced with employment and sales volatility, showing that the latter measures have slightly weaker impacts on the investment rate. In Table 2.15, after controlling for profit levels (the first moment), investment sensitivity to increased profit volatility (the second moment) is more pronounced among firms with high irreversible investment and low dividends. The findings about the investment sensitivity to demand are consistent with Kermani and Ma (2023).

In Appendices B and G, we document that the downward trend in the average investment rate from 1980 to 2018 persists even when considering alternative investment measures. These measures control for the effects of depreciation, inflation, capital stock, and liquidity. Similarly, in Appendix C, we show that the upward trend in profit volatility remains robust after controlling for demographic factors. Finally, the validity of using quantile regression estimates is provided in Appendix E.

The OLS estimation of equation (2.1) may face two potential sources of endogeneity: reverse causality and omitted variables. We consider lagged profit volatility to address reverse causality. Furthermore, the omission of productivity shocks can simultaneously influence both investment and profit volatility. For instance, a positive productivity shock stimulates current capital investment and induces more volatile profit.[48] To mitigate this concern, we instrument our profit volatility variable with its lagged version, allowing us to partial out

[48]Given capital adjustment costs, this effect may persist over time.

the effects of shocks.[49] Our IV regression results are presented in Table 2.16 in Appendix K. Investment responses do not change when profit volatility is instrumented with one lagged year, but they become weaker as the lagged years increase. By splitting the sample into constrained and unconstrained groups minimizes potential endogeneity concerns because homogeneous group removes variation in financial or real frictions.

Finally, we estimate the impact of profit volatility on cash holding. The results from Figure 2.23 in Appendix K indicate that when uncertainty about future profits increases high-investing firms tend to reduce the investment rate and increase cash holdings for a precautionary reason.

2.4 Model Environment

We develop a dynamic general equilibrium model with heterogeneous firms and a representative household. The model aims to evaluate which frictions explain investment behaviour in the last four decades and to understand the role of interconnecting frictions in investment decisions under uncertainty. We focus on a precautionary motive - a traditional explanation for decreased investment - which would suggest that cash reserves and positive net dividends should increase when uncertainty increases.[50]

Firms make dynamic decisions on capital, net borrowing, net dividends, and static decisions on labor demand to maximize the expected discounted equity value of shareholders. Shareholders own firms and decide on consumption, labor supply and savings to maximize the utility.

2.4.1 Productivity and Technology

Since firms ex-ante face the same decision problems, we refer to a single firm without the loss of generality. Firms are ex-post heterogeneous once they are hit by an idiosyncratic productivity shock. The next period, firm-level productivity z' is generated by a Markov

[49] Our non-parametric estimates in Appendix F predict that the uncertainty pattern follows a persistent process, supporting the use of lagged firm-specific uncertainty as an instrument for profit uncertainty.

[50] Financial responses of cash reserves and positive net dividends serve as a buffer against the increased probability of negative profit shocks.

chain with transition function $\Gamma(z', z)$. We assume that $Pr\{z' = z_j | z = z_i\} = \Gamma_{ij} \geq 0$ and $\sum_j \Gamma_{ij} = 1$ for each $i = 1, \ldots, n_z$. An exogenous shock to productivity is observed by the manager at the beginning of the period and follows a log AR(1) process:

$$lnz' = \rho \cdot lnz + \sigma_\epsilon \cdot \epsilon', \quad \epsilon' \overset{iid}{\sim} \mathcal{N}(0, 1), \tag{2.2}$$

where the productivity shocks ϵ' are independent across firms and are normally distributed with mean zero and standard deviation σ_ϵ. The persistence of idiosyncratic productivity satisfies $\rho \in (0, 1)$. Equation (2.2) indicates that today's volatility σ_ϵ determines the distribution of tomorrow's productivity $z'(\sigma_\epsilon)$. High volatility today induces a more spread distribution of tomorrow's productivity, i.e. firms face a higher probability of both positive and negative productivity levels. Given that the volatility is identical for all firms, an increase in σ_ϵ affects all firms.

Following the realization of idiosyncratic productivity z in each period, firms use predetermined capital stock k and labor rented from a competitive labor market n to produce a homogeneous good y. We assume that $y(k, z) := F(k, n; z) = zk^{\alpha_k} n^{\alpha_n}$, where $0 < \alpha_k + \alpha_n < 1$. Therefore, output is produced using a decreasing return to scale production technology, which implies that there is an upper bound $\bar{k}$ on the optimal level of capital stock. We assume a competitive consumption goods market, and thus the price of consumption goods is the same for all firms and normalized to one. Operating profit function is defined as:

$$\Pi(k, z) := \max_{n \geq 0} \; F(k, n, z) - wn(k, z), \tag{2.3}$$

where w is a wage rate determined by labor market clearing. We assume that there is no aggregate uncertainty. By the law of large numbers, all aggregate quantities, including the risk-free rate, are deterministic over time.

2.4.2 Frictions

This subsection incorporates frictions in the model through costly adjustment of capital investment (real frictions) and costly external funds in terms of equity flotation costs and collateral constraints (financial frictions).

In each period, the firm begins with a pre-determined capital stock k, while a constant fraction δ of capital stock depreciates. Investment in capital is determined by the choice of next-period capital k' as $i(k, k') = k' - (1-\delta)k$. As in Melcangi (2024), Alfaro et al. (2024) and Bloom (2009), the capital stock is partially irreversible and is subject to convex and fixed adjustment costs. The partially irreversible capital stock refers to capital specificity such that for each unit of capital, only $0 \leq \nu < 1$ fraction is useful for other firms. Investment is also more risky as firms will not invest in the current period if it seems likely that they need to disinvest when facing future negative shocks. Additionally, convex capital adjustment costs $\psi > 0$ prevent the firm from a quick response to productivity shocks. Capital partial adjustment costs function with the associated convex part is defined as:

$$AC^{PC}(k, k') = \begin{cases} \dfrac{\psi}{2} \cdot \dfrac{(k' - (1-\delta)k)^2}{k}, & k' \geq (1-\delta)k \\ -\nu \cdot i(k, k') + \dfrac{\psi}{2} \cdot \dfrac{(k' - (1-\delta)k)^2}{k}, & k' < (1-\delta)k \end{cases} \tag{2.4}$$

When new capital stock is either installed or sold, a fixed fraction $\theta > 0$ of capital is lost. The fixed disruption costs are important to make capital investment lumpy, i.e. the firm changes capital investment only for large productivity shocks. They are scaled by capital such that if the firm produces more, these costs do not outgrow the benefits of increasing production. Capital fixed adjustment costs function is then represented as:

$$AC^{F}(k, k') = \theta \cdot k \cdot \mathbb{1}_{\{k' \neq (1-\delta)k\}} \tag{2.5}$$

The firm can save in cash when $b \leq 0$, generating risk-free taxable interest rate r_f. If $b > 0$, the firm borrows external funds by issuing a one-period (short-term) discount bond. Note that the firm can hold either outstanding debt or save in cash, but it cannot do both. According to the U.S. tax code, a firm pays tax on profits τ_c, and receives tax rebates from economic depreciation and interest payments. Available internal funds are:

$$CF(k, b, z) = \Pi(k, z) - \tau_c \cdot \underbrace{(\Pi(k, z) - \delta k - r_f b)}_{income\ tax\ bill} + (1-\delta)k - (1 + r_f)b \tag{2.6}$$

Equation (2.6) implies that the firm can increase internal funds (cash flow) through either an expansion of its capital stock or by increasing savings. When cash flows are insufficient to cover investment needs, the firm can cover financial deficit by borrowing external funds from either the credit market $b' > 0$ or the equity market $d < 0$.[51] If cash flows are larger than investment needs (financial surplus), the firm uses the rest of available funds for paying dividends to shareholders $d > 0$. Therefore, the budget constraint is defined as:

$$d = CF(k, b, z) - k' - AC^{PC}(k, k') - AC^{F}(k, k') + b'$$

The ability to borrow is subject to the limited enforceability of debt constraints and equity issuance costs. For the non-defaultable debt to be risk-free, the firm needs to repay its debt to the lender by selling capital in the worst case scenario. Similar to Melcangi (2024), the collateral constraint is defined as:

$$b \leq \eta \cdot (1 - \nu) \cdot k, \quad 0 < \eta < 0$$

where η denotes the pledgeability of capital. The above equation implies that only the undepreciated fraction of capital can be pledged. The lender can sell the seized capital at a lower resale price. Notice that the parameter η is common across firms and is time invariant.

We also assume that equity issuance incurs flotation costs ϕ:

$$\Phi(d) = \begin{cases} \phi \cdot |d|, & d \leq 0 \\ d, & d > 0 \end{cases} \tag{2.7}$$

The firm cannot reduce dividends without limits. Otherwise, costless external finance will make the financial problem of the firm negligible. Similarly, without a costly equity market, the firm could easily circumvent the debt market by issuing new equity.

2.4.3 The Firm Problem

The firm decides on investment in capital k', net borrowing b' and net dividends d in order to maximize the expected present value of the stream of future net dividends to shareholders. Shareholders receive positive net dividends, but also need to pay costs $\Phi(d)$.

[51] Debt is tax preferable over equity issue due to tax deductibility of interest payments. Therefore, firms can decrease their taxable income by issuing more debt.

The value function is defined as:

$$V(k,b,z) = \max_{\{k',b',d\}} \; d - \Phi(d) + \beta E_{z'|z} V(k',b',z') \tag{2.8}$$

subject to:

$$d = CF(k,b,z) - k' - AC^{PC}(k,k') - AC^{F}(k,k') + b' \tag{2.9}$$

$$b \leq \eta \cdot (1-\nu) \cdot k \tag{2.10}$$

Individual income tax rate is denoted as τ_i, and annual discount factor is $\beta = 1/(1 + r_f(1-\tau_i))$. The firm problem is limited upward by $\bar{b}$ for cash holdings, $\bar{k}$ for capital and $\eta(1-\nu)\bar{k}$ for collateral. The continuation firm value is:

$$E_{z'|z} V(k',b',z') = \int_{z'} V(k',b',z') d\Gamma(z',z)$$

Although borrowing is tax preferable to equity issuance, which is observed from $CF(k,b,z)$ in equation (2.6), capital specificity makes borrowing less collateralizable in equation (2.10).

Timing of Events: In each period, a firm begins with a capital stock k, cash holdings $b < 0$, or debt obligations $b > 0$. After observing idiosyncratic productivity shocks, the firm decides on labor, and together with existing capital, produces output and generates revenue. The firm observes current idiosyncratic uncertainty σ_ϵ, and forms expectations about next-period idiosyncratic productivity using the Markov chain. The firm then decides on new capital k' and new debt b', and pays its wage bills and current debt obligations.

2.4.4 The Household Problem

There is a unit mass of households that chooses consumption, labor supply and investment in firm shares. Households own all firms and receive dividend payments in each period. Since households can perfectly insure against firm-specific uncertainty, their decisions are described by a representative household.

The household utility maximization problem is defined as:

$$\max_{\{C_t,N_t\}} U(C_t,N_t) = \sum_{t=0}^{\infty}\beta^t\left(log(C_t) - h\frac{N_t^2}{2}\right), \tag{2.11}$$

subject to:

$$C_t + \int p_t\chi_{t+1}d\mu_t \;\leq\; (1-\tau_i)w_tN_t + \int(d_t\cdot\mathbb{1}_{\{d_t>0\}} + p_t - p_{t-1})\chi_{t+1}d\mu_t + T_t, \tag{2.12}$$

where $\beta \in (0,1)$ is the household's discount factor, C_t is consumption, N_t is labor supply, $h > 0$ denotes the disutility of working. The household buys new shares χ_{t+1} at price p_t and obtains after-tax dividends and capital gains for shares bought at price p_{t-1}. T_t is the lump-sum government transfer, and μ_t is the measure of firms over idiosyncratic states (k_t, b_t, z_t). The equation (2.12) implies that the household's spending on consumption and investment cannot exceed the sum of after-tax labor income and returns from financial assets.

2.4.5 Government Transfers

The government collects revenue from taxing the labor income of the household and taxing corporate profits, and rebates them back to the household in a lump-sum manner. The budget constraint of the government is

$$T = \tau_i wN + \tau_c\int(\Pi(k,b,z) - \delta k - r_f b)\,\mu(dk,db,dz) \tag{2.13}$$

2.4.6 Optimal Firm Policies

In this section, we analyze the optimal investment and financial policy of a firm. The value function is not concave and differentiable due to the fixed cost of capital adjustment. However, for simplicity, we assume that $V(\cdot)$ exhibits concavity and differentiability. Optimal policies enable us to explore the precautionary channel: the trade-off between illiquid and partly collateralizable assets (capital) and liquid but unproductive assets (cash and positive net dividends) in the face of the increased uncertainty. This trade-off is largely influenced by the real and financial adjustment costs. Real frictions make returns to capital investment asymmetric, while financial frictions do not allow firms to easily avoid financial constraints.

Optimal Financial Policy

The first-order conditions of the maximization problem (2.8) with respect to b' is:

$$\underbrace{(1-\Phi_{b'}(d))}_{MB_{borrowing}} = \underbrace{\beta\int\Big((1+(1-\tau_c)r_f)\cdot(1-\Phi_{b'}(d'))+\lambda'\Big)d\Gamma(z',z)}_{MC_{borrowing}}, \tag{2.14}$$

where λ is a Lagrange multiplier associated with the constraint (2.10). If $b \leq 0$, there is negative net borrowing, and thus the firm is saving. The left term of (2.14) is the marginal benefit (cost) of an additional unit of debt (saving), while the right term represents the marginal cost (benefit) of debt (saving).

The left term implies that, holding investment policy and productivity fixed, the marginal benefit of debt is higher when additional borrowing is used for reducing costly equity issuance $1+\phi$. The right term represents the marginal cost of paying the debt obligations $1+(1-\tau_c)r_f$ in the next period. Servicing higher next-period debt obligations will reduce cash flow tomorrow, and thus increase a probability of issuing costly equity. On the one hand, if the firm expects to issue new equities in the next period, the cost of additional debt in the current period is higher.[52] On the other hand, higher expected dividends in the next period could be used to pay debt and avoid costly equity issuance, and thus reduce the marginal cost of debt. Notice that firms can also use debt to reduce their corporate income tax bill.

The first order condition with respect to dividends is:

$$\Phi_d(d) = \begin{cases} 1+\phi, & d \leq 0 \\ 1, & d > 0 \end{cases} \tag{2.15}$$

The marginal value of cash flow to shareholders is one plus equity costs in face of negative net dividends or one for positive net dividends.

[52]If the firm expects positive productivity shocks tomorrow, accumulating liquid assets (higher negative net borrowing) in the current period enables the firm to finance future investment opportunities without tapping into the costly equity market.

Optimal Investment Policy

The first order condition of the maximization problem (2.8) with respect to k' is:

$$\frac{1}{1+r_f(1-\tau_i)} \cdot \int \Big((1-\Phi_{k'}(d')) \cdot (CF_{k'}(k',b',z') - AC_{k'}^{PC}(k',k'') - AC_{k'}^{F}(k',k'',z')) + \lambda' \cdot \eta \cdot (1-\nu) \cdot (1-\delta)\Big) d\Gamma(z',z) \ = (1-\Phi_{k'}(d)) \cdot \Big(AC_{k'}^{PC}(k,k') + AC_{k'}^{F}(k,k',z)\Big) \tag{2.16}$$

The left-hand side of equation (2.16) represents the marginal benefit of investing in an additional unit of capital MB_k, while the right-hand side is the marginal cost of capital investment MC_k. Holding productivity fixed, the left term indicates that an additional unit of next-period capital increases future internal funds $CF_{k'}$ net of capital adjustment costs and relaxes the collateral constraint. The right term implies that investing in current capital stock either reduces current dividends or increases equity issuance. Notice that real frictions, characterized by partial and fixed capital adjustment costs ($AC_{k'}^{PC}(\cdot)$, $AC_{k'}^{F}(\cdot)$, ν), diminish the liquidity and collateral values of capital, *ceteris paribus*.

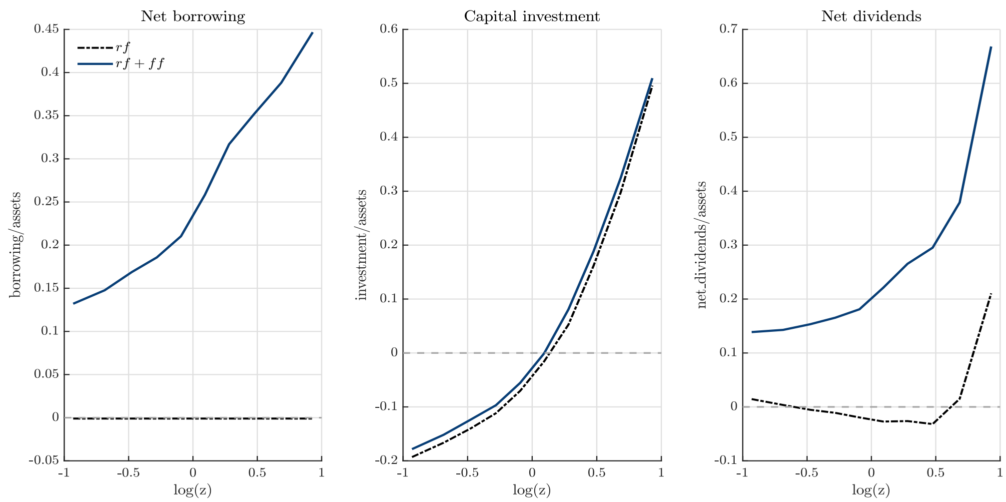
The primary role of partial capital adjustment costs is to make the marginal product of capital a concave function in productivity. Although both good and bad states of the productivity shocks are equally likely, firms are more sensitive to adverse outcomes. On the one hand, a high productivity shock increases MB_K primarily through $CF_{k'}$, stimulating firms to increase current investment in capital that limits the rise in MB_K. On the other hand, following a low productivity shock, $AC_{k'}^{PC}$ limits the decline in MB_K when selling capital. Hence, the increased profit volatility leads to a decrease in capital investment.[53] Moreover, with the fixed capital adjustment costs, firms tend to remain investment inactive and (dis)invest only for large enough shocks. Therefore, firms need to incorporate the possibility that a negative shock requires the sale of capital at a lower value and triggers the fixed adjustment cost.

The impact of increased firm-specific uncertainty on investment is ambiguous analytically when we consider the combination of financial and real frictions. This is because financial frictions directly increase the difficulties of financing capital expenditure through interest

[53] The relevance of capital irreversibility for determining profit volatility's impact is contingent upon the presence of an intertemporal trade-off between current and future capital investment. In our model, this assumption is justified by a DRTS technology.

rates for loans, collateral constraint, and equity issuing costs. It becomes more difficult for firms to finance the costs of investment inaction such as wage bills, capital depreciation, and foregone returns.

Figure 2.6: Policy functions in initial steady state



Notes: All policy functions are shown for different log levels of productivity shocks and median levels of capital stock and savings. Total assets include capital stock and cash holdings. Negative investment indicates that depreciation erodes the existing capital stock.

Figure 2.6 depicts decision rules in the initial steady state for the average firm with net borrowing, capital investment and net dividends (dividends minus equity issuance) at various levels of productivity. Holding uncertainty about future profit constant, we examine two cases: one with only real frictions and another with both real and financial frictions. Considering real frictions, firms with low productivity have low capital liquidity, which limits their capacity to generate sufficient internal funds. Consequently, these firms respond by issuing new equity (negative net dividends) and reducing capital investment. High-productivity firms can afford to pay dividends to shareholders. When financial frictions ($\phi > 0,\ \eta > 0$) are added to real frictions, firms substitute equity financing with borrowing due to the tax benefits and increase capital investment.

2.4.7 Stationary Equilibrium

A Stationary Recursive Competitive Equilibrium (SRCE) is a set of quantities $\{C, N, k', b', d, n\}$, prices $\{p, w, r\}$, life utility and value functions $\{U, V\}$, cross-sectional distribution of firms over state $\mu(k, b, z)$, and capital adjustment costs $\{AC^F, AC^P\}$ such that:

- Given w^*, $V(k, b, z; w^*)$, $k'(k, b, z; w^*)$, $b'(k, b, z; w^*)$, $d(k, b, z; w^*)$, $n(k, b, z; w^*)$ solve the firm's problem.
- Given w^*, $U(C, N)$, C and N solve the household's problem.
- The stationary distribution is $\mu^*(k, b, z; w^*)$.
- The labor market clears: $\bar{N} = \int n(k, b, z; w^*)d\mu(k, b, z; w^*)$.
- The equity market: χ'=1.
- The goods market clears: $Y(\mu^*; w^*) = C(\mu^*; w^*)+I(\mu^*; w^*)+AC^F(\mu^*; w^*)+AC^P(\mu^*; w^*)$.

We exclude financial adjustment costs from the goods market clearing conditions as they do not represent real costs. The costs related to issuing new equities (ϕ) is attributed to households. A general equilibrium setting allows wages to adjust such that the impact of the uncertainty becomes weaker compared to a partial equilibrium model.

2.4.8 Quantitative Analysis

In this section, we calibrate the model to rationalize investment responses to increased uncertainty and study their implied financial implications. As the model does not have an analytical solution, we solve it numerically. For that purpose, we use value function iteration on a discrete grid with interpolation.

2.4.7.1 Calibration

There are two groups of parameters. The first group of outside parameters is either set according to the literature or has a data counterpart. The second set of inside parameters is estimated using the simulated method of moments, minimizing the weighted sum of squared differences between model-generated and observed data moments. To evaluate the impact of the increased uncertainty and frictions on the investment rate over time, we divide the sample into two periods. The first period corresponds to the 1980-1998 period (early period) in which the model is estimated in a steady state by matching moments from Compustat data for publicly-listed U.S. firms. For the 1999-2018 period (late period), we re-estimate the same parameters using moments specific to this period.

The group of outside parameters for the early and late periods are reported in Table 2.2. We follow Hennessy and Whited (2005) in setting corporate and individual income tax rates.[54] The key variable of interest is firm-level profit volatility, σ_ϵ.[55] We construct the firm-specific volatility as the estimated residual from the regression of operating profit on capital, controlling for time fixed effects.[56] The estimated values of σ_ϵ amount to 0.1915 (early period) and 0.2038 (late period). These estimates are within the range used in the literature: 0.116 in Melcangi (2024) and 0.209 in Alfaro et al. (2024). The capital depreciation rate is set to 0.069 as in Zhao (2020) because the measure of capital depreciation in Compustat data is too high. Finally, the annual risk-free interest rate is fixed at 4%, which is a common assumption in the literature. Firms' annual discount factor is set at 0.973 to ensure that cash holdings of some firms do not completely absorb the financial constraints.

The remaining six parameters are jointly estimated using the simulated method of moments:

$$\gamma = \{\psi,\ h,\ \nu,\ \theta,\ \phi,\ \eta\} \tag{2.17}$$

All parameters from (2.17) jointly affect various model moments. Still, some parameters have a larger impact on a specific moment. Estimated parameters with targets for the early period (1980-1998) and the late period (1999-2018) are reported in Table 2.3. The mean and standard deviations are cross-sectional. Overall, the model is able to reproduce the key features of the data.

[54] Production input parameters, persistence of productivity process and uncertainty are directly estimated to avoid making the program too slow when looping in estimation routine.

[55] The productivity AR(1) process in (2.2) is discretized by Tauchen and Hussey (1991). This method generates a grid of 10 points and a Markov transition matrix.

[56] Fixed effects in our simple regression capture changes in aggregate productivity, inflation, etc.

Table 2.2: Outside parameters

Parameters	Description	$Value^e$	$Value^l$	Source
τ_c	Corporate profit tax rate	0.460	0.460	Hennessy and Whited (2005)
τ_i	Income tax rate	0.296	0.296	Hennessy and Whited (2005)
α_k	Capital share in production	0.326	0.326	Compustat data
α_n	Labor share in production	0.650	0.650	Compustat data
ρ	Persistence of log productivity	**0.774**	**0.792**	Compustat data
σ_ϵ	Std. dev. of innov to log prod	**0.191**	**0.208**	Compustat data
δ	Capital depreciation rate	0.069	0.069	Zhao (2020)
r_f	Risk-free interest rate	0.040	0.040	Typical
β	Annual discount factor	0.973	0.973	$1/(1+r_f(1-\tau_i))$

Notes: Columns 3 and 4, denoted as $Value^e$ and $Value^l$, refer to the parameter values for the early period (1980-1998) and late period (1999-2018), respectively.

Convex capital adjustment costs is disciplined by matching the standard deviation of the annual investment-capital ratio, directly having an effect on the intensive margin of investment.[57] The observed volatility of the investment rate decreases from 0.114 to 0.091 between 1980 and 2018. The estimated ψ increases from 2.013 to 2.340 to match this trend. The frequency of positive investment spikes is informative about the fixed costs of capital adjustment as a higher θ stimulates firms to make fewer and larger investments.[58] In 1980, 19.5% of firms had lumpy investment, while this significantly reduced to 12.3% in 2018. The estimated θ increased from 5.9% to 6.2% between 1980 and 2018 to reflect this trend. The partial irreversibility ν is disciplined by the fraction of investment inaction. Firms tend to remain investment inactive for a longer period, increasing this moment from 1.31% in 1980 to 2.09% in 2018. We estimate ν around 2%, which is in the range of 1% from Ayres and Raveendranathan (2023) and 34% from Alfaro et al. (2024) and Melcangi (2024).

As for the collateral constraint, we target the average cash-assets ratio between periods. This moment is informative about a tendency of firms to accumulate cash in the face of increased uncertainty as access to external financing is limited and costly. An additional

[57]Larger investment in machines and equipment induces larger planning and evaluation costs.

[58]Fixed costs can be observed as technological constraints as firms face production disruptions when installing new capital, regardless of how much new capital is bought.

problem for firms is the partial adjustment costs as more irreversible assets reduce the collateral value of capital. The estimated drop for η parameter indicates that cash holdings experienced a significant rise from 6.1% to 6.2%. Next, the average equity-capital ratio is informative about the equity flotation cost ϕ. Our model is limited to match the observed rise in equity financing. The preferences for leisure h is identified by the equilibrium labor supply of 0.3, which corresponds to the average fraction of time spent on the labor market.

Table 2.3: Estimated parameters and targeted moments

	early (1980-1998)		late (1999-2018)					
Targeted Moments	Model	Data	Model	Data	Parameter	Description	early	late
std(inv/cap)	0.127	0.114	0.110	0.091	ψ	Convex capital adj costs	2.013	2.340
frac(inv/cap≥0.20)	0.184	0.195	0.105	0.123	θ	Fixed capital adj costs	0.059	0.062
frac(|inv/cap|<0.01)	0.029	0.013	0.046	0.021	ν	Partial capital adj costs	0.022	0.024
mean(cash/ass)	0.090	0.107	0.135	0.168	η	Collateral constraint	0.322	0.251
mean(equity/cap)	0.057	0.061	0.052	0.108	ϕ	Equity costs	0.390	0.415
labor share	0.314	0.300	0.282	0.300	h	Leisure preference	6.559	7.018

Notes: Total assets involves capital stock and cash holdings. The parameters are separately estimated for the early and late period. We use Compustat data for the analysis.

2.4.7.2 Model Fit

We evaluate the validity of the model by comparing the model-generated moments with nontargeted data moments. In Table 2.4, we show that while the model explains about one-third of the observed reduction of the investment rate in the data, it is much more successful in matching financial patterns.

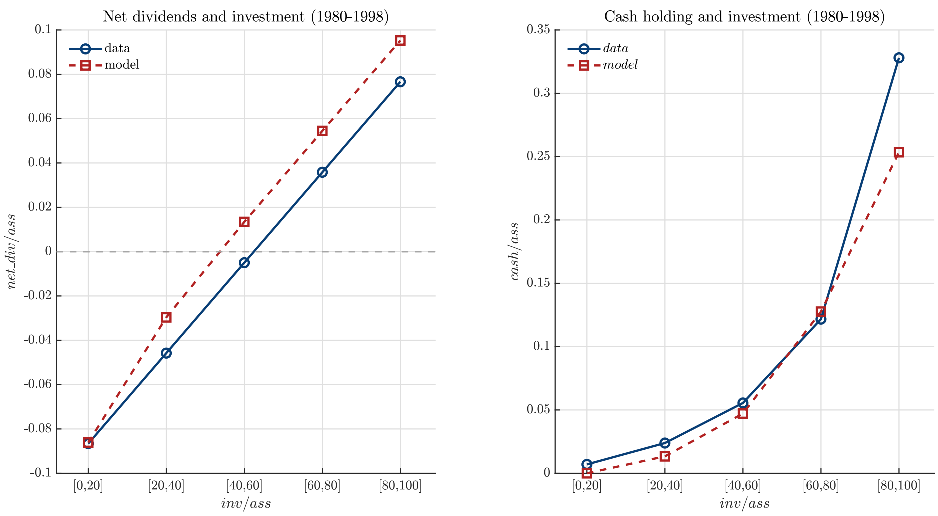
Figure 2.7 and Figure 2.8 show that the model is successful in matching the non-targeted net dividends and cash holdings through the 1980-2018 period. First, the figures suggest that firms with a greater investment in capital tend to generate higher internal funds, which can be used for higher positive net dividends and cash holdings. These financial metrics serve as a buffer against increased idiosyncratic uncertainty about future profits. Second, firms in the lowest investment bins face financial constraints, resulting in negative net dividends. A good model fit with data supports the reliability of using the model in determining the role of frictions in propagating the financial effects of uncertainty shocks.

Table 2.4: Model fit: Model vs. Data

	early (1980-1998)		late (1999-2018)	
Nontargeted Moments	Model	Data	Model	Data
mean(inv/cap)	0.131	0.138	0.124	0.110
mean(inv/ass)	0.123	0.081	0.109	0.053
mean(netdiv/ass)	0.100	0.110	0.149	0.181
std(inv/ass)	0.125	0.075	0.105	0.060
std(cash/ass)	0.104	0.134	0.111	0.184

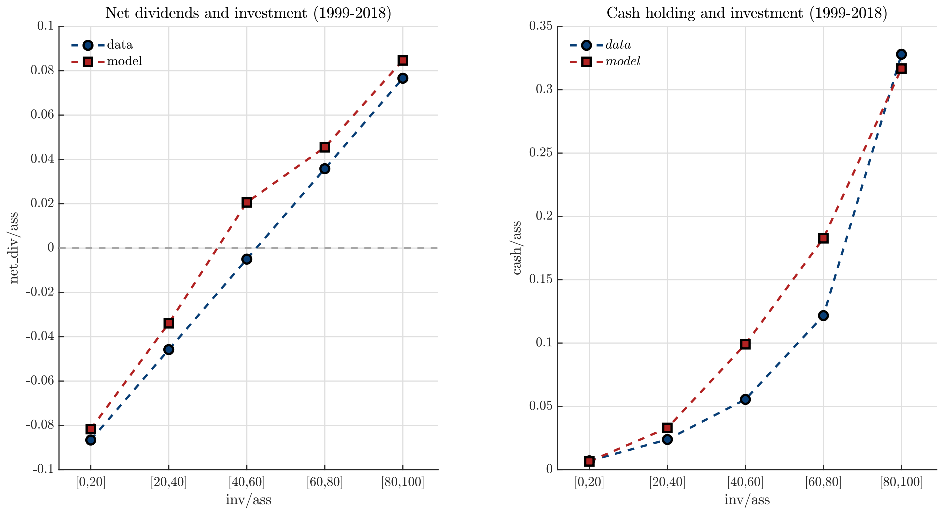
Notes: Total assets involves capital stock and cash holdings. Net dividends equals dividends minus equity issuance and plus cash holdings. The parameters are separately estimated for the early and late period. We use Compustat data for the analysis.

Figure 2.7: Net dividends and cash holdings vs. investment (early period)



Notes: Figure 2.7 displays net dividends and net borrowing across five bins for the 1980-1998 period. The first bin contains firms with investment-asset ratio below the 20th percentile, and the last bin includes firms above the 80th percentile. In data, net dividends are computed as total dividends minus equity issuance plus share repurchases, and then normalized by total assets.

Figure 2.8: Net dividends and cash holdings vs. investment (late period)



Notes: Figure 2.8 displays cash holdings across five bins of the investment rate for the 1999-2018 period. The first bin contains firms with investment-asset ratio below the 20th percentile, and the last bin includes firms above the 80th percentile.

2.4.7.3 Quantitative Results

In this section, we conduct several counterfactual experiments to evaluate the quantitative importance of uncertainty and frictions in explaining the downward trend in investment between 1980 and 2018, and to examine the roles of frictions in amplification and propagation of shocks on financial variables.

The Impact of Uncertainty

In our accounting exercise, we start by increasing volatility in firm-level profitability from the estimated value of 0.1915 to 0.2085, while all other model parameters are fixed at their initial values. This simple experiment can exogenously quantify the contribution of uncertainty. Table 2.5 shows that the model matches the trends in investment and precautionary savings observed in data. Specifically, the increased uncertainty accounts for around 6% of the decrease in the investment rate. This evidence is consistent with our empirical observation in Section 2.3.3.

In Table 2.5, we observe that, following the increased uncertainty about future profitability, fewer firms choose large investment and more firms make negligible or zero

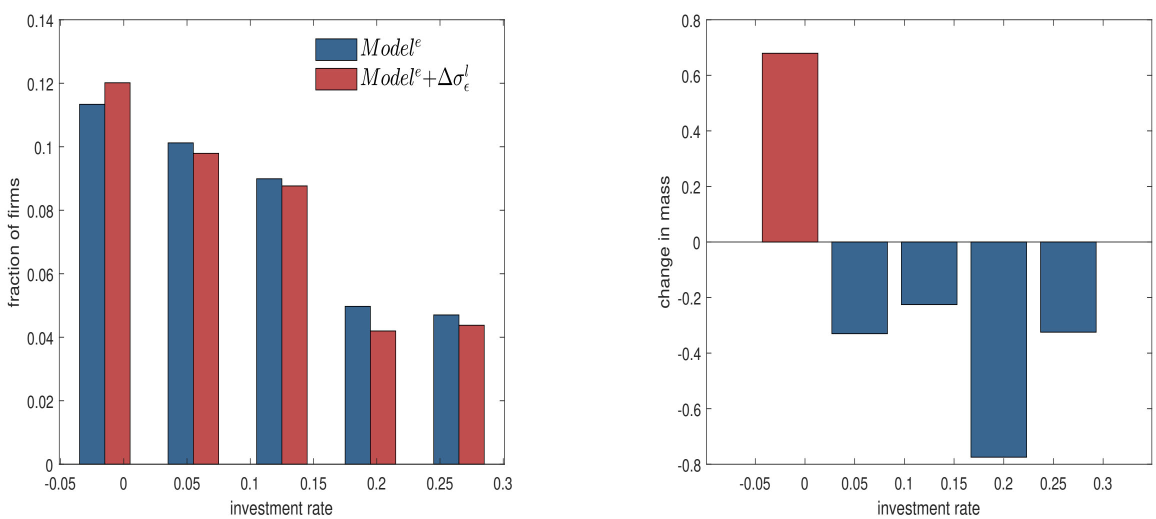
Table 2.5: The impact of uncertainty, 1980-2018

Statistics	$Model^e$	$Model^e$+$\Delta\sigma_\epsilon^l$
mean(inv/ass)	0.1229	0.1204
frac(inv/cap>0.20)	0.1843	0.1822
frac(|inv/cap|<0.01)	0.0291	0.0348
mean(cash/ass)	0.0897	0.1001
mean(netdiv/ass)	0.0999	0.1085

Notes: $Model^e$ is the model estimated for the early period 1980-1998, while $\Delta\sigma_\epsilon^l$ takes the uncertainty value from the late period 1999-2018. We keep all other parameters at their initial values from the early period.

investment. Figure 2.9 shows the effects of uncertainty shocks on the distribution of the investment rates, suggesting that firms indeed tend to avoid large capital commitments and remain inactive to keep their financial flexibility. We also decompose the effects of uncertainty on the investment rate into the extensive and intensive margins. Consistent with the empirical evidence in Section 2.3.3, our model predicts that the extensive margin accounts for 37% of the changes in the annual investment rate.

Figure 2.9: Profit volatility and the distribution of investment rates



(a) investment rate distribution

(b) change in distribution

The Impact of Frictions

Next, we separately consider the effect of frictions. In Table 2.6, real friction parameters take values from the late 1999-2018 period, whereby all other parameters are held fixed at their initial values from the early period. While the fixed capital adjustment costs are the common factor in the literature to explain the spike rate, our model shows that the increased fixed costs also generate the counterfactual prediction that the inaction rate should decrease. We reconcile this prediction through higher convex capital adjustment costs. The fixed costs also largely explain the rise in cash holdings and net dividend payments. The direct effects of irreversible capital costs in the model are negligible. In Table 2.7, we observe that either a tighter collateral constraint or an increase in equity costs reduces the investment rate.

Table 2.6: Decomposition of *real* frictions, 1980-2018

Statistics	$Model^e$	$Model^e$ $+\Delta\nu^l$	$Model^e$ $+\Delta\theta^l$	$Model^e$ $+\Delta\psi^l$	$Model^e$ $+\Delta(\nu^l, \theta^l, \psi^l)$	$Model^l$	$Data^e$	$Data^l$
mean(inv/ass)	0.1229	0.1230	0.1134	0.1116	0.1115	0.1087	0.0806	0.0527
frac(inv/cap>0.20)	0.1843	0.1840	0.0989	0.0980	0.0978	0.1051	0.1954	0.1229
frac(|inv/cap|<0.01)	0.0291	0.0287	0.0184	0.0379	0.0381	0.0462	0.0131	0.0209
mean(cash/ass)	0.0897	0.0897	0.1199	0.1090	0.1094	0.1353	0.1072	0.1679
mean(netdiv/ass)	0.0999	0.1004	0.1387	0.1294	0.1315	0.1492	0.1098	0.1806

Notes: $Data^e$ contains values of statistics for the early period (1980-1998), while $Data^l$ is related to the late period (1999-2018). Parameters ν, θ and ψ are related to partial irreversibility costs, fixed and convex capital adjustment costs, respectively.

Our findings indicate that financial frictions have an impact on the investment rate equal to that of the combined real frictions. However, investment responses to increased uncertainty at the extensive margin (the spike rate) are slightly better explained by financial frictions, while real frictions account for the increase in the inaction rate. Finally, Table 2.8 shows that the irreversible costs amplify the impact of uncertainty by increasing investment inaction observed in the late period. The combination of collateral constraint and irreversible capital reduces the liquidity and collateral value of capital, stimulating a reallocation of resources from capital to cash reserves (and positive net dividends). This response is consistent with a precautionary savings channel. The investment rate drops by 8.3% and cash holdings increase by 42.3% between periods in the model without irreversibility costs ($\nu = 0$).

Table 2.7: Decomposition of *financial* frictions, 1980-2018

Statistics	$Model^e$	$Model^e$ $+\Delta\phi^l$	$Model^e$ $+\Delta\eta^l$	$Model^e$ $+\Delta(\phi^l, \eta^l)$	$Model^l$	$Data^e$	$Data^l$
mean(inv/ass)	0.1229	0.1132	0.1128	0.1115	0.1087	0.0806	0.0527
frac(inv/cap>0.20)	0.1843	0.0993	0.0987	0.0998	0.1051	0.1954	0.1229
frac(|inv/cap|<0.01)	0.0291	0.0186	0.0209	0.0200	0.0462	0.0131	0.0209
mean(cash/ass)	0.0897	0.1227	0.1250	0.1327	0.1353	0.1072	0.1679
mean(netdiv/ass)	0.0999	0.1402	0.1430	0.1514	0.1492	0.1098	0.1806

Notes: $Data^e$ contains values of statistics for the early (1980-1998) period, while $Data^l$ is related to the late (1999-2018) period. Parameters ϕ and η are related to equity flotation costs and collateral constraint, respectively.

Table 2.8: Role of irreversibility costs

Statistics	$Model^e$	$Model^e$ $+\nu^e = 0$	$Model^l$ $+\nu^l = 0$	$Model^l$
mean(inv/ass)	0.1229	0.1226	0.1124	0.1087
frac(inv/cap>0.20)	0.1843	0.1844	0.1070	0.1051
frac(|inv/cap|<0.01)	0.0291	0.0285	0.0260	0.0462
mean(cash/ass)	0.0897	0.0926	0.1318	0.1353
mean(netdiv/ass)	0.0999	0.1024	0.1429	0.1492

Notes: $Data^e$ contains values of statistics for the early (1980-1998) period, while $Data^l$ is related to the late (1999-2018) period. Parameters ν^e and ν^e are related to irreversibility costs for the early and late periods, respectively.

2.5 Conclusion

This paper explores a negative relationship between firm-level uncertainty about future profit and fixed capital investment. Using Compustat data, we focus on U.S. public firms over the past four decades. Two main takeaways of this paper suggest that (1) the distributional analysis of uncertainty is important to understand investment responses in an uncertain environment, and (2) interconnecting frictions is important for capturing spillover effects between frictions.

In a quantile regression model, we find that high-investing firms cut their investment rate more than other firms in the economy. Two statistics, including the drop in the positive investment spike and the rise in the inaction rate, support the importance of the extensive margin effects of uncertainty. We also document that the effect of increased volatility on irreversible investment decreases in the presence of financial constraint. Next, we build a heterogeneous-firm model to rationalize these findings and explore the financial implications of the negative investment-uncertainty relationship. A comprehensive capital cost structure helps to capture an increased fraction of firms that have small or zero investment, while costly external funds can help to account for a decreased fraction of firms with lumpy (large, one-time) investment. In anticipation of future profit shocks, firms reduce capital investment and increase demand for cash holdings. In the model, the increased variance in firm-level profitability explains 6% of the decline in investment and 20% of the increase in cash holdings.

2.6 Appendix

A: Variable Construction

This section describes the firm-specific and aggregate variables used in our empirical analysis. The construction of variables follows the literature (see, e.g., Ottonello and Winberry, 2020; Almeida and Campello, 2007), and is based on annual firm-level (Compustat) data and industry-level (NIPA, FFA) data. Compustat satisfies important requirements of our study: it contains a long panel, which allows us to exploit within-firm variation; it has rich balanced information.[59] The regression sample covers the period from 1980 to 2018 for all publicly-traded firms. The beginning of the sample period is chosen mostly to be comparable with the literature.

Firm-level Variables, Based on Public Firms from Compustat Annual Data

1. Investment. We incorporate four measures of the investment rate to facilitate comparison with previous studies. Our main dependent variable is the nominal investment rate. First, the benchmark investment rate is defined as gross capital expenditure (`capx`, item 128) to the lagged book value of total assets (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (`PPE`). For the panel data analysis, we normalize investment by lagged total assets in order to absorb large firm-level heterogeneity present in the data. Differences in firm size may cause heteroskedasticity in investment. This ratio is a common practice in microeconometric studies. The model counterpart of the investment rate is

$$inv\ rate = \frac{i_t}{k_t + \mathbb{1}_{(b_t<0)} b_t},$$

   where total assets involves capital stock k_t and cash holdings $\mathbb{1}_{(b_t<0)} b_t$.

   Second, we follow the approach by Ottonello and Winberry (2020) to define capital investment as $\Delta log(k_{i,t+1})$, where $k_{i,t+1}$ is the tangible capital stock of firm i at the end of year t. The first value of $k_{i,t+1}$ is set to a level of the gross property, plant and

[59] For detailed instructions on accessing Compustat data via the Wharton Research Data Services (WRDS), please refer to our `stata` code.

equipment (`ppegt`, item 7) for each firm and year in which this value appers. Afterwards, the dynamics of $k_{i,t+1}$ are computed using the net property, plant and equipment (`ppent`, item 8). A linear interpolation is used to deal with missing observations of `ppent`. The interpolation is not used if two or more consecutive observations are missing. Gross capital investment is then adjusted by the depreciation rate to derive net investment. Annual depreciation rates for industries are computed as the depreciation-to-stock ratio. BEA, Fixed Asset Table contains information on stock, investment and depreciation. Stock variable includes equipment, structure and intellectual property. Depreciation rates are disaggregated at the 2-digit (1997 NAICS) industry level. In the model, the net investment rate is

$$net\ inv\ rate = \frac{i_t - \delta_t k_t}{k_t + \mathbb{1}_{(b_t<0)} b_t},$$

where δ_t denotes the depreciation rate.

Third, we consider the capital expend property, plant and equipment (`capxv`, item 30) normalized by the lagged book value of total assets as a measure of the investment rate.

Fourth, investment is measured as the ratio of current capital expenditures `capx` scaled by lagged `ppent`, as in Almeida and Campello (2007).

2. Firm-level uncertainty. The uncertainty measure is defined as the rolling standard deviation of the firm-level growth rate of earnings (`oibdp`, item 13):

$$\sigma_{i,t} = \left[\frac{1}{5}\sum_{\tau=-4}^{0}(\lambda_{i,t+\tau} - \bar{\lambda}_{i,t})^2\right]^{1/2},$$

where we define earnings growth as in Alfaro et al. (2024):

$$\lambda_{i,t} = \frac{2\cdot(\texttt{oibdp}_{i,t} - \texttt{oibdp}_{i,t-1})}{\texttt{oibdp}_{i,t} + \texttt{oibdp}_{i,t-1}},$$

and the moving average growth rate of earnings between year $t-4$ and year t for a firm i is defined as

$$\bar{\lambda}_{i,t} = \frac{1}{5}\sum_{\tau=-4}^{\tau=0}\lambda_{i,t+\tau}$$

An annual average of earnings volatility across all firms in the sample is used as an aggregate measure of firm volatility in a given year:

$$\sigma_t = \frac{1}{N_t}\sum_{i=1}^{N_t}\sigma_{i,t}$$

To further validate the observed the upward trend in firm-level volatility observed in data, we also consider the standard deviation of sales (`sale`, item 12) and employment (`emp`, item 29). We move our sample back up to 1976 to construct a backward-looking measure of uncertainty for our starting year 1980. Specifically, the standard deviation of the profit growth rate over the 1976-1980 period is used as the observation on profit volatility for year 1980. We create an uncertainty measure over five-year overlapping periods, spanning from 1976-1980, 1977-1981, ..., to 2014-2018.

3. Tobin's Q is measured as the ratio of the lagged ex-dividend market value of equity to the lagged book value of liabilities (`ceq`, item 60). The market value of equity is the product of the total number of common equity outstanding (`csho`, item 25) and the closing equity price at the end of the fiscal year (`prccf`, item 199):

$$Q = \frac{\texttt{csho} \cdot \texttt{prccf}}{\texttt{ceq}}$$

The above formulation of Tobin's Q is common in the literature (see, e.g., Gourio and Miao, 2010). The average Tobin's Q for physical capital serves as a proxy for the marginal product of capital, providing insights into future firm-level investment opportunities. Given the importance of investment opportunity in our analysis, we also explore an alternative measure of Tobin's Q. Following Almeida and Campello (2007). Tobin's Q is computed as

$$Q = \frac{\texttt{csho} \cdot \texttt{prcc} + \texttt{at} - \texttt{ceq} - \texttt{txdb}}{\texttt{at}},$$

where `txdb` refers to deferred taxes (item 74), the book value of equity is the sum of `ceq` and `txdb`, and close price (`prcc`, item 24).

4. Sales variable is computed as the ratio of lagged sales (`sale`, item 12) to lagged total assets. It serves as an additional measure of firm-level opportunity, which is needed to address concerns about measurement error in Tobin's Q.

5. Cash holdings (liquidity) are calculated as the sum of lagged cash and short-term investment (`che`, item 1), normalized by lagged total assets. Cash is the sum of

currency, deposits and cash equivalents (commercial paper that is near maturity). Short-term investments is the sum of trading, held-to-maturity and available-for-sale securities that will be sold within one year. The model counterpart of liquidity is $\mathbb{1}_{(b_t<0)}b_t$.

6. Firm size is measured as the log of lagged total assets.

7. Firm age is the number of years since a firm enters the sample. We take the log of lagged firm age.

8. Earnings are computed as the first lag of operating income before depreciation (`oibdp`, item 13) divided by the second lag of total assets. Operating income is also used as a measure of the marginal product of capital. The variable `oibdp` is obtained as sales minus operating costs. Operating costs consist of the cost of goods sold (`cogs`, item 41) and selling, general and administrative expense (`xsga`, item 189). In the literature, earnings refers to (a) earnings before interest, taxes, depreciation and amortization (*EBITDA*), and (b) earnings before interest and taxes (*EBIT*). In the model, operating surplus is
$$EBITDA = \frac{\Pi_t}{k_t + \mathbb{1}_{(b_t<0)}b_t}.$$

9. Operating cash-flow (surplus) is measured as the first lag of operating income before depreciation (`oibdp`, item 13) minus lagged interest expenses (`xint`, item 15) and minus lagged income taxes (`txt`, item 16), all divided by the second lag of total assets:
$$CF = \frac{\texttt{oibdp} - \texttt{xint} - \texttt{txt}}{\texttt{at}}.$$
The numerator of this metric is equivalent to the sum of income before extraordinary items (`ib`, item 18) and depreciation and amortization (`dp`, item 14). The model counterpart of operating surplus is
$$CF = \frac{y_t - w_t n_t - \tau_t^{income}}{k_t + \mathbb{1}_{(b_t<0)}b_t}.$$

10. Dividends are measured as the sum of preferred dividends (`dvp`, item 19) and common dividends (`dvc`, item 21).

11. Equity repurchases are defined as purchase of common and preferred stock (`prstkc`, item 115).

12. Equity issuance is defined as sale of common and preferred stocks (`sstk`, item 108).

13. Book leverage is measured as

$$lev^b = \frac{\texttt{dltt} + \texttt{dlc}}{\texttt{dltt} + \texttt{dlc} + \texttt{ceq}},$$

where long-term debt refers to `dltt` (item 9), while debt in current liabilities is `dlc` (item 34).

14. Market leverage is measured as

$$lev^m = \frac{\texttt{dltt} + \texttt{dlc}}{\texttt{dltt} + \texttt{dlc} + \texttt{mkt}}.$$

15. Net leverage is measured as

$$lev^n = \frac{\texttt{dltt} + \texttt{dlc} - \texttt{che}}{\texttt{dltt} + \texttt{dlc} + \texttt{ceq}}.$$

Investment-to-earnings ratio is defined as

$$\frac{gross\ inv}{gross\ CF} = \frac{\texttt{capx}}{\texttt{oibdp} - \texttt{xint} - \texttt{xtxt}}, \text{ and}$$

$$\frac{net\ inv}{net\ CF} = \frac{\texttt{capx} - \delta \cdot \texttt{ppegt}}{\texttt{oibdp} - \texttt{xint} - \texttt{xtxt} - \delta \cdot \texttt{ppegt}}.$$

Sample Selection for Firm-level Variables

1. Sector criterion. We exclude firms from the following sectors: finance, insurance and real estate ($\texttt{sic} \in [6000, 6999]$), utility ($\texttt{sic} \in [4900, 4949]$). Since these sectors face additional government regulations, they may have different investment behaviour than that of non-excluded firms. For instance, decisions of financial firms are affected by capital adequacy regulations that are irrelevant for nonfinancial public firms.

2. Firm-origin criterion. We consider firms incorporated in the United States (`fic=="USA"`).

3. We drop firm-year observations that satisfy one of the following criteria:

    (a) Negative and missing value of capital, total assets, sales, stock price, outstanding common shares, book value of shares;

    (b) Observations with gross capital less than $5 million and total assets less than $1 million in order to avoid rounding errors;

    (c) Acquisitions (`aqc`, item 129) larger than 5% of total assets;

    (d) Less than a 5-year old firm since the firm entered the sample;

    (e) Growth rate of real sales beyond -1 and 1.

Transformation of Firm-level Variables

1. Deflated using the BLS implicit price deflator;

2. Winsorized using the fifth and ninety-fifth percentiles as thresholds in order to reduce the impact of outliers. Following Crouzet and Eberly (2019), we control for missing observation before winsorization.

Aggregate-level Variables

Aggregate data for the US economy is obtained from the FFA accounts and NIPA through FRED. We consider the following variables: aggregate investment is defined as private nonresidential fixed investment (`PNFI`); implicit price deflator (`A008RD3Q086SBEA`); real gross domestic product (`GDPC1`); unemployment rate (`UNRATE`); implicit price deflator for all employed persons (`IPDNBS`); consumer price index for all urban consumers (`CPIAUCSL`); CBOE Volatility Index (`VIXCLS`); Federal funds effective rate (`FEDFUNDS`); Market Yield on U.S. Treasury Securities at 3-Month Constant Maturity (`DGS3MO`); Market Yield on U.S. Treasury Securities at 1-Year Constant Maturity (`DGS1`); Market Yield on U.S. Treasury Securities at 5-Year Constant Maturity (`DGS5`); Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity (`DGS10`).

Real Constraints

Irreversibility suggests that PPEs are specific to the firm, and thus may have only little value to some other firms. Consequently, resale prices could be significantly below its replacement costs, i.e. most of capital expenditure is sunk. We consider two common measures of irreversible investment in the literature. The irreversibility dummy takes a value of one if the firm's capital intensity ratio cir is above the median cir of two-digit NAICS industry. In the spirit of Chirinko and Schaller (2009), an irreversible asset is assigned one if the depreciation rate is below the median depreciation rate of the industry.

$$\text{capital intensity ratio}: \ cir = \begin{cases} 1 & \text{if} \ \ \frac{capital}{assets} \geq median_{ind}(\frac{capital}{assets}) \\ 0 & \text{o.w.} \end{cases}$$

$$\text{Chirinko and Schaller (2009)}: \quad cir = \begin{cases} 1 & \text{if} \quad deprec < median_{ind}(deprec) \\ 0 & \text{o.w.} \end{cases}$$

Financial Constraint

The rational behind using firm size as a good observable measure of financial constraint is that small firms are typically young, less well known, and thus more vulnerable to capital market imperfections. The KZ-index is a relative measurement of reliance on external financing. Companies with higher KZ-index scores are more likely to experience difficulties when financial conditions tighten, as they may have difficulties in financing their ongoing operations.

$$KZindex = -1.001909 \times CF + 0.2826389 \times Q + 3.139193 \times lev^n$$
$$-39.3678 \times div - 1.314759 \times CH$$

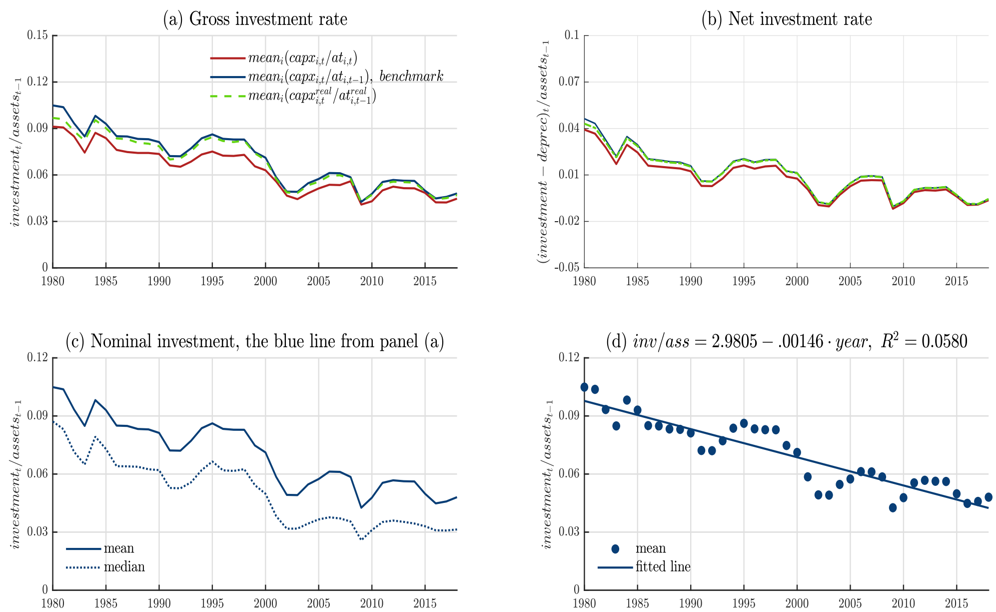
where CF is cash flow, Q is Tobin's Q, lev^n is net leverage, div is total dividends, CH is cash holdings.

$$WWindex = -0.091 \times CF - 0.062 \times div + 0.021 \times totlev$$
$$-0.044 \times size + 0.102 \times med_{ind}(sales) - 0.035 \times realsalegrowth$$

where CF is cash flow, div is an indicator that takes one if the firm pays dividends, $totlev$ is book leverage, $size$ is the log of total assets, $med_{ind}(sales)$ is two-digit industry sales growth.

B: Alternative Measures of the Investment Rate

Figure 2.10: Measures of aggregated firm-level capital investment, 1980-2018



Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to the book value of total assets (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Depreciation is obtained as a multiplication between depreciation rate and gross PPE. Variables are deflated by inflation price deflator. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities; U.S. Bureau of Economic Analysis (BEA).

Figure 2.10, Panel (a) is useful for two purposes: (1) to check whether the downward trend in the investment rate of the average firm persists even after considering alternative measures of the investment rate; (2) to evaluate the influence of assets on the investment rate over time. The benchmark investment rate is colored blue, while counterfactuals include red line and green dashed line. The green line is the real counterpart of the investment rate. A small deviation of the green line from the blue line refers to a relatively stable inflation rate over the observed sample period. Relative to the blue line, the red line presents a decrease in the investment rate for a given capital expenditure. This implies that total assets increased from period $t-1$ to t. The gap between the red line and the blue line is mostly pronounced in the first half of the sample. The gap could indicate the importance of the financial position of the average firm in transmitting the influence of the uncertainty measure on the investment rate.[60]

Figure 2.10, Panel (b) presents a small gap between the gross and net investment rates over the 1980-2018 period. This observation reduces concerns that a high depreciation rate may quickly dimish capital stocks (see Gutiérrez and Philippon, 2016 for similar observation).

In Figure 2.10, Panel (c) we compare the mean and median values of the aggregated investment rate to address concerns that the trend in investment is driven by a few but very large firms due to positive skewness of the investment distribution. There is no major difference between the mean and median value of aggregated investment, implying that there are no large outliers in our sample, and thus there is no serious skewness of investment distribution. However, Figure 2.17 and Figure 2.19 show that we still need a quantile regression analysis of the investment-uncertainty relationship.

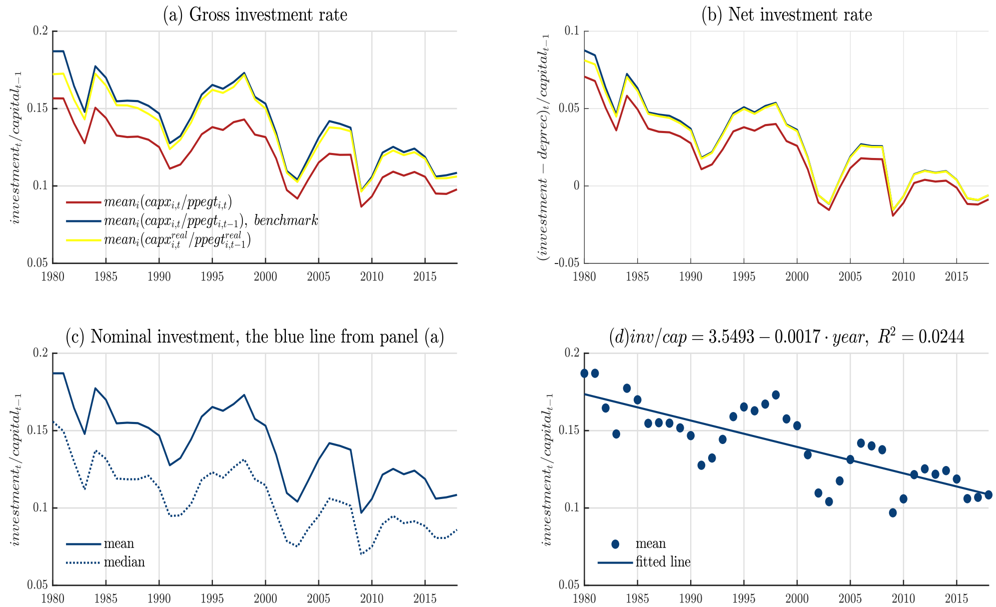
In Figure 2.10, Panel (d) we estimate a simple regression of the investment-asset ratio on a constant and time trend in order to confirm the presence of a statistically significant trend in the investment rate. Such simple regressions are only useful to characterize the evolution of investment during the sample period. It also indicates that we should include year fixed-effects to control for time variation in the investment rate. The coefficient of the time trend for the average investment rate corresponds to a yearly decrease of 0.15%, which is statistically significant. The R-squared of the regression is around 6%.

Figure 2.11 presents a downward trend in the investment-capital ratio, mirroring the trend observed in the investment-asset ratio from Figure 2.10.

While Figure 2.10 shows the evolution of the average investment ratio, Figure 2.12 (red dashed line) shows the evolution of average investment ratio weighted by assets. When considering the aggregate investment to aggregate assets, the decreasing trend persists. Fig-

[60] The importance of financial position of firms for the investment rate, particularly liquidity as a non-investment component of assets, is depicted in Figure 2.12 and Figure 2.22 (Panel (b) and Panel (c)).

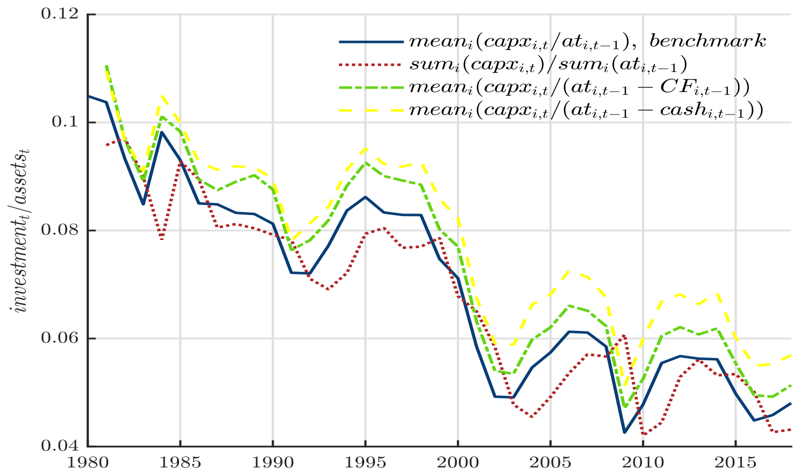
Figure 2.11: Measures of aggregated firm-level capital investment, 1980-2018



Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to gross property, plant and equipment (`ppegt`, item 7). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Depreciation is obtained as a multiplication between the depreciation rate and gross PPE. Variables are deflated by inflation price deflator. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities; U.S. Bureau of Economic Analysis (BEA).

ure 2.12 shows that cash holdings has the strongest impact on the investment rate. Green and yellow lines include counterfactual exercises in which we isolate a component of assets that is not affected by liquidity measures (cash-flow and cash holdings). We then check the impact of residual assets on the investment rate. These exercises provide the initial indication of the importance of liquidity measures in determining the strength of the indirect channel of uncertainty on investment. We partial out the impact of liquidity measures on the investment-uncertainty relationship in Appendix G.

Figure 2.12: Alternative measures of aggregated investment rate, 1980-2018



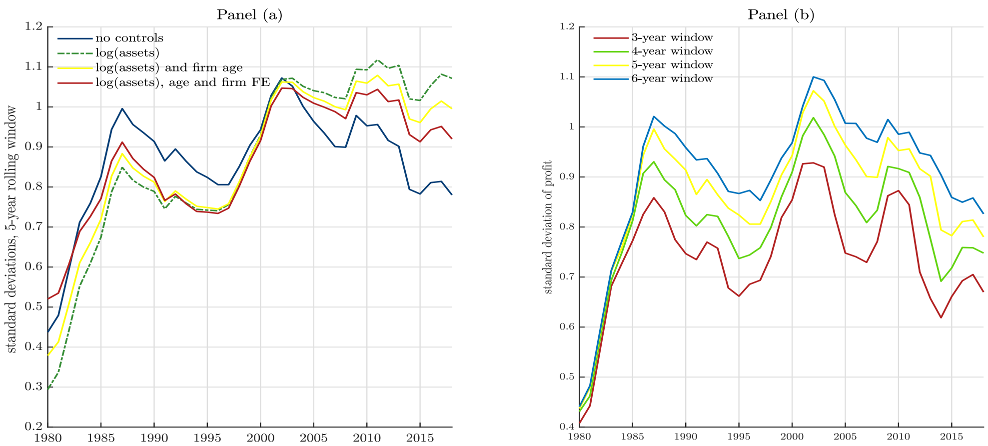
Notes: The investment rate is defined as gross capital expenditure (`capx`, item 128) to gross property, plant and equipment (`at`, item 6). Capital expenditure involves investment in tangible capital stock, including property, plant and equipment (PPE). Cash-flow (CF) is measured as operating income before depreciation (`oibdp`, item 13) minus interest expenses (`xint`, item 15) and minus income taxes (`txt`, item 16), divided by total assets. Cash holdings is defined as the sum of lagged cash and short-term investment (`che`, item 1) divided by total assets. Variables are also winsorized. Data source: U.S. Compustat Annual, excluding financial companies and utilities.

C: Uncertainty Measure

We focus on a lagged measure of uncertainty to alleviate concerns about a reverse impact of investment behavior on profit volatility. This approach is also applied by Kermani and Ma (2023) and Ottonello and Winberry (2020). In computing the time-series measure of uncertainty, we exclude the average growth rate for the firm in the window. This allows us to control for firm-specific aspects that affect profit growth rates.

A potential concern about the profit volatility is that its upward trend is the result of changes in the composition of the firm sample over time. Under this scenario, the upward trend in firm specific uncertainty could be simply driven by a larger share of smaller and younger firms, whose profits are by construction more volatile. To address this issue, we perform several robustness checks to ensure that there is no composition bias. Our task is to isolate a component of volatility that is not explained by demographic factors (size and

Figure 2.13: Measures of aggregated firm-level uncertainty, 1980-2018



Notes: Construction of uncertainty measure is provided in Appendix A. Variables are winsorized.

Data source: U.S. Compustat Annual, excluding financial companies and utilities.

age), and then check movements in residual uncertainty. Figure 2.13, Panel (a) illustrates the upward trend in profit volatility. Up to 2002, factors including size (measured by assets), age and firm FE (fixed effects) have a positive impact on profit volatility. Relatively larger and older firms took more risky projects and pushed up the average uncertainty until 2002. Afterwards, the internet boom opened the space for a much larger number of small and young firms to enter the market. Panel (b) of Figure 2.13 presents uncertainty measures over different time windows.

D: Baseline Regression Results and Extensive Margin

The results from Table 2.9 support the literature finding that firm-level uncertainty has negative effects on *average* fixed capital investment.

All OLS estimated variables from Table 2.9 have expected signs and are statistically significant. Specification (1) refers to the classic investment regression. It shows a larger impact of the persistent demand for firm's output than average Tobin's Q. This result is common in the literature. Specification (2) highlights strong and negative effects of profit volatility on the investment rate, *ceteris paribus*. Year fixed-effects from Specification (3) have quite similar results of an investment-uncertainty relationship to the one with the real interest rate and real GDP growth rate from Specification (6). In Specification (4), larger and older firms tend to decrease investment relatively more than other firms as they are less productive. Results of our baseline model are presented in Specification (5). It implies that a one-SD(1.3565) increase in profit volatility leads to a 0.5917%(=1.3565 × 0.0044) decrease in the average investment rate. Beside its statistical significance, the estimated coefficient is also economically significant. Given the unconditional mean annual investment rate of 7.07%, this is a decline of 6.22%(=-0.0044/0.0707) per year. The literature's findings on the impact of firm-level uncertainty on the investment rate fall in the range of 0.38% and 0.96% (see e.g., Alfaro et al., 2024; Liu and Wang, 2021; Panousi and Papanikolaou, 2012; Baum et al., 2008; Leahy and Whited, 1996). Although the results from Table 2.9 are not directly comparable to the literature due to different uncertainty measures and empirical frameworks, they could still give an indication of how firm-level uncertainty affects the investment rate.

Specification (5) of Table 2.9 shows that controlling for cash holdings does not alter the impact of uncertainty on investment. That is, the impact of profit volatility on investment is the first order relevant compared to its indirect impact on investment through average cash holdings. We also quantify the impact of the profit volatility on investment for different levels of cash holdings. In addition to a continuous measure of cash holdings expressed in levels, we introduce a discrete measure of cash holdings.[61] Results of additional analyses are presented in Table 2.12. The estimated coefficients imply that the negative impact of volatility on investment is much weaker with higher cash holdings.

[61] Note that the discrete measure is sensitive to the choice of an exogenous threshold.

Table 2.9: Fixed-effects regression estimates

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)
vol(profit)		-0.0047***	-0.0039***	-0.0044***	-0.0044***	-0.0039***
		(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
mkt/book	0.0070***	0.0066***	0.0075***	0.0072***	0.0071***	0.0075***
	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
sale/asset	0.0265***	0.0263***	0.0163***	0.0127***	0.0135***	0.0188***
	(0.0012)	(0.0012)	(0.0010)	(0.0011)	(0.0011)	(0.0011)
cash/asset					0.0160***	0.0188***
					(0.0032)	(0.0031)
size				-0.0074***	-0.0071***	
				(0.0007)	(0.0007)	
age				-0.0037***	-0.0037***	
				(0.0007)	(0.0007)	
r10yTCMR						0.0028***
						(0.0001)
RGDPgrowth						0.1185***
						(0.0100)
Num. of obs.	81076	81076	81076	81076	81070	81070
R-sq(within)	0.0674	0.0771	0.1564	0.1639	0.1647	0.1403
Num. of firms	7178	7178	7178	7178	7178	7178
Firm FE	yes	yes	yes	yes	yes	yes
Year FE	no	no	yes	yes	yes	no

Table 2.9 presents OLS estimation results from regression model (1). The sample contains Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual investment in PPE, while $vol(profit)_{i,t-1}$ is the key independent variable related to the annual standard deviation of profit growth over the recent five years. Size is the natural logarithm of total assets, age is number of years since a firm enters the sample, and $r10yTCMR$ is 10-year real Treasury constant maturity rates. Time FE is not reported in Table 2.9, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Extensive Margin Investment Decisions

The average investment rate (i_t) is the weighted sum of investment spike (i_t^s) and nonspike (i_t^{ns}):

$$E[i_t] = E[\gamma_t \cdot i_t^s] \;+\; E[(1-\gamma_t) \cdot i_t^{ns}]$$

The fraction of firms with investment spike is denoted by γ_t. Investment spike refers to an investment rate that exceeds 20%. We know that $E[\gamma_t \cdot i_t^s] = E[\gamma_t] \cdot E[i_t^s] + cov(\gamma_t, i_t^s)$. Using the linearity of expectation, $E[(1-\gamma_t)i_t^{ns}] = E[i_t^{ns}] - E[\gamma_t i_t^{ns}]$, and substituting in $E[\gamma_t i_t^{ns}] = E[\gamma_t]E[i_t^{ns}] + cov(\gamma_t, i_t^{ns})$, we obtain $E[(1-\gamma_t)i_t^{ns}] = E[i_t^{ns}] - (E[\gamma_t]E[i_t^{ns}] + cov(\gamma_t, i_t^{ns}))$. Finally, the average investment rate is expressed as

$$E[i_t] = E[\gamma_t] \cdot E[i_t^s] + cov(\gamma_t, i_t^s) + (1 - E[\gamma_t]) \cdot E[i_t^{ns}] - cov(\gamma_t, i_t^{ns})$$

Differentiating the above expression with respect to uncertainty:

$$\begin{aligned}\frac{\partial E[i_t]}{\partial \sigma_t} &= \underbrace{E[\gamma_t]\frac{\partial E[i_t^s]}{\partial \sigma_t} + (1-E[\gamma_t]) \cdot \frac{\partial E[i_t^{ns}]}{\partial \sigma_t}}_{\text{intensive margin}} \\ &\quad + \underbrace{\frac{\partial E[\gamma_t]}{\partial \sigma_t}\Big(E[i_t^s] - E[i_t^{ns}]\Big) + \frac{\partial cov(\gamma_t, i_t^s)}{\partial \sigma_t} - \frac{\partial cov(\gamma_t, i_t^{ns})}{\partial \sigma_t}}_{\text{extensive margin}}\end{aligned}$$

Two covariance terms are excluded from the analysis as they have a negligible contribution.

E: Financial and Real Frictions

Impact of Frictions

In this section we focus on quantifying the impact of two frictions on the investment-uncertainty relationship. On one hand, it is costly to borrow external funds, either in the equity market from shareholders or in the capital market. Equity financial costs include flotation costs, such as commissions paid to brokers, legal fees and accounting costs. Firms also have limited access to borrowing due to collateral in capital markets. On the other hand, firms cannot easily sell previously acquired capital goods due to their specificity. Installing a new production line requires high planning costs, installation costs, and costs related to learning new production process, which cannot be recovered if a project fails.

We test whether the negative relationship between profit volatility and investment is stronger for financially constrained firms and those with irreversible assets through two steps. First, following Fazzari et al. (1988) we use a dividend-to-profit ratio as an ex-ante indicator to determine the degree of financial constraint that firms face. Firms are sorted into financially constrained if they spend less than 20% of their profits on dividends. Second, equation (2.1) is estimated separately for the financially constrained and unconstrained groups of firms. We conduct a similar procedure for exploring the influence of the real constraint on investment. Capital intensity ratio serves as our benchmark proxy for investment irreversibility. The assumption is that the more tangible ratio of fixed investment to total assets, the more difficult it is to recover net property, plant and equipment relative to intangible capital.

Results from Table 2.10 illustrate how the investment-uncertainty relationship varies with the level of financial constraints and the degree of irreversible investment. Specifically, increasing dividends above a threshold or decreasing the tangibility of capital below a threshold amplifies both the negative effects of the profit volatility on investment and the positive effects of cash reserves on investment. This suggests that dividends and reversible capital may serve as a buffer against adverse profit shocks.

Results from Columns (4) and (5) are consistent with the real options theory (Dixit and Pindyck, 1994), which predicts that firms with more tangible investment optimally choose to postpone investment in the face of higher uncertainty.[62]

[62] The role of irrevesibility is empirically documented in Panousi and Papanikolaou (2012), Bulan (2005), Leahy and Whited (1996), among many others. Real option theory predicts that increased uncertainty raises the option value of waiting to invest in new projects more than it raises expected marginal profit, which leads to the higher investment threshold and reduced current investment. Accordingly, the investment decisions of the firm requires involving the costs related to the ability to reverse projects in the future.

Table 2.10: Effects of uncertainty and frictions

investment/asset	(1)	(2)	(3)	(4)	(5)
vol(profit)	-0.0044^{***}	-0.0045^{***}	-0.0014	-0.0063^{***}	-0.0028^{***}
	(0.0003)	(0.0003)	(0.0010)	(0.0004)	(0.0003)
mkt/book	0.0071^{***}	0.0075^{***}	0.0040^{***}	0.0094^{***}	0.0052^{***}
	(0.0002)	(0.0003)	(0.0006)	(0.0004)	(0.0003)
sale/asset	0.0135^{***}	0.0127^{***}	0.0203^{***}	0.0170^{***}	0.0099^{***}
	(0.0011)	(0.0011)	(0.0033)	(0.0019)	(0.0012)
cash/asset	0.0160^{***}	0.0183^{***}	0.0125^{*}	0.0452^{***}	0.0126^{***}
	(0.0032)	(0.0033)	(0.0073)	(0.0061)	(0.0033)
size	-0.0071^{***}	-0.0073^{***}	-0.0038^{*}	-0.0094^{***}	-0.0067^{***}
	(0.0007)	(0.0007)	(0.0022)	(0.0012)	(0.0007)
age	-0.0037^{***}	-0.0039^{***}	0.0007	-0.0069^{***}	-0.0016^{**}
	(0.0007)	(0.0008)	(0.0029)	(0.0013)	(0.0007)
Sample	all	dpr ≤ 0.20	dpr > 0.20	$cir > med(cir)$	$cir \leq med(cir)$
R-sq(within)	0.1647	0.1686	0.1079	0.1788	0.1291
Num. of obs.	81070	71218	9796	40533	40537
Firm FE	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes

Table 2.10, Column (1) presents our benchmark OLS regression results from model (1). Columns (2) and (3) determine the impacts of financial frictions. Columns (4) and (5) determine the impacts of real frictions. The sample contains Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual investment in PPE, while $vol(profit)_{i,t-1}$ is the key independent variable related to the annual standard deviation of profit growth over the recent five years. Capital intensity ratio $cir_{i,t-1} = \texttt{ppent}_{i,t-1}/\texttt{at}_{i,t-1}$ is the lagged net property, plant and equipment normalized by lagged total assets. Irreversibility dummy takes a value of one if firms' *cir* is above the median *cir* of two-digit NAICS industry, and such firms have irreversible investment. Financial friction is determined by dividend-to-profit ratio $dpr_{i,t-1} = (\texttt{dvp}_{i,t-1} + \texttt{dvc}_{i,t-1})/\texttt{oibdp}_{i,t-1}$ is the lagged total dividends normalized by lagged operating profit. Robust standard errors presented in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, **=10%.

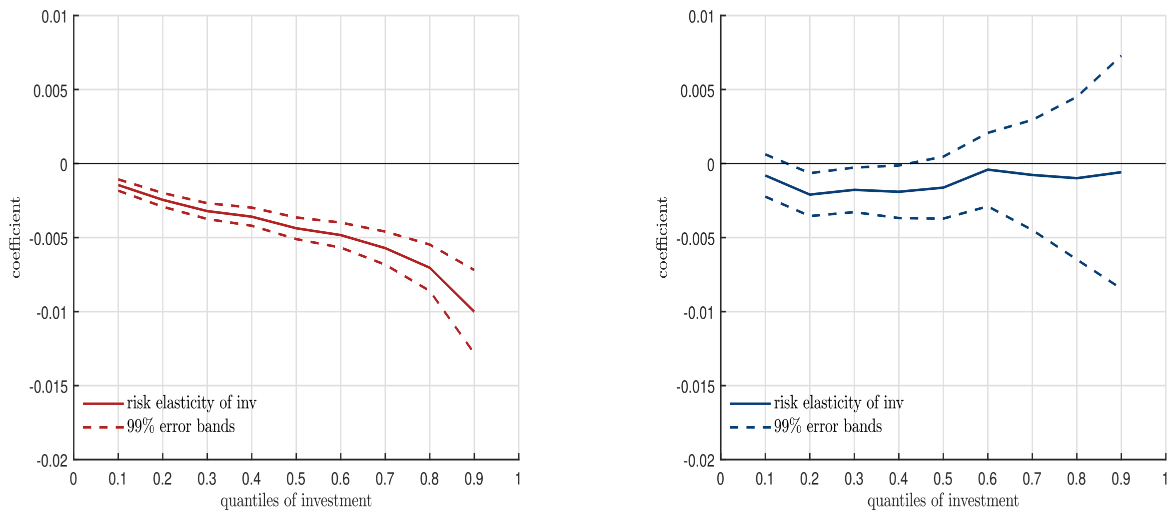
Heterogenous Impact of Frictions

Figure 2.14 shows that the impact of profit volatility on investment increases with the level of investment among constrained firms (see Panel a). The costs of cutting investment, in terms of foregone returns, become smaller at higher investment relative to the costs of external funds.[63] As for unconstrained firms, the impact of idiosyncratic uncertainty on investment

[63]This theoretical argument implicitly assumes that firms operate a DRTS technology, a common assumption

is marginally significant at low levels of investment (see Panel b). That is, uncertainty shocks strongly affect firms operating around the dividend threshold. Although the dividend threshold is exogenous, we find a robust result when other measures of financial friction are considered (see estimates below).

Figure 2.14: Financial frictions and levels of investment



(a) fin constrained: $dpr \leq 0.2$ (b) fin unconstrained: $dpr > 0.2$

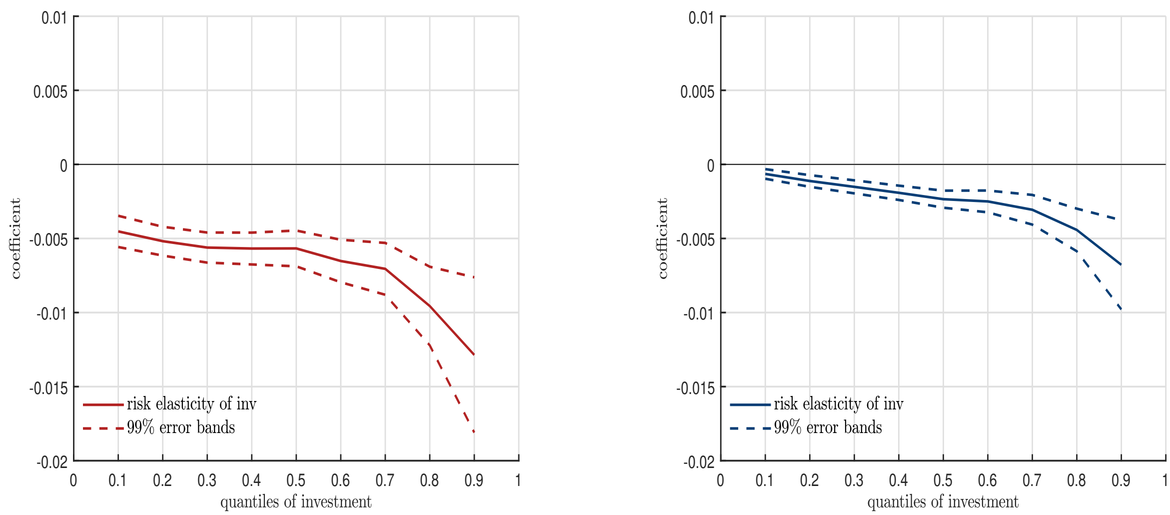
Figure 2.14 plots the responsiveness of investment to profit volatility at different investment quantiles for the two financial groups of firms. Dividend-to-profit ratio $dpr_{i,t-1} = (\texttt{dvp}_{i,t-1} + \texttt{dvc}_{i,t-1})/\texttt{oibdp}_{i,t-1}$ is the lagged total dividends normalized by lagged operating profit. Financial dummy takes a value of one if firms spend less than 20% of their profits on dividends, and such firms are classified as financially constrained.

In Panel (a) of Figure 2.15, we observe that as the level of investment rises, the fixed costs of adjusting capital become larger than the marginal product of capital, resulting in a higher sensitivity of investment to uncertainty. Since firms simply do not like uncertainty about future profits because of the possibility to get stuck with an excessive stock of capital in the future, they are willing to delay investment in new investment projects (see Panel b). Figure 2.18 supports the negative relationship between investment and uncertainty when the

in the literature. Additionally, heightened uncertainty may increase the costs of external financing because more risky projects induce higher costs of evaluating projects, as empirically documented by Minton and Schrand (1999). External funds are costly due to a degree of asymmetric information between managers and the market about the true value of a firm. This capital market imperfection is more pronounced for small firms because they are less covered by the popular press.

depreciation rate is instead used as a proxy for real friction. Although the capital intensity ratio and depreciation levels are crude measures of real frictions, the regression results remain consistent with findings from previous studies (see e.g., Kermani and Ma, 2023 and Kim and Kung, 2017).

Figure 2.15: Real frictions and levels of investment



(a) irreversible inv: $cir > med(cir)$ (b) reversible inv: $cir \leq med(cir)$

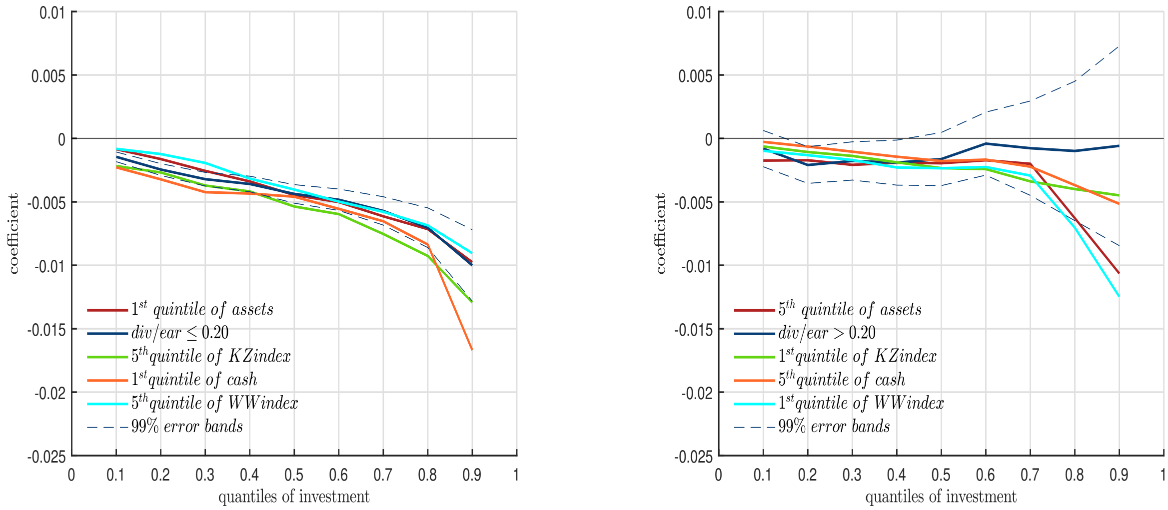
Figure 2.15 plots the responsiveness of investment to profit volatility at different investment quantiles for firms with (ir)reversible assets. Capital intensity ratio $cir_{i,t-1} = \texttt{ppent}_{i,t-1}/\texttt{at}_{i,t-1}$ is the lagged net property, plant and equipment normalized by lagged total assets. Irreversibility dummy takes a value of one if firms' cir is above the median cir of two-digit NAICS industry, and such firms have irreversible investment.

Robustness Checks on Frictions

We show the influence of increased firm-specific profit volatility on fixed investment conditional on various proxies of financial and real constraints. More specifically, we consider size measured by assets, KZ (Kaplan-Zingales) index, cash holdings, and WW (Whited-Wu) index as alternative proxies of financial constraint. Figure 2.16 and Figure 2.18 present robust responses of investment to increased uncertainty.

Figure 2.17 and Figure 2.19 plot the coefficient estimates on profit volatility at different investment quantiles, contingent on financial and real constraints, respectively. The estimated coefficients for the quantile regression (red line) vary largely at the tails of the investment distribution, diverging from those obtained using OLS regression (green line). Therefore,

Figure 2.16: Other measures of financial frictions

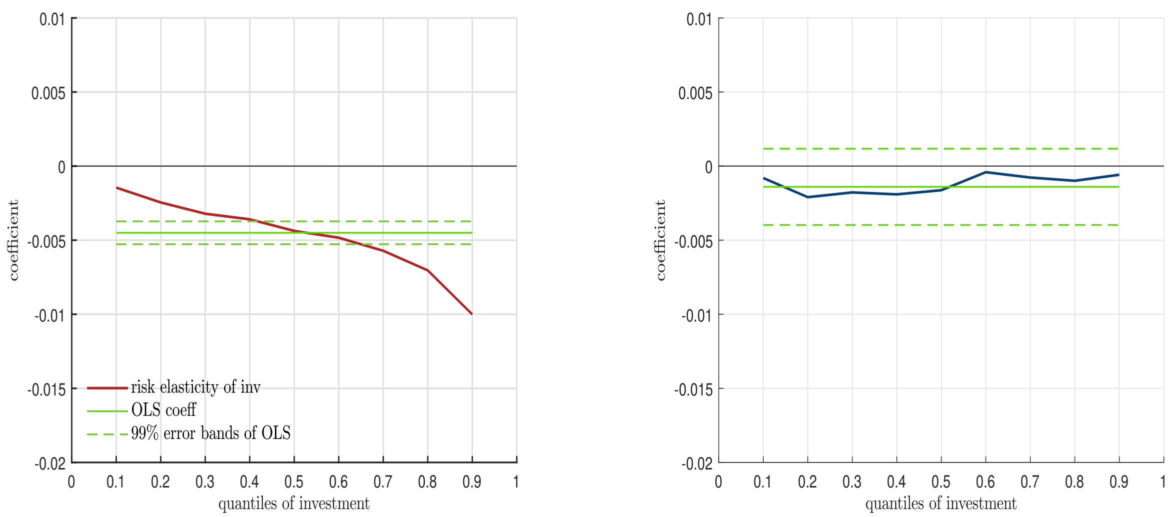


(a) fin constrained firms

(b) fin unconstrained firms

Note: Construction of the constraints is available in Appendix A.

Figure 2.17: Quantile regressions vs OLS regressions



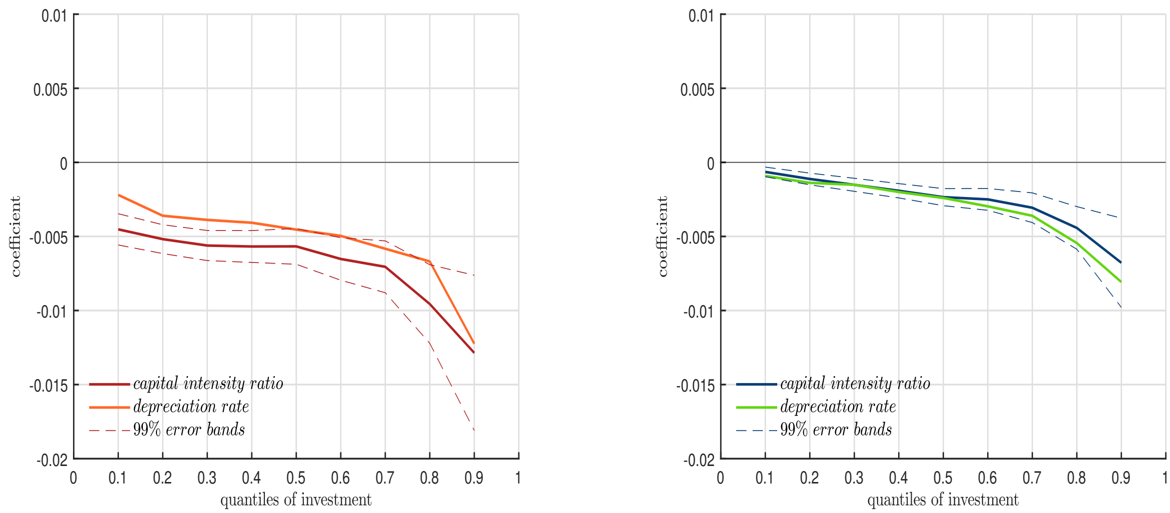
(a) fin constrained ($div/prof \leq 0.2$)

(b) fin unconstrained ($div/prof > 0.2$)

Note: Construction of the constraints is available in Appendix A. The OLS estimated coefficients are -0.0045 and -0.0014 for left and right Panel, respectively. We apply 300 bootstrap replications in computing Quantile Regression point estimates and standard errors.

the use of quantile regression is justified by showing that the estimated quantile regression coefficients lie outside the confidence intervals of OLS regression estimates.

Figure 2.18: Other measures of real frictions



(a) irreversible inv (b) reversible inv

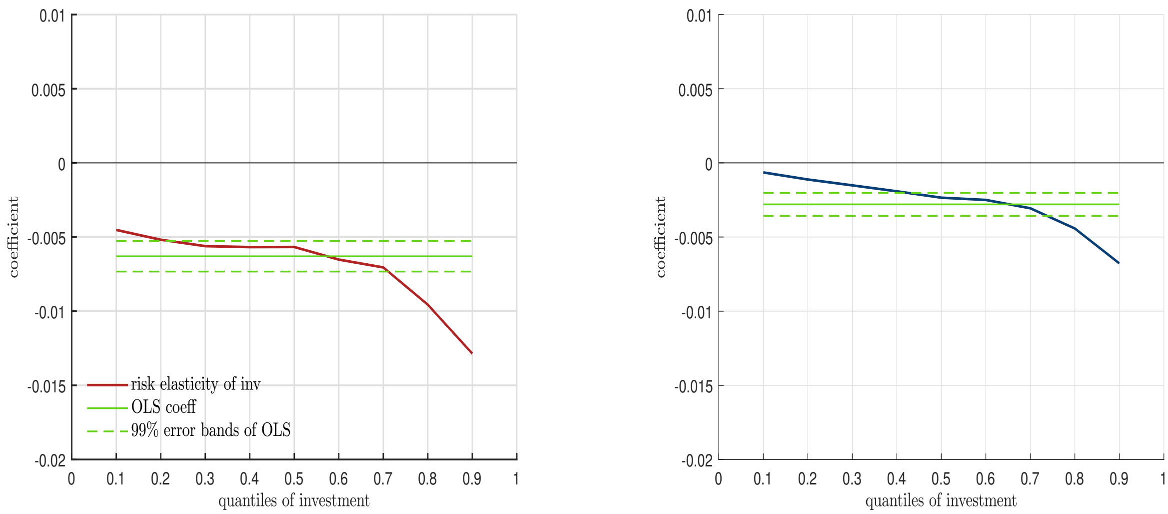
Note: Construction of the constraints is available in Appendix A.

F: Predictability of Profit Volatility

Our non-parametric estimates predict that when a firm faces increased uncertainty about profitability in the recent 5 years, the firm is likely to experience increased profit volatility in the subsequent year. Figure 2.20 shows that changes in profit volatility are predictable. The uncertainty pattern follows a persistent process as we expect any positive change to sustain in the future. This persistence implies a slow convergence to its historical averages, potentially due to higher capital market imperfections (asymmetric information problem) induced by higher uncertainty itself. Negative responses in profit volatility are rather small and statistically insignificant.

We estimate kernel regressions (2.17) and (2.18) such that we first partial out the effects of firm-specific and macro controls for investment opportunities and demographic factors on both current uncertainty and future uncertainty. Afterwards, we run a simple kernel regression of future uncertainty residuals on the current uncertainty residuals using an

Figure 2.19: Quantile regressions vs OLS regressions



(a) irreversible inv

(b) reversible inv

Note: Construction of the constraints is available in Appendix A. The OLS estimated coefficients are -0.0063 and -0.0028 for left and right panels, respectively. We apply 300 bootstrap replications in computing Quantile Regression point estimates and standard errors.

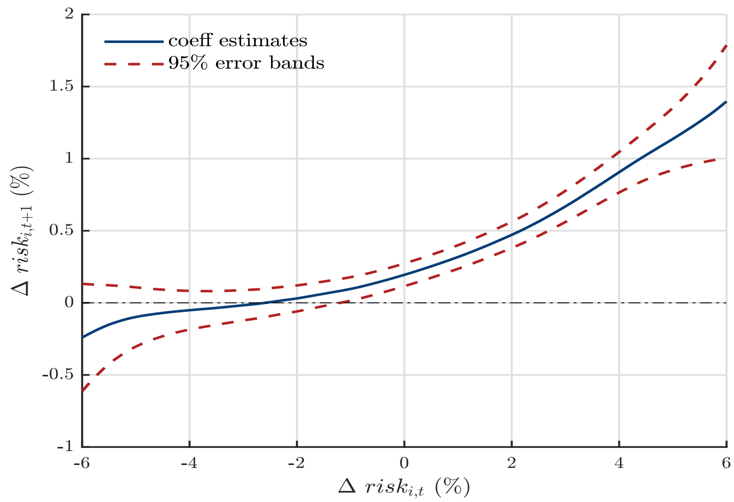
Epanechnikov kernel. Our procedure imposes linearity in the relationship between current uncertainty and controls or future uncertainty and controls while allowing the data to uncover any remaining nonlinearity between future and current uncertainty.

$$\sigma_{i,t+1} = \alpha + \beta' \cdot X_{i,t} + \gamma \cdot real\_10yTCMR_t + \theta \cdot rgdp\_gr_t + \epsilon_{i,t} \tag{2.17}$$

$$\sigma_{i,t} = \alpha + \beta' \cdot X_{i,t} + \gamma \cdot real\_10yTCMR_t + \theta \cdot rgdp\_gr_t + \epsilon_{i,t} \tag{2.18}$$

The vector of control variables includes market-to-book ratio, sale-to-asset ratio, cash-asset ratio, log(assets), log(age). Variable $real\_10yTCMR_t$ refers to real U.S. 10-year Treasury Constant Maturity Rate, while $rgdp\_gr_t$ implies real GDP growth rate.

Figure 2.20: Predictability of profit volatility in data

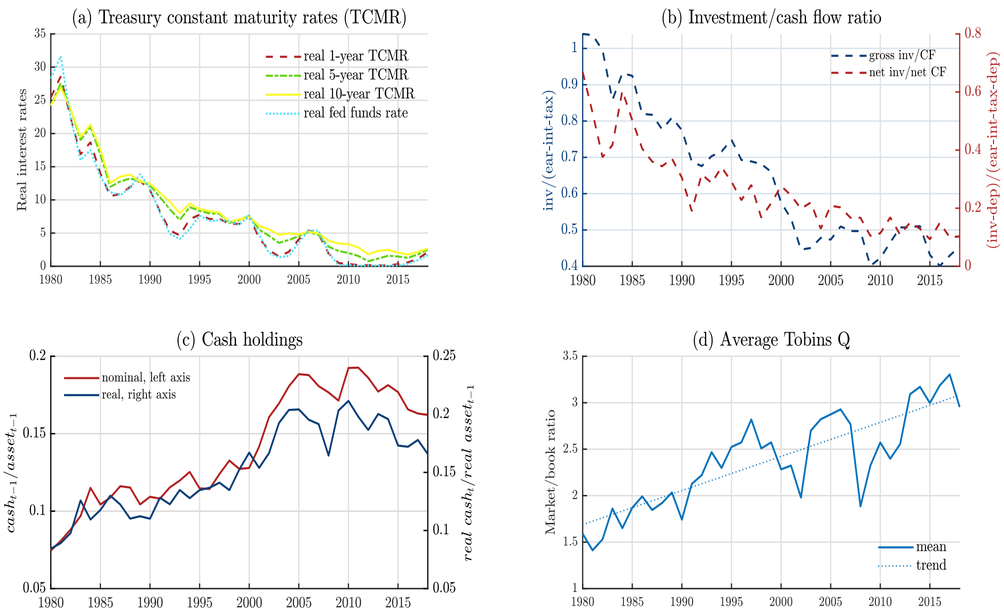


Notes: Variables $\Delta\sigma_{i,t} = \sigma_{i,t} - \sigma_{i,t-1}$ and $\Delta\sigma_{i,t+1} = \sigma_{i,t+1} - \sigma_{i,t}$. Periods $t-1$ and $t+1$ imply moving one year backward and forward, not moving 8 years backward and forward. The uncertainty measures are trimmed at 10% and 90%. Data source: U.S. Compustat Annual, excluding financial companies and utilities.

G: Traditional Drivers of the Investment Rate

This section investigates the traditional factors that could explain why firms underinvest, i.e. invest in capital below its first-best level. Figure 2.21, Panel (a) shows the evolution of real interest rates. To sustain capital market functionality, expansionary monetary policies steadily reduce real interest rates up to the zero lower bound in the last decade. The real 10-year government bond yield acts as a proxy for the real user cost of capital. However, a downward trend in capital investment implies that cheap and accessible financing provides a small direct stimulus to investment. One might think that capital expenditure is low due to a lack of internal funds. Panel (b) illustrates that this is not the case since the investment-cash flow ratio steadily falls due to a stronger rise in cash flow. Panel (c) reinforces this trend, revealing a strong increase in nominal and real cash holdings over the past four decades. Finally, weak investment opportunities imply that firms may not expect returns from expanding capital stock to exceed their risk-adjusted cost of capital. However, Panel (d) shows relatively high returns on capital via the average Tobin's Q, though it exhibits a highly cyclical pattern.

Figure 2.21: Interest rates, cash holdings and investment incentives, 1980-2018

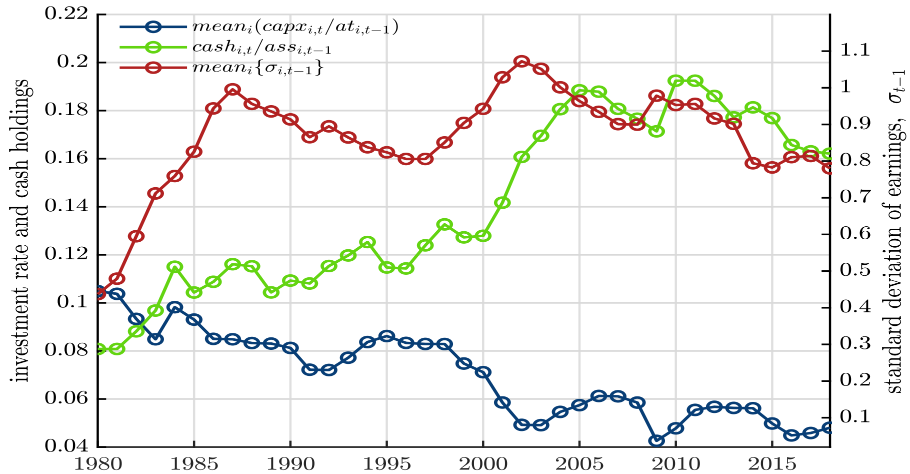


Note: Variables are deflated by BLS implicit price deflator. Data sources: U.S. Compustat Annual and BEA.

H: Capital Investment and Cash Holdings

Why did public firms in the US reduce capital investment and accumulate large cash? We claim that a large precautionary demand for cash holdings, induced by financial and real frictions, is the key reason. Different firms save for different reasons in anticipation of adverse profit shock realization. On the one hand, relatively younger and smaller firms increase cash holdings to avoid having to finance future investment with costly external equity. On the other hand, older and relatively larger firms save to avoid accumulating irreversible capital in the future as it induces large adjustments costs. Our previous Figure 2.13 shows that a rising trend in average uncertainty until 2002 is driven by larger firms. The strong drop in dividend taxes in 2003 could reduce their precautionary concerns, mitigating the rise in cash holdings and the reduction in capital expenditure.

Figure 2.22: Aggregated firm-specific investment, cash holdings and uncertainty



Note: Intertemporal behaviour of firms is important to understand the connections among capital investment, cash holdings and profit volatility. Data source: U.S. Compustat Annual.

Table 2.11: Pearson correlation

	inv_ass_{-1}	$sd(ear)_{-1}$	$cash\_ass_{-1}$
inv_ass_{-1}	1.0000		
$sd(ear)_{-1}$	-0.5669^{***}	1.0000	
$cash\_ass_{-1}$	-0.8876^{***}	0.5254^{***}	1.0000

Visual inspection of the data in Figure 2.22 and simple correlation analysis in Table 2.11 indicate a strong negative relationship between idiosyncratic uncertainty and investment among publicly-traded firms in the United States over the past four decades. Over the same period, large cash holdings is observed across firms, potentially contributing to capital underinvestment.

J: Importance of Cash Holdings for Investment

Cash holdings provide firms with financial flexibility to exploit future investment opportunities. In our sample, higher profit volatility induces firms to reduce current investment to finance future investment via cash holdings. Consequently, they gradually accumulate capital stock. Firms with low cash holdings are forced to reduce investment, while firms with high cash holdings could absorb increased uncertainty, and thus raise their capital expenditure. The opposite outcomes occur with cash-flow.

Table 2.12 presents several specifications, with Specification (1) serving as our benchmark. It shows that higher profit volatility leads to lower capital expenditure, regardless of cash levels. In Specification (2), the coefficient on uncertainty represents the negative effect of uncertainty on investment when cash holdings are at their mean level. The coefficient on the interaction term indicates that firms with more than average cash holdings respond by increasing investment. The net effect of uncertainty on investment, net effect $= -0.0057 + 0.0079 \cdot cash/ass$, indicates that for firms with cash larger than 72% of total assets the interaction term exceeds the direct negative effect, making the net effect positive. In Specification (3), the negative effects of uncertainty on investment are also largely mitigated with higher cash holdings when considering a discrete measure of cash holdings (CH). Squared cash holdings (CH^2) in Specification (4) control for a potential non-linear relationship between investment and CH. On average, there is a hump-shaped relationship between investment and cash, with a turning point at 32%. Firms probably decide to payout dividends because of the high opportunity costs of holding large cash reserves. More leveraged firms in Specification (5) reduce investment on average. In Specification (6), firms with more cash flow decrease investments in the face of higher profit uncertainty, which is consistent with findings from Minton and Schrand (1999).

Table 2.12: Investment, uncertainty and cash holdings

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)
vol(profit)	-0.0044^{***}	-0.0057^{***}	-0.0052^{***}	-0.0059^{***}	-0.0052^{***}	-0.0028^{***}
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
LCH			-0.0043^{***}			
			(0.0007)			
HCH			-0.0001			
			(0.0008)			
vol(profit) × LCH			-0.0004			
			(0.0004)			
vol(profit) × HCH			$.0025^{***}$			
			(0.0004)			
cash/ass	0.0160^{***}	0.0013		0.0471^{***}	-0.0722^{***}	
	(0.0032)	(0.0032)		(0.0055)	(0.0046)	
vol(profit) × cash/ass		0.0079^{***}		0.0090^{***}	0.0069^{***}	
		(0.0010)		(0.0010)	(0.0010)	
$(cash/ass)^2$				-0.0851^{***}		
				(0.0079)		
leverage					-0.0701^{***}	
					(0.0032)	
CF/ass						0.1123^{***}
						(0.0072)
vol(profit) × CF						-0.0167^{***}
						(0.0019)
R-sq(within)	0.1647	0.1655	0.1668	0.1680	0.1825	0.1818
Num. of obs.	81070	81070	81076	81070	80802	77219
Num. of firms	7178	7178	7178	7178	7171	7086
Controls	yes	yes	yes	yes	yes	yes
Firm FE	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes

Table 2.12 reports the indirect effects of uncertainty measure on the investment rate via cash holdings. The sample is Compustat firms from 1980 to 2018. Dependent variable $inv_{i,t}/asset_{i,t-1}$ is annual capital expenditure, and $vol(profit)_{i,t-1}$ is the annual standard deviation of profit growth over the recent five years. Control variables, which include $mkt_{i,t-1}/book_{i,t-1}$ and $sale_{i,t-1}/asset_{i,t-1}$, $ln(asset)_{i,t-1}$ and $ln(age)_{i,t-1}$, are significant and have predicted signs. LCH is the lowest (1-3) decile of $cash_{i,t-1}/asset_{i,t-1}$. Cash-flow is computed as CF=profit-interest expenses-income taxes. The turning point for cash holding is -(0.0549/(2*(-0.0851))=0.32. Robust standard errors presented in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

K: Additional Robustness Checks

Table 2.13: Fixed capital investment and firm-level uncertainty

	(1) inv/ass	(2) inv	(3) inv/ass2	(4) inv/cap	(5) inv/ass	(6) inv/ass	(7) inv/ass
vol(profit)	-0.0044***	-2.3266***	-0.0043***	-0.0167***	-0.0038***	-0.0015***	-0.0014***
	(0.0003)	(0.3692)	(0.0003)	(0.0009)	(0.0003)	(0.0003)	(0.0003)
mkt/book	0.0071***	0.0958***	0.0067***	0.0260***		0.0044***	0.0056***
	(0.0002)	(0.0376)	(0.0002)	(0.0007)		(0.0003)	(0.0003)
sale/ass	0.0135***	1.0816***	0.0141***		0.0116***	0.0066***	0.0045***
	(0.0011)	(0.2034)	(0.0011)		(0.0011)	(0.0011)	(0.0012)
cash/ass	0.0160***	2.6179***	0.0193***		0.0009	0.0072**	-0.0119***
	(0.0032)	(0.5169)	(0.0031)		(0.0032)	(0.0034)	(0.0034)
size	-0.0071***		-0.0076***		-0.0076***	-0.0093***	-0.0079***
	(0.0007)		(0.0007)		(0.0007)	(0.0008)	(0.0008)
age	-0.0037***	-9.9812***	-0.0036***	-0.0152***	-0.0027***	-0.0019*	-0.0023**
	(0.0007)	(1.4375)	(0.0007)	(0.0022)	(0.0007)	(0.0011)	(0.0011)
size2		34.9564***					
		(1.6287)					
sale/cap				0.0096***			
				(0.0004)			
cash/cap				0.0173***			
				(0.0011)			
size3				-0.0347***			
				(0.0020)			
mkt/book2					0.0200***		
					(0.0005)		
CF/ass						0.1902***	0.1612***
						(0.0058)	(0.0058)
booklev							-0.0401***
							(0.0021)
Num. of obs.	81070	69954	81069	81070	77661	68369	68217
R-sq(within)	0.1647	0.1026	0.1759	0.2206	0.1813	0.1945	0.2078
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

Table 2.13, Column (1) is our baseline specification. In Columns (2)-(4), we replace `capx/at` with the net investment rate as in Ottonello and Winberry (2020), `capxv/at` and `capx/ppent`, respectively. Firm size is measured by size1=`at`, size2=replacement value of capital, size3=`ppent`. Columns (5)-(7) consider alternative measure of investment opportunity and check the impact of cash flow and book leverage. Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks are significance levels: ***=1%, **=5%, *=10%.

Table 2.14: Different uncertainty measures and rolling windows

investment/assest	(1)	(2)	(3)	(4)	(5)	(6)	(7)
mkt/book	0.0070***	0.0070***	0.0071***	0.0071***	0.0071***	0.0073***	0.0073***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
sale/ass	0.0131***	0.0133***	0.0135***	0.0136***	0.0137***	0.0133***	0.0129***
	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
cash/ass	0.0151***	0.0157***	0.0160***	0.0161***	0.0162***	0.0162***	0.0180***
	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)	(0.0032)
size	-0.0069***	-0.0070***	-0.0071***	-0.0071***	-0.0071***	-0.0058***	-0.0058***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
age	-0.0040***	-0.0038***	-0.0037***	-0.0035***	-0.0035***	-0.0043***	-0.0041***
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
vol(profit)3y	-0.0054***						
	(0.0003)						
vol(profit)4y		-0.0049***					
		(0.0003)					
vol(profit)5y			-0.0044***				
			(0.0003)				
vol(profit)6y				-0.0041***			
				(0.0003)			
vol(profit)7y					-0.0039***		
					(0.0003)		
vol(emp)						-0.0299***	
						(0.0030)	
vol(sale)							-0.0470***
							(0.0036)
Num. of obs.	81070	81070	81070	81070	81070	78654	81070
R-sq(within)	0.1676	0.1661	0.1647	0.1639	0.1633	0.1619	0.1618
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

Table 2.14, Columns (1)-(5) consider the influence of different time windows of profit volatility, while all other variables are defined as in Table 2.9. Columns (6)-(7) replace profit volatility with employment and sale volatility, respectively. Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Table 2.15: Effects of uncertainty and profits

investment/asset	(1)	(2)	(3)	(4)	(5)	(6)	(7)
vol(profit)	-0.0044***	-0.0012***	0.0002	0.0003	0.0017	-0.0000	-0.0002
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0013)	(0.0005)	(0.0003)
mkt/book	0.0071***	0.0038***	0.0035***	0.0039***	0.0021***	0.0049***	0.0029***
	(0.0002)	(0.0002)	(0.0002)	(0.0003)	(0.0007)	(0.0004)	(0.0003)
sale/ass	0.0135***	0.0051***	0.0052***	0.0046***	0.0166***	0.0055***	0.0043***
	(0.0011)	(0.0011)	(0.0011)	(0.0012)	(0.0037)	(0.0018)	(0.0012)
cash/ass	0.0160***	0.0012	0.0009	0.0024	0.0075	0.0166***	0.0055
	(0.0032)	(0.0032)	(0.0032)	(0.0034)	(0.0071)	(0.0060)	(0.0034)
size	-0.0071***	-0.0100***	-0.0100***	-0.0105***	-0.0040*	-0.0122***	-0.0092***
	(0.0007)	(0.0007)	(0.0007)	(0.0008)	(0.0023)	(0.0013)	(0.0008)
age	-0.0037***	-0.0019*	-0.0019*	-0.0023**	0.0021	-0.0054***	0.0003
	(0.0007)	(0.0010)	(0.0010)	(0.0011)	(0.0039)	(0.0018)	(0.0010)
profit		0.1494***	0.1779***	0.1835***	0.0972***	0.2347***	0.1088***
		(0.0045)	(0.0060)	(0.0064)	(0.0171)	(0.0087)	(0.0066)
profit $\times$ vol(profit)			-0.0443***	-0.0477***	-0.0394**	-0.0570***	-0.0223***
			(0.0044)	(0.0046)	(0.0190)	(0.0069)	(0.0047)
Sample	all	all	all	dpr $\leq$ 0.20	dpr $>$ 0.20	$cir > med(cir)$	$cir \leq med(cir)$
Observations	81070	71764	71764	62619	9094	35852	35912
R-squared	0.1647	0.1959	0.1986	0.2020	0.1171	0.2235	0.1462
Firm FE	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes

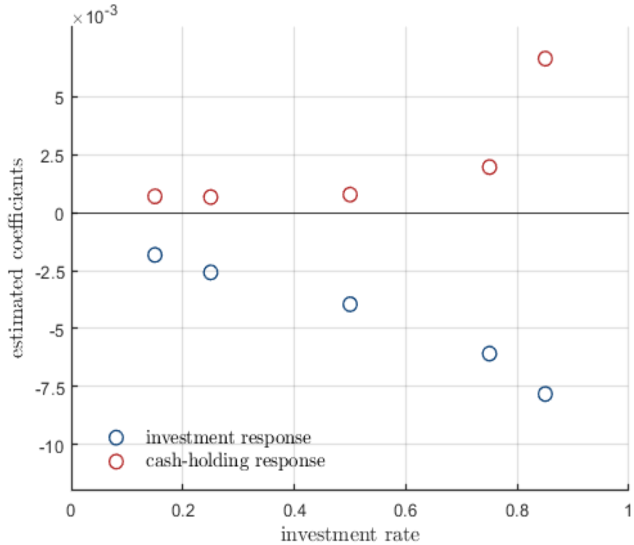
Table 2.15, Columns (1) is our baseline regression specification. Column (2) controls for the impacts of the first moment of profits. Column (3) explores the influence of both the first and second moments of profits. Columns (4)-(7) measure the investment sensitivity to demand, conditional on the level of financial constraint and the degree of irreversible investment, as in Kermani and Ma (2023). Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Table 2.16: Instrumenting profit volatility with past profit volatility

investment/asset	(1)	(2)	(3)	(4)
vol(profit)	-0.0044***	-0.0044***	-0.0030***	-0.0018*
	(0.0003)	(0.0004)	(0.0005)	(0.0011)
mkt/book	0.0071***	0.0070***	0.0068***	0.0068***
	(0.0002)	(0.0003)	(0.0003)	(0.0003)
sale/ass	0.0135***	0.0140***	0.0150***	0.0162***
	(0.0011)	(0.0012)	(0.0013)	(0.0014)
cash/ass	0.0160***	0.0143***	0.0133***	0.0132***
	(0.0032)	(0.0033)	(0.0035)	(0.0037)
size	-0.0071***	-0.0070***	-0.0069***	-0.0064***
	(0.0007)	(0.0008)	(0.0008)	(0.0010)
age	-0.0037***	-0.0034***	-0.0034**	-0.0043**
	(0.0007)	(0.0011)	(0.0014)	(0.0018)
Num. of obs.	81043	75281	65745	58049
R-sq(within)	0.1647	0.1604	0.1533	0.1519
Firm FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes
Instrument		1y lag	2y lag	3y lag

Table 2.16, Column (1) contains our baseline OLS regression results. Uncertainty about profit growth rate is instrumented with one, two, and three lagged years. The IV regression results are presented in Columns (2)-(4). Time FE is not reported, while firm FE is eliminated using the within transformation. Robust standard errors reported in parentheses are clustered at the firm level. Asterisks refer to significance levels: ***=1%, **=5%, *=10%.

Figure 2.23: Investment and cash-holding responses to uncertainty



Notes: Blue dots present point estimates from the OLS regression of the investment rate on firm-level profit growth volatility. These regression results are obtained from equation (2.1) at different points in the investment rate distribution. Similarly, red dots illustrate the impact of idiosyncratic profit volatility on cash holdings at various quantiles.

3 Corporate Income Tax Changes and Aggregate Productivity

Co-authored with Dušan Stojanović (CERGE)

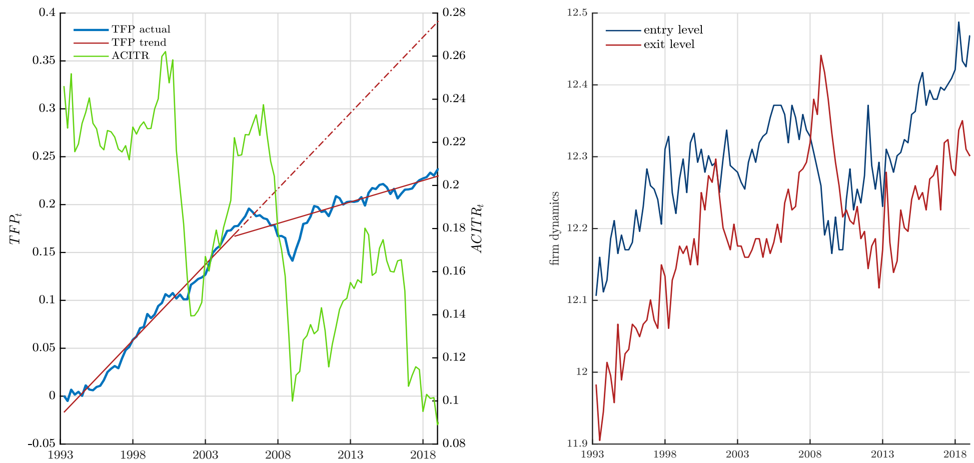
3.1 Introduction

Over the past three decades, the average corporate income tax rates (ACITRs) in the U.S. economy have steadily reduced from 25% to 10%. Concurrently, aggregate total factor productivity (TFP) and the net entry of firms recorded an increase (see Figure 3.1). The standard macro theory predicts that tax cuts boost productive capital investment by reducing the user cost of capital, which then increases aggregate TFP. However, the intended benefits of tax cuts may be offset by several other factors. For instance, tax cuts may enable low-productive firms to remain profitable and continue operating. In addition, many firms may remain financially constrained to finance their growth potential at early stage of their life. This particularly applies to high-productive firms that are discouraged from entering the economy due to restricted borrowing capacity. The existing literature is salient about whether the productivity-enhancing effects of the tax cuts can occur and persist in the presence of firms' entry and exit dynamics and corporate borrowing.

To evaluate the dynamic effects of corporate income tax shocks on TFP and other U.S aggregates, we apply two methodologies commonly used in the literature. First, we use a proxy structural vector autoregression model developed by Mertens and Ravn (2013) to identify tax shocks. Second, we implement the approach of Wong (2015) to construct a counterfactual economy in which firms are restricted from borrowing. Specifically, we generate a sequence of borrowing shocks of sufficient magnitude to fully offset the response of borrowing to a 1% tax shock for a period of 40 quarters. This counterfactual framework allows us to evaluate the role of borrowing in the transmission of tax shocks to changes in firms' composition, aggregate productivity and output.

Our paper provides two novel empirical findings for the U.S. economy. First, we document that when there is increased net entry of firms and borrowing in the capital market,

Figure 3.1: Aggregate productivity, average taxes and firm dynamics, 1993q2-2019q4



Note: ACITRs refer to average corporate income tax rates. ACITRs come from NIPA, while aggregate TFP is from table of John G. Fernald, entry and exit levels are from BLS, BED.

the average corporate income tax cuts lead to a temporary rise in aggregate TFP and real GDP. Second, these expansionary effects persist only if firms have the ability to borrow additional external funds. The intuition is that increased capital accumulation, stimulated by tax cuts, relaxes collateral constraints, providing existing firms with additional funds to sustain previously increased aggregate TFP and output growth. The availability of external funds allows new entrants to finance their high growth potential, amplifying the positive effects of tax cuts.

The remainder of this chapter is organized as follows. Section 3.2 reviews the related literature. In Section 3.3, we present the empirical results. Section 3.4 concludes. In the appendix, we conduct a set of robustness checks of our empirical results.

3.2 Related Literature

The objective of this paper is to provide a novel empirical analysis of the dynamic relationship between average corporate income tax rates (ACITRs) and aggregate productivity gains and other macroeconomic aggregates in the presence of firms' entry and exit dynamics and corporate borrowing. To achieve this goal, we connect two strands of literature.

The first strand of literature evaluates tax effects using external instruments in VAR models. While Mertens and Ravn (2013) and Romer and Romer (2010) document short-run stimulative tax effects on output, Cloyne et al. (2022) find long-run positive tax effects on productivity and output through R&D expenditure. The recent work by Colciago et al. (2023) studies the tax effects on labor market outcomes in the context of entry and exit of firms, and show an increase in productivity and output in the short run. We contribute to this literature by highlighting the role of the interaction of firms' entry and exit with corporate borrowing in the transmission of stimulating tax effects on aggregates over the short and long term.

We claim that there is no guarantee that the tax effects are productivity enhancing because lower ACITRs increase the after-tax income of existing low-productive firms, enabling them to continue operating. In addition, new firms are discouraged from entering the economy as their access to external funds remaines restricted. Consequently, the change in the number of firms in the economy (extensive margin) and the reallocation of resources to firms with low productivity (intensive margin) may slow down the rise in aggregate productivity and output growth.[64] Further, we argue that it matters how firms finance their capital investment. Corporate borrowing could magnify tax effects through the close interaction between capital and collateral constraint. Our results indicate that the interplay between firms' entry and exit dynamics and borrowing makes tax effects productivity enhancing over a forty-quarter time horizon.

A second strand of literature deals with approaches to evaluate the empirical relevance of the mechanisms in a SVAR framework. While the literature mostly relies on estimated impulse response functions or historical decomposition, Wong (2015) and Sims and Zha (2006) propose generating counterfactual impulse response functions to shocks. Specifically, to explore inflation expectations as a channel for transmitting real oil price shocks on actual inflation, Wong (2015) conducts a counterfactual experiment where inflation expectations are set insensitive to oil price shocks. We follow the idea about forming a counterfactual experiment but focus on the channels between tax shocks and macroeconomic aggregates.

[64] The inclusion of firms' entry and exit in our analysis is justified by Foster et al. (2018), who highlights their important role in explaining innovation in the capital market.

3.3 Empirical Evidence

In Figure 3.1, we observe a slowdown in aggregate productivity growth over the past three decades. This could be attributed to many factors, including depleted innovations, global recession, etc.[65] Our study investigates whether ACITRs, in the presence of firms' entry and exit, is behind this slow down in productivity. Corporate income tax changes are one of the most polarizing topics in fiscal policy due to different channels at work with potentially opposing effects. We contribute to the debate on tax policy changes by addressing the following two questions. How effective are ACITRs in stimulating aggregate productivity and output growth across different time horizons? What role do firms' entry and exit dynamics and borrowing play in transmitting the effects of ACITRs?

Empirical Model. To isolate exogenous variation in taxes, we use a proxy Structural Vector Autoregressive (SVAR) developed by Mertens and Ravn (2013). It combines a SVAR with the narrative approach. We use narrative measures of tax changes by Romer and Romer (2010) as our proxy, which imposes the restrictions that they are correlated with the structural tax shock but are not correlated with other structural shocks. The benchmark proxy SVAR model includes the following variables: ACTIRs, nonresidential fixed investment, real GDP, aggregate TFP, entry and exit levels, and corporate debt.

Data. We analyze quarterly observations from 1993q2 to 2019q4. All variables are expressed in real per capital terms. We use U.S. data on firms' entry and exit from the Bureau of Labor Statistics (BLS). Availability of these data from 1993q2 determines the start of our sample. The average corporate income tax rates are computed as:

$$ACITRs = \frac{\text{federal taxes on corporate income}}{\text{corporate profits} - \text{Federal Reserve Bank profits}}$$

Results. Figure 3.2 illustrates the impulse responses of selected variables to a one-percentage-point decrease in ACITR. The blue solid line represents the point estimates, while the blue and red dashed lines represent 90% and 68% bootstrap confidence intervals, respectively. It is evident that the unexpected shock significantly reduces ACITR for the first three quarters before going back to zero, its historical average. This tax change can be

[65]For more information on the reasons behind week aggregate productivity growth, look at Akcigit and Ates (2021).

Table 3.1: Aggregate US data, 1993q2-2019q4

Variable	Description	Source
ACITR	average corporate income tax rate	NIPA
ACITB	average corporate income tax base	NIPA
NRI	nonresidential fixed investment	NIPA
GDP	gross domestic product	NIPA
TFP	total factor productivity	John G. Fernald
entry	entry level	BLS BED
exit	exit level	BLS BED
corp_debt	corporate debt	FoF
m_CI	narratively-identified shock	MR(2013) and HHP(2021)

Notes: NIPA is National Income and Product Accounts; BLS is Bureau of Labor Statistics; BED is Business Employment Dynamics; FoF is Flow of Funds; MR refers to Mertens and Ravn (2013); HHP is Hanson et al. (2021).

interpreted as a temporary reduction in taxes.

We observe several aggregate responses to the tax shock within our benchmark model. First, investment as a GDP component reacts significantly, with an impact increase of 1%.[66] Second, despite the transitory nature of the corporate tax cut, short-term increases in real GDP and aggregate TFP persist over the ten-year period. Third, firms' entry and exit levels initially respond in opposite directions. Specifically, entry increases, while exit decreases.[67] Given that the fiscal stimulus and the associated boom fade away over time, low-productive incumbents become unprofitable and tend to exit the economy. In addition, lower profits per firm discourage the creation of new firms, reducing competition by entering firms. Fourth, corporate borrowing exhibits a hump-shaped response to the tax shock. Responses of all aggregates to the tax shock are statistically significant.

[66] According to standard macroeconomic theory, lower corporate tax rates reduce the rental rate of capital, stimulating firms to increase capital investment.

[67] The rise in net entry of firms primarily drives the increase in aggregate TFP on impact. This claim is clearly justified in Figure 3.3 when another important financial channel (borrowing) is excluded from the analysis.

Figure 3.2: Impulse Responses to ACITRs, 1993q2-2019q4

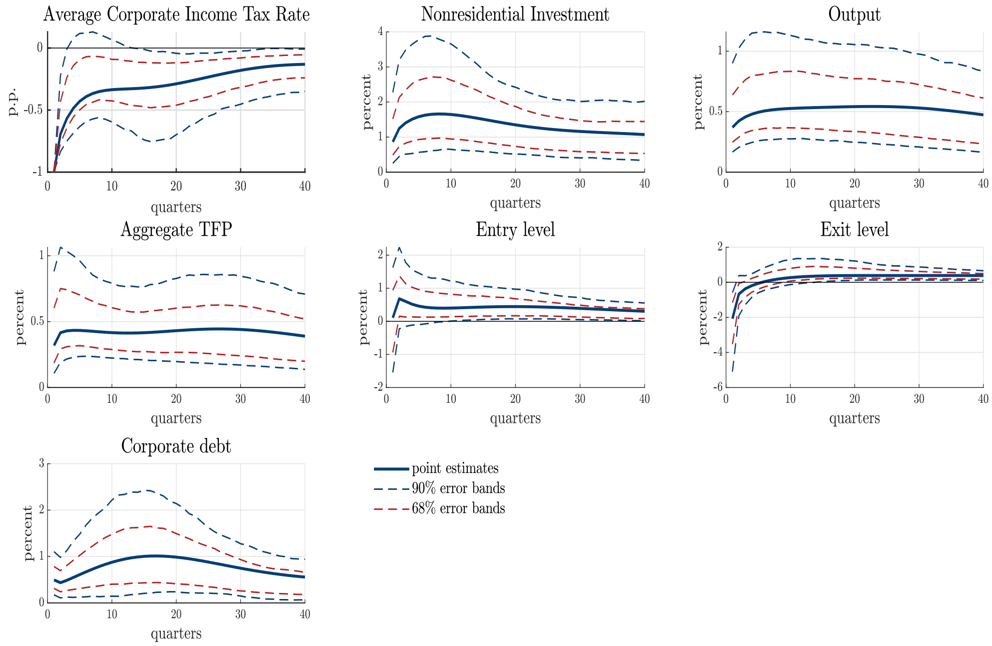


Table 3.2 suggests how our main results contribute to the understanding of the dynamic effects of tax shocks in the empirical literature. In contrast to Cloyne et al. (2022) who focus on tax effects along the intensive margin of investment, we highlight the importance of both intensive and extensive effects of the tax shocks. Relative to Colciago et al. (2023), who explore labor market, our paper focuses on capital market, emphasizing the role of corporate borrowing in the long run. We focus on the capital market because capital investment is the most volatile component of aggregate output, and most firms in the US rely on borrowing, with capital serving as collateral.

We find that, on impact, a temporary reduction in corporate taxes increases aggregate investment and aggregate output in the presence of an increase in after-tax internal funds.[68] As the corporate taxes gradually increase, their stimulative effects on investment become smaller, but their positive effects on output persist. In the long run, investment remains at its initial response level because the initial capital accumulation increases future cash-flows

[68] In the left upper panel of Figure 3.4 in Appendix, we show that the drop in ACITR increases corporate profits by 1.16% on impact and remains significantly above the pre-shock level for one year, and then gradually reduces as the tax cuts are reduced.

and allows firms to relax borrowing constraints. Real GDP remains at high levels because of a strong rise in consumption, as depicted in Figure 3.4 in Appendix.

Table 3.2: Responses to a one percentage point cut in the ACITR

	Mertens and Ravn (2013)	Cloyne et al. (2022)	Colciago et al. (2023)	Our paper
Statistics	non-resid inv	R&D inv	firms' entry & exit and labor market	firms' entry & exit and capital market
Yagg on impact	0.4	0.4	0.7	0.4
Yagg in q20	0.5	0.7	1.2	0.5
TFPagg on impact	-	0.2	-	0.3
TFPagg in q20	-	0.4	-	0.4
Iagg on impact	0.5	0.8	-	0.9
Iagg in q20	0.2	2.0	-	1.3

Notes: The sample period in Mertens and Ravn (2013) and Cloyne et al. (2022) is from 1950q1 to 2006q4. Colciago et al. (2023) consider the period from 1979q1 to 2006q1. Our paper covers the period from 1993q2 to 2019q4.

Robustness Checks. To confirm the robustness of our empirical findings, we perform a set of additional checks. The results are presented in the figures in Appendix. Figure 3.4 shows a statistically significant rise in consumption, indicating potentially strong demand effects on the economy that push up production and profits. As regards the labor market outcomes, we observe that higher capital investment increases wages in spite of the reduced employment rate.[69]

Given the importance of changes in firm's composition for the transmission of tax shocks, we reestimate the tax effects in the model where firms' entry and exit levels are replaced with firms' entry and exit rates. In Figure 3.5, we observe that the initial drop in exit rates is stronger than the drop in entry rates, leading to a rise in net entry rates upon impact. However, as ACITRs gradually increase, exit rates increase, which for a relatively constant entry rates diminish the total number of active firms.

We also test the responses of alternative measures of productivity, including the

[69]As for the employment rate, the transmission of the tax shocks is fully absorbed.

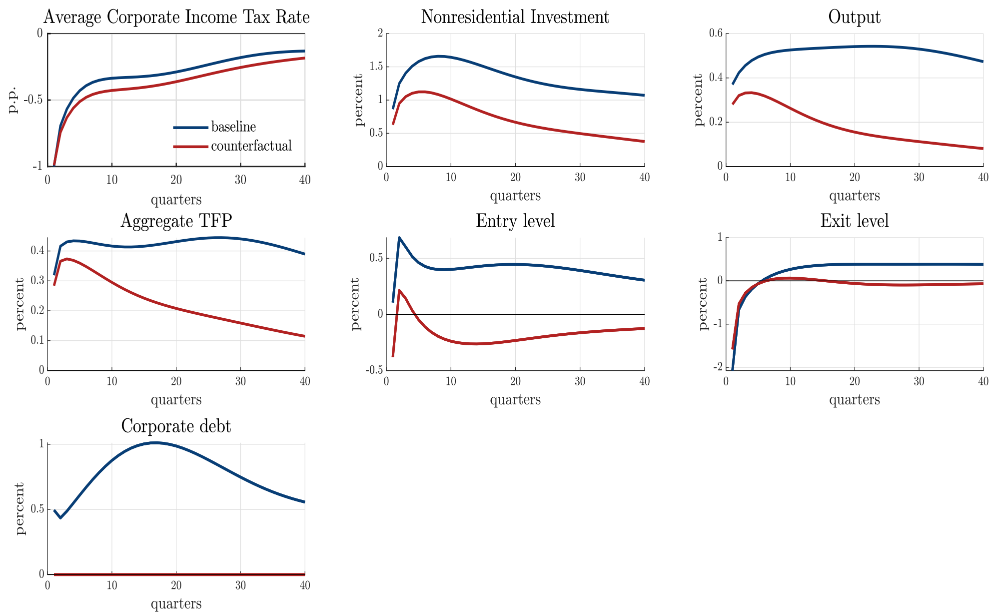
adjusted TFP and labor productivity. The utilization-adjusted TFP measure from Fernald (2014) aims to isolate changes in productivity that are not influenced by endogenous changes in factor utilization. The estimation results, depicted in Figure 3.6 in Appendix, are similar to those observed with our baseline measure of productivity, aggregate TFP.

The role of corporate borrowing. We construct a counterfactual scenario to simulate the effects of a tax shock in the absence of corporate borrowing. Following the approach by Wong (2015), we generate a sequence of corporate borrowing shocks just large enough to fully offset the response of corporate borrowing to a 1% tax shock for all 40 quarters. If corporate borrowing serves as an important mechanism in transmitting tax shocks, the counterfactual impulse response functions of macro aggregates tend to deviate significantly from their baseline estimates. This exercise answers the question about the role of firm dynamics and borrowing in propagating the tax shock.

Figure 3.3 compares the estimated IRFs of the baseline proxy SVAR model (blue line) with the counterfactual IRFs (red line). Without borrowing, the red line shows that the responses of aggregate TFP and output are small on impact. However, their responses are significantly mitigated in the long run, accompanied by a strong decline in the net entry of firms. This highlights the significant contribution of borrowing to the transmission of a tax shock to the economy through changes in entry and exit of firms. We also generate a counterfactual impulse response function to a shock by setting all coefficients in the borrowing equation to zero. The estimation results of this alternative approach are shown in Figure 3.7.

In Figure 3.3, we also observe that the distance between the blue and red lines is larger for entry levels than exit levels. Five quarters after the shock, incumbent firms have sufficient time to accumulate internal funds to be away from the exit decision, stabilizing exit around its historical average. Conversely, entering firms face lower internal funds due to a relatively higher tax rate and a fully restricted access to external funds. A reduced competition, which is mainly driven by a reduced entry level, leaves a larger space for active firms to continue their operation in the economy, pushing down aggregate TFP. Our findings complement the study by Hamano and Zanetti (2022), which shows that a contractionary *monetary* policy decreases the entry of new firms. This shields incumbent firms from the competition of new entrants and reduces aggregate productivity.

Figure 3.3: Counterfactual analysis with zero borrowing, 1993q2-2019q4



Note: Counterfactual analysis is in the spirit of Wong (2015) and Sims and Zha (2006).

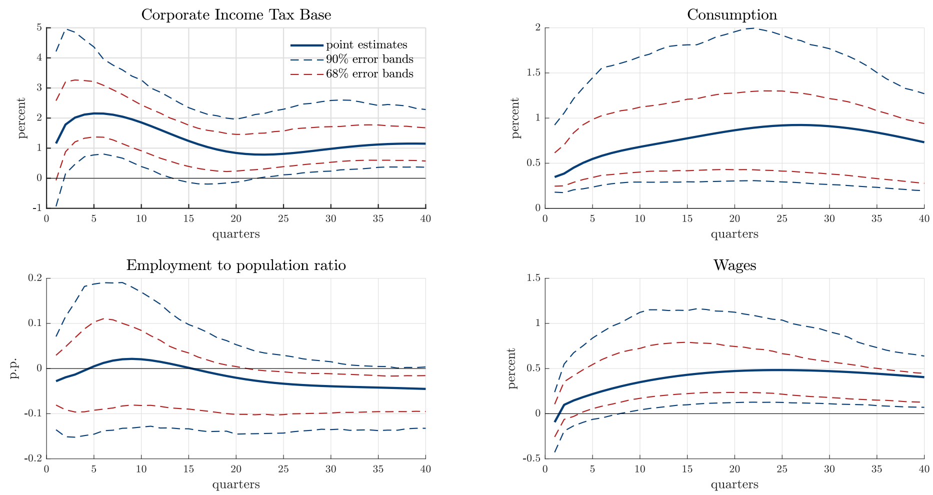
3.4 Conclusion

This paper provides new insights into the aggregate effects of tax cuts and their transmission through firms' entry and exit dynamics and borrowing over time. Our empirical results reject a theoretical consideration that the corporate income tax cuts may reduce aggregate TFP and output growth in the short-run, showing instead that these positive responses persist in the long run. Specifically, we find that the corporate income tax cuts generate the cleansing of low-productive firms from the market, enhancing aggregate output growth. The ability of firms to borrow amplifies the influence of the increased net entry of firms. For the future research, it would be interesting to explore the interplay between firms' entry and exit dynamics and borrowing on the basis of micro-level data. This additional exercise is an important for understanding the effects of tax cuts on reallocating resources from low to high productivity firms, which may drive a large portion of productivity growth.

3.5 Appendix

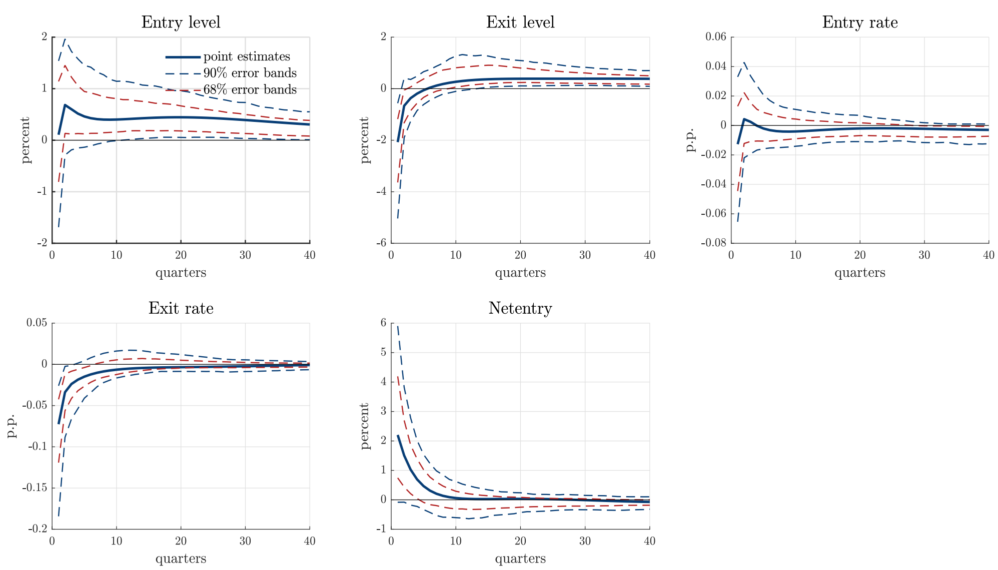
3.5.A Robustness Checks

Figure 3.4: Impulse Responses to ACITR, 1993q2-2019q4



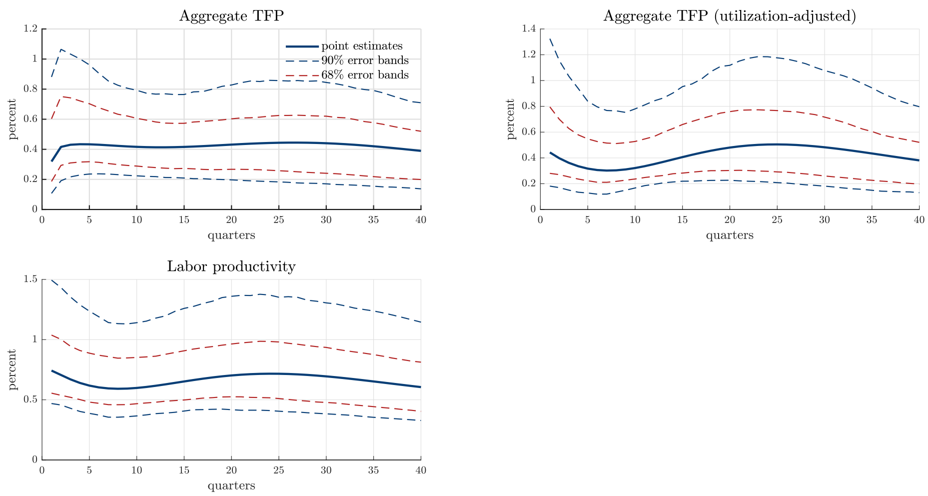
Note: Each additional variable is added to the baseline data vector one at the time to avoid a sharp increase in the number of parameters to be estimated.

Figure 3.5: Firms' entry and exit, 1993q2-2019q4



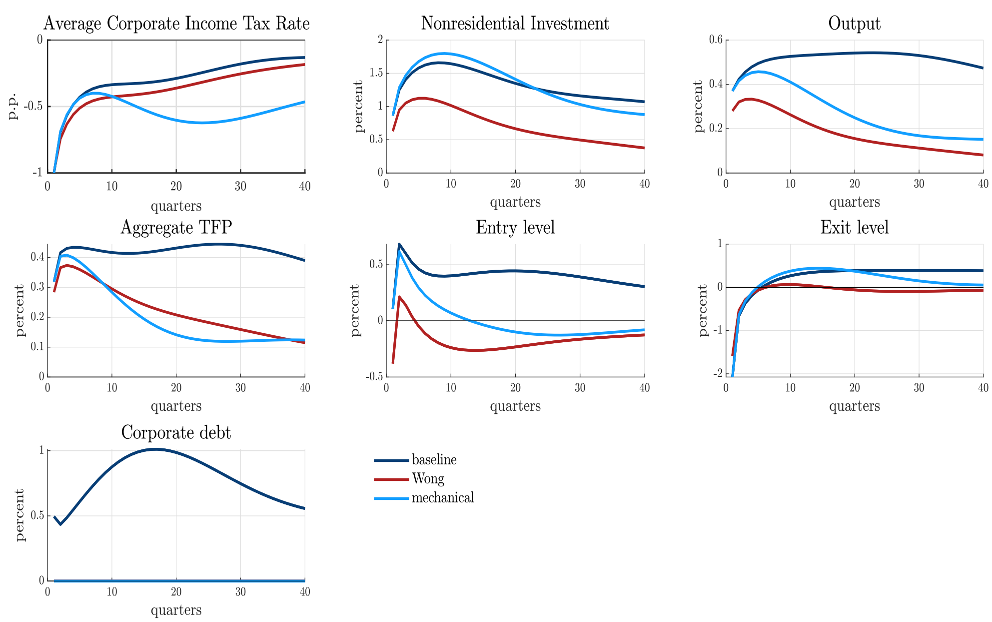
Note: Each additional variable is added to the baseline data vector one at the time to avoid a sharp increase in the number of parameters to be estimated.

Figure 3.6: Aggregate productivity, 1993q2-2019q4



Note: Each additional variable is added to the baseline data vector one at the time to avoid a sharp increase in the number of parameters to be estimated.

Figure 3.7: Different approaches to constructing counterfactual IRFs, 1993q2-2019q4



Note: Counterfactual analysis is in the spirit of Wong (2015).

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