

## **EUROPEAN SUMMER SYMPOSIUM IN FINANCIAL MARKETS**

**Generously hosted by**  
Study Center Gerzensee

Monday 15-26 July 2013

### **Rising Intangible Capital, Shrinking Debt Capacity, and the US Corporate Savings Glut**

Antonio Falato (Federal Reserve Board), \*Dalida Kadyrzhanova (University of Maryland) and Jae Sim (Federal Reserve Board)

# Rising Intangible Capital, Shrinking Debt Capacity, and the US Corporate Savings Glut

Antonio Falato  
Federal Reserve Board

Dalida Kadyrzhanova  
University of Maryland

Jae W. Sim  
Federal Reserve Board<sup>1</sup>

November 2012. This version: June 2013

<sup>1</sup>For helpful comments and suggestions, we thank Hengjie Ai, Max Croce, John Graham, Cam Harvey, Kose John, Paige Oiumet, Manju Puri, Adriano Rampini, David Robinson, Dan Sichel, Vish Viswanathan, Luke Taylor, Andrea Eisfeldt, and seminar participants at Duke University, University of North Carolina, University of British Columbia, and Society for Economic Dynamics 2013 meeting. All remaining errors are ours. Corresponding author: Jae W. Sim, Phone: (202) 452-2680. Email: [jae.w.sim@frb.gov](mailto:jae.w.sim@frb.gov).

## **Abstract**

This paper explores the hypothesis that the rise in intangible capital is a fundamental driver of the secular trend in US corporate cash holdings over the last decades. Using a new measure, we show that intangible capital is the most important firm-level determinant of corporate cash holdings. Our measure accounts for almost as much of the secular increase in cash since the 1980s as all other determinants together. We then develop a new dynamic dynamic model of corporate cash holdings with two types of productive assets, tangible and intangible capital. Since only tangible capital can be pledged as collateral, a shift toward greater reliance on intangible capital shrinks the debt capacity of firms and leads them to optimally hold more cash in order to preserve financial flexibility. In the model, firms with growth options tend to hold more cash in anticipation of (S,s)-type adjustments in physical capital because they want to avoid raising costly external finance. We show that this mechanism is quantitatively important, as our model generates cash holdings that are up to an order of magnitude higher than the standard benchmark and in line with their empirical averages for the last two decades. Overall, our results suggest that technological change has contributed significantly to recent changes in corporate liquidity management.

# 1 Introduction

Public corporations in the US have steadily increased their cash holdings over the last decades. This dramatic trend in corporate liquidity management is a hotly debated issue that has attracted wide attention in the popular press, with commentators dubbing it the "corporate saving glut," expressing concerns it might hamper growth of the US economy, and even raising calls to heavily tax corporate savings. Yet, understanding which fundamental economic determinants drive the secular trend in corporate cash holdings and why corporations now hold almost three times as much cash as they used to in the 1970s<sup>1</sup> represents a big outstanding challenge for both empirical and theoretical research in corporate finance.

In particular, on the empirical side, existing evidence on the determinants of the secular trend in corporate cash holdings is at best mixed. Several explanations have been put forth such as, for example, agency conflicts between managers and shareholders, or precautionary motives in the face of uncertainty (Bates, Kahle, and Stulz (2006)). However, these standard cross-sectional determinants of corporate cash holdings have been relatively stable over time and, thus, can offer at best only a partial explanation of why cash holdings have risen so much over time. On the theory side, the cash to asset ratios predicted by standard calibrations of existing models are much smaller than their empirical counterparts (Riddick and Whited (2009)). Thus, the current high levels of cash represent a quantitative puzzle for standard dynamic corporate finance theory.

This paper shows that firms' growing reliance on intangible capital in their production technology can help to address both the empirical and the theoretical challenges. Intangible capital cannot be easily verified or liquidated and, as such, cannot be pledged as collateral to raise debt financing. Under frictional capital markets where external funds command substantial premiums, we argue that its rising importance as an input of production may have boosted firms' precautionary demand for cash in order to insure that they have sufficient liquidity to weather adverse shocks and to exploit investment opportunities. Empirically, we construct a new firm-level measure of intangible capital and introduce it into an otherwise standard reduced-form model of the determinants of corporate cash holdings (Opler, Pinkowitz, Stulz, and Williamson (1999)). We show that our measure explains a large fraction of the secular increase in cash since the 1980s: in-

---

<sup>1</sup>Survey evidence from CFOs confirms that that liquidity management tools such as cash are essential components of a firm's financial policy (Lins, Servaes, and Tufano (2007), Campello, Giambona, Graham, and Harvey (2009)).

tangible capital emerges as the most important firm-level determinant of corporate cash holdings, accounting for almost as much of the secular increase in cash as all other standard determinants together. We then develop a new model of corporate cash holdings that introduces intangible capital into an otherwise standard dynamic corporate finance setup (Bolton, Chen, and Wang (2009), Riddick and Whited (2009); see also Froot, Scharfstein, and Stein (1993) for a seminal model of corporate liquidity management). Our model generates cash holdings that are up to an order of magnitude higher than the standard benchmark, thus offering a potential resolution of the quantitative puzzle in the literature. Overall, these results suggest that intangible capital is crucial to providing a satisfactory analytical account of corporate cash holdings.

Our focus on intangible capital builds on a large body of evidence spanning various literatures, including the economics of innovation, macroeconomics, and industrial organization, which shows that over the last few decades there has been a dramatic shift away from physical capital investments toward intangible capital. There is solid evidence at the aggregate level that investments in intangible capital by US firms have picked up substantially since the 1980s (Corrado, Hulten, and Sichel (2009) and Corrado and Hulten (2010)), especially investments in computerized information and private R&D. There is also evidence that organizational capital is becoming increasingly important (Lev (2001)). This well-documented shift in firms' mode of production is an economy-wide phenomenon, something that the literature has dubbed a general purpose technology (GPT) shock, or the third industrial revolution, in that it affected firms across the board, well beyond simply the high-tech sector (Jovanovic and Rousseau (2005)). This body of evidence broadly suggests that fundamental technological changes, or shocks, in the 1980s and 1990s have had a pervasive effect on public corporations.

In the first part of our analysis, we explore the link between the rise in intangible capital and the secular trend in corporate cash empirically. We begin by constructing a new firm-level measure of intangible capital. The main hurdle one faces in constructing this measure is that intangible assets are not reported on the firms' balance sheet and investments in intangibles are generally treated as expenses. Existing attempts at measuring intangible capital empirically have been mostly in macroeconomics and, thus, involve constructing aggregate measures of intangible capital for the US economy. For example, one approach is to construct a proxy using aggregate stock market or accounting data (Hall (2001), McGrattan and Prescott (2007)). While these approaches measure in-

tangibles as unexplained (by physical capital) residuals of stock market value or firm productivity, a more direct recent approach is to construct aggregate measures of the different components of intangible capital, which include the stock of assets created by R&D expenditures, brand equity, and human and organizational capital using NIPA accounts (Corrado, Hulten, and Sichel (2009) and Corrado and Hulten (2010)).

We build on this latter approach and use standard accounting data to construct new comprehensive firm-level measures of intangible capital and its different components for all non-financial firms in Compustat between 1970 and 2010. Our measure is defined as the sum of three main components: the stock of information technology (IT) capital, the stock of innovative (R&D) capital, and the stock of human and organizational capital. The stock of innovative capital is constructed by capitalizing R&D expenditures using a standard perpetual inventory method (e.g., Hall (2001)), while the stock of human and organizational capital capitalizes SG&A expenditures. IT capital is constructed capitalizing expenditures in computer software from BEA.

Our empirical analysis introduces this firm-level measure of intangible capital into an otherwise standard reduced-form model of the determinants of corporate cash holdings (Opler, Pinkowitz, Stulz, and Williamson (1999)). We show that there is a strong link between intangible capital and corporate cash both in the cross-section and in the time-series. In particular, intangible capital is the most important firm-level determinant of cash both in pooled OLS and in firm fixed-effects specifications. These empirical results are robust to performing a standard battery of sensitivity tests.

We also offer a complementary assessment of the economic importance of intangible capital for cash holdings decisions by performing a simple out-of-sample forecasting exercise that follows the approach of Bates, Kahle, and Stulz (2006). This exercise consists in first estimating our reduced-form model for the pre-1990 period. We then use the model's estimated coefficients and the changes in the underlying explanatory variables to generate a prediction for implied cash changes in the post-1990 period. The results show that an economically significant part, in fact almost half, of the overall predicted increase in cash holdings can be attributed to increases in intangible capital. Overall, our empirical results show that there is a strongly economically significant relation between intangible capital and corporate cash holdings.

In order to better understand the economic forces that drive the empirical link between in-

tangible capital and cash holdings, we next develop a new model of cash holding decisions that introduces intangible capital into an otherwise standard dynamic corporate finance setup (Bolton, Chen, and Wang (2009), Riddick and Whited (2009)). The model is cast in a standard infinite-horizon, discrete-time stochastic environment, where managers make value-maximizing investment decisions in tangible, intangible, and financial assets under a costly external financing friction. The model has two key ingredients: first, we allow for the interplay of real frictions, that arise since investment is partially irreversible and subject to fixed costs of adjustment, and financial frictions, that arise since debt financing is subject to a collateral constraint while equity financing involves dilution costs; second, intangible capital matters for financing and investment decisions since it cannot be pledged as collateral for borrowing. For a realistic parametrization, we show that intangible capital improves the quantitative performance of the model. In particular, our model generates cash holdings that are up to an order of magnitude higher than the standard benchmark without intangible capital. Overall, our theory results show that intangible capital is a first-order driver of cash holding decisions.

Our paper contributes to the literature along three main dimensions. First, we contribute to the vast reduced-form empirical literature on the determinants of corporate cash holdings (e.g., Opler, Pinkowitz, Stulz, and Williamson (1999)) by constructing a new comprehensive measure of intangible capital and using it to document key stylized facts of corporate cash holdings. Second, we contribute to the small but growing theory literature on dynamic corporate finance models of liquidity management (e.g., Bolton, Chen, and Wang (2009), Riddick and Whited (2009); see also Froot, Scharfstein, and Stein (1993) for a seminal model of corporate liquidity management) by showing that a richer production-side is key to improve the quantitative performance of this class of models. Finally, since our model is relatively parsimonious in terms of number of parameters, it is amenable to structural estimation and, thus, can be used to develop new structural tests of dynamic corporate finance models.

## **2 Intangible Capital and the Rise in Cash Holdings: The Evidence**

The central message of this paper is that there is a link between the rise in intangible capital and the secular trend in corporate cash holdings. In this section we evaluate this prediction empirically.

First, we show that the decades when cash holdings have trended up are also a period marked by fundamental changes in the nature of production, which has been increasingly moving toward greater reliance on intangible capital. We then use regression analysis to assess the empirical relation between intangible capital, cash holdings, and corporate investment. Finally, we use sample split analysis to investigate the importance of financing and investment frictions as potential forces behind this relation. Throughout, we retrieve standard accounting data from Compustat to assemble a large panel of 18,535 US corporations over the 1970 to 2010 period (176,877 firm-year observations).<sup>2</sup>

## 2.1 Measuring Intangible Capital

Our empirical proxy for the amount of capital accumulated by past investments in intangible assets is a measure of intangible capital for each firm-year. The main hurdle with measuring intangible capital is that, although investments in intangible assets are expensed, the capital that is created by such investments is not reported on firm balance sheets.<sup>3</sup> We use annual data on expenses in three broad categories of intangible investment whose importance has been emphasized in the literature on the economics of innovation (Corrado, Hulten, and Sichel (2009) and Corrado and Hulten (2010)): knowledge capital, organizational capabilities, and computerized information and software. Intangible capital is defined as the sum of the stocks of investments in these three categories divided by net book assets.

First, we construct the stock of knowledge capital from past R&D expenses using the perpetual inventory method:

$$G_{it} = (1 - \delta_{R\&D}) G_{it-1} + R\&D_{it} \quad (1)$$

where  $G_t$  is the end-of-period stock of knowledge capital,  $R\&D_{it}$  is the (\$1990 real) expenditures on R&D during the year, and  $\delta_{R\&D} = 15\%$  (Hall, Jaffe, and Trajtenberg (2000)).<sup>4</sup> Second, we construct the stock of organizational capital from past sales, general, and administrative (SG&A)

<sup>2</sup>As is standard in the literature, we exclude financial firms (SIC codes 6000-6999), regulated utilities (SIC codes 4900-4999), and firms with missing or non-positive book value of assets and sales in a given year.

<sup>3</sup>Corrado, Hulten, and Sichel (2005) estimate that roughly \$1 trillion of intangible investment is excluded from NIPAs annually over the period 2000 to 2003.

<sup>4</sup>If R&D expenditures are constant (in real terms), the stock of knowledge capital is  $G_t = \sum_{s=0}^{\infty} (1 - \delta)^s R\&D_{t-s} = \frac{R}{\delta}$ . We set the initial stock to be equal to the R&D expenditures in the first year divided by the depreciation rate  $\delta_{R\&D}$ . In addition, we interpolate missing values of R&D following Hall (1993) who shows that this results in an unbiased measure of R&D capital. For firms that do not report R&D, we set R&D to zero.



expenses also using the same method with  $\delta_{SG\&A} = 20\%$  Lev and Radhakrishnan (2005), Eisfeldt and Papanikolaou (2013)). These investments enhance the value of brand names and other knowledge embedded in firm-specific human and structural resources and include employee training costs, payments to management and strategy consultants, and distribution systems. Since SG&A expenditures include other expenses unrelated to investments in organizational capabilities, we follow Corrado, Hulten, and Sichel (2009) and only weigh the stock of organizational capital by 0.2.<sup>5</sup>

Third, we construct the stock of computerized information and software by applying again perpetual inventory method with a depreciation rate of 31% as in the BEA data. Since these expenses are not reported at the firm level, we use the annual (2-SIC) industry level BEA Fixed Reproducible Tangible Wealth (FRTW) data. We then construct a multiple of this stock to tangible capital stock at the industry level and apply the multiple to each firm's tangible capital stock (PPE) to derive a firm-level stock.<sup>6</sup>

Our resulting estimate for average intangible to tangible capital is about 1.2, which is comparable to the estimate in Corrado, Hulten, and Sichel (2009) based on aggregate NIPA accounts.

## 2.2 Stylized Facts

We begin our analysis by considering basic stylized facts of the evolution of corporate cash holdings over time. Figure 1 shows the annual average ratio of cash holdings to book assets (top panel) and of intangible capital to net book assets (bottom panel) over the last four decades, while Panels A and C of Table 1 show averages (and medians) by decades of the cash ratio and net leverage for the entire sample and for the sub-sample of firms that invest in R&D, respectively. Mean (median, not shown) cash holdings display a pronounced secular upward trend from about 9% (5%) in 1970 to about 20% (13%) by 2010. The rise was not concentrated in any particular decade, but rather has been steady.<sup>7</sup> In addition, the panels in Table 1 show evidence of increased reliance on cash over time to finance growth opportunities, as cash rich firms have on average been investing increas-

---

<sup>5</sup>In robustness analysis we have explored alternative weights in a wide (+/- 50%) range, which leave our results qualitatively unchanged.

<sup>6</sup>Our results are little changed if we do not include this stock in our measure of intangible capital.

<sup>7</sup>In additional graphical analysis, we have divided the sample into terciles each year by size and age, high-tech and other sectors, and incumbent and entrant firms (based on whether firms are present in all years in the sample or enter the sample in any given year). This analysis shows that the secular trend in cash has not been confined to any particular subset of firms and, thus, has been an economy-wide development.

ingly more and growing increasingly faster in the last two decades than relatively cash strapped ones. Finally, the bottom panel of Figure 1 shows that, in line with the evidence in Corrado, Hulten, and Sichel (2009), there was a substantial increase in intangible capital over the same period, with the intangible ratio rising tenfold from about 5% of net book assets in 1970 to about 60% in 2010.

Next, we explore cross-sectional variation. In our data (results not shown), we replicate another well-documented stylized feature of the rise in intangibles: there was an economy-wide shift in firms' mode of production - which is referred to in the literature as a general purpose technology (GPT) shock or the third industrial revolution (Jovanovic and Rousseau (2005)) - that affected all firms well beyond just high-tech sectors. Intangible capital relative to net assets has steadily risen in all broad industry categories (12-Fama and French) over our sample period. While the increase has been more dramatic in some industries (e.g., by a factor of almost 40, from 0.13 to 5.07, in Healthcare), the intangible ratio went up by a factor of 10 (from 0.01 to 0.10).

dian) cash ratios strongly and monotonically increase from about 8% (4%) in the bottom quartile of intangible capital to about 23% (12%) in the top quartile. The univariate relation between cash and intangible capital is even stronger when we restrict the sample to exclude firms that do not invest in R&D, with mean (median) cash ratios now going up to about 30% (23%) in the top quartile. Finally, the columns to the right show that firms in the top quartile are also those for which cash matters the most to finance growth opportunities, as especially in this top quartile cash rich firms have on average been investing relatively more and growing faster than cash strapped ones.

While illustrative, this univariate evidence suggests that intangible capital may have contributed significantly to the rise in corporate cash holdings.

## 2.3 Panel Evidence

To corroborate the stylized facts, we use standard panel regression techniques and examine both cross-sectional and time-series variation in intangible capital and cash holdings. To that end, we regress cash holdings and net leverage ratios on our measure of intangible capital, while controlling for a set of standard determinants of cash holdings (e.g., Opler, Pinkowitz, Stulz, and Williamson (1999) and Bates, Kahle, and Stulz (2006)). We consider both OLS and firm fixed effects<sup>8</sup> versions of this baseline model, with firm-level controls that include industry cash flow volatility, market-to-book ratio, firm size, cash flow, capital expenditures, (cash) acquisitions expenditures, and a dummy for whether the firm pays dividend in any given year, as well as year effects to control for time variation in cash holdings. We evaluate statistical significance using robust clustered standard errors adjusted for non-independence of observations within firms.

The resulting estimates are reported in Panel A of Table 2 for the overall sample (Columns (1)-(4)) and for the subset of firms that report positive R&D (Columns (5)-(8)), to address the concern that the overall sample may reflect spurious differences in average cash holdings between non-innovative vs. innovative firms.<sup>9</sup> The coefficient on intangible capital is robustly positive and statistically significant across the two samples and both specifications.<sup>10</sup> Intangible capital is

<sup>8</sup>Although the time dimension of our sample is long (40 years), the panel is unbalanced. In order to reduce the “within groups bias” on explanatory variables, we exclude firms with less than five years of data. For the fixed-effects specification we report the within-group  $R^2$ .

<sup>9</sup>The results are robust to using median regressions that address the concern that outliers firm-year observations with very high levels of cash may be driving the OLS estimates, as well as OLS estimates for a specification in changes, rather than levels.

<sup>10</sup>Signs and statistical significance of coefficients on control variables are also unchanged across specifications and

also economically significant. For example, for the baseline OLS specification in Column (1), one standard deviation increase in intangible capital is associated with about 8 and 1/2 % increase in the cash ratio, which is equal to about half the sample mean value of the cash ratio of 15%. In the specification with firm fixed effects (Column (2)), the estimates decline by only about 2 and 1/2%, suggesting that intangible capital is also an economically significant determinant of the within-firm time-series evolution of cash holdings. Finally, estimates for firms with positive R&D are even larger than those for the entire sample, which suggests that our baseline OLS result is not spurious and that intangible capital is an even more important economic determinant of cash holdings for innovative firms.

When we replicate our tests for net leverage, which is the ratio of total debt net of cash to book assets, the coefficient on intangible capital is robustly negative and statistically significant across both samples and specifications. It is also economically significant. For example, for the baseline OLS specification in Column (3), one standard deviation increase in intangible capital is associated with about 11 % decrease in net leverage ratio, which is almost as large as the sample mean value of net leverage of 14%. These results suggest that intangible capital is not only an important determinant of firms' cash holdings decisions, but also of their capital structure and net indebtedness.<sup>11</sup>

**Quantifying the Contribution of Intangible Capital to the Rise in Cash** Figure 1 shows that cash holdings increased by about 10% over the last decades, from about 8% in 1970 to about 20% by 2010. How much does intangible capital really help in explaining such a large increase? To answer this question, we investigate how changes in firm characteristics over time affect cash ratios.<sup>12</sup> The intuition for this exercise is as follows: sample average intangible capital was 0.42 in 1980 and 0.75 in 2000. If the (unscaled) coefficient on intangible capital is 0.087, then we infer

---

are in line with the findings of the previous literature, with large firms and firms that pay dividends holding less cash, and firms with higher cash flow volatility and market-to-book holding more. The coefficients on capital expenditures and acquisitions are negative and significant, consistent with firms using their cash holdings to pursue investment opportunities.

<sup>11</sup>In additional checks, we have verified that these results are robust to controlling for R&D expenditures (flow), to using different definitions of cash ratios (cash as a ratio to market value of assets or net book assets), and to excluding entrants (i.e., firms that are not present in every year of the sample period) and firms in high technology sectors.

<sup>12</sup>To ease comparison and gauge the relative contribution of intangible capital compared to other standard determinants, we use the approach in Bates, Kahle, and Stulz (2006) and augment the OLS specification with net debt and equity issuance.

that, holding all other variables constant, the average cash ratio increased by 2.8 percentage points from 1980 to 2000 because of the increase in intangible capital, going from 3.7 percentage points ( $=0.087 \times 0.42$ ) in 1980 to 6.5 percentage points ( $=0.087 \times 0.75$ ) in 2000.

Panel A of Table 2 shows the results of this analysis that quantifies the contribution to the overall increase in the predicted cash ratio of changes in the firm-level determinants of that ratio. We first estimate the augmented OLS regression specification of Column (1) in the first half of the sample, i.e. the pre-1990 period. Using these coefficient estimates, we construct measures of the contributions of each of the explanatory variables in explaining changes in cash holdings between the 2000s and the pre-1990 period. Changes in intangible capital stand out as the most important driving factor of the rise in cash, with an increase in cash of about 3 (5) percentage points attributable to the increase in intangible capital in the overall sample (in the sub-sample of positive R&D firms). Changes in all other standard determinants have quite limited explanatory power for the rise in cash.

**Intangible Capital and Cash Dynamics** We further probe the role of intangible capital in driving the time-series dynamics of corporate cash management by adding a lagged dependent variable to our baseline specification. This new ingredient allows us to do two things: first, though we do not report the coefficient estimates for brevity, we check that our results are robust to allowing for imperfections in cash rebalancing or partial adjustment in cash ratios (Lemmon, Roberts, and Zender (2008)); second, we gather additional evidence on the role of financing frictions. In particular, we examine the hypothesis that intangible capital lowers the speed of adjustment (SOA) of cash: if intangibles make it more difficult to raise external finance, then they should be expected to increase adjustment costs of cash, thus leading to lower SOA (see Faulkender, Flannery, Hankins, and Smith (2012) for more details on this intuition).

Because there is an ongoing debate in the literature about the proper estimation procedure of SOA, Panel B of Table 2 reports results for a wide battery of SOA estimators. The annual SOA of cash ranges between 0.27 and 0.54 (not shown), suggesting that cash is imperfectly adjusted toward its target. To provide economic intuition, we translate these SOAs into half-lives, the time that it takes a firm to adjust one-half the distance to its target cash after a one unit shock to the error term. The half-life ranges from about 1 to about 2 years. Robustly across the different estimation

techniques, SOAs decline monotonically with intangible capital. For example, OLS estimates in Column (1) imply that the half-life of 3 years for firms in the top quartile of the distribution of intangible capital is almost three times larger than for firms in the bottom quartile. These results are consistent with the hypothesis that intangible capital increases adjustment costs of cash.

**Corporate Investment and Firm Dynamics** Our last set of empirical regularities pertains to the real side decisions of firms. We ask whether cash holdings are an important source of financing for firm investment and growth and, if so, whether their importance varies systematically with intangible capital. To that end, we regress total investment (the ratio of the sum of capex and R&D to net book assets) and sales growth on lagged cash holdings, while controlling for a set of standard determinants of investment (e.g., Gomes (2001)). We consider both OLS and firm fixed effects versions of this baseline model, with firm-level controls that include industry cash flow volatility, market-to-book ratio, firm size, cash flow, and a dummy for whether the firm pays dividend in any given year, as well as year effects. We evaluate statistical significance using robust clustered standard errors adjusted for non-independence of observations within firms.

The resulting estimates are reported in Panel A of Table 3 for the overall sample (Columns (1)-(4)) and for the subset of firms that report positive R&D (Columns (5)-(8)). The coefficient on lagged cash holdings is robustly positive and statistically significant across the two samples and both specifications, and is also economically significant. For example, for the baseline OLS specification in Column (1), an increase in lagged cash holdings from their lowest to their highest levels leads to about 7% increase in investment, which is almost as large as the sample mean value of investment of 10%. The estimate declines just a bit in the specification with firm fixed effects, and is even larger for firms with positive R&D, suggesting that cash holdings are an even more important source of financing growth opportunities for innovative firms.

Panel B of Table 3 shows that intangible capital strengthens the relation between cash holdings and firm investment and growth. In fact, when we run our investment and sales growth regressions separately for each of four bins of our sample depending on quartiles of the empirical distribution of intangible capital, the size of the coefficient on lagged cash holdings increases monotonically and about doubles as we move from the bottom to the top quartile. These findings hold robustly for both investment and sales growth, as well as for both the entire sample and the

sub-sample of firms that are active in R&D.

In summary, the empirical regularities on intangible capital, firm financing, and corporate investment are:

- Firm cash holdings (net indebttness) have increased (decreased) over time.
- Firm cash holdings (net indebttness) are positively (negatively) related to intangible capital, and their dynamics is more sluggish if intangible capital is high.
- Firm investment and growth are positively related to their cash holdings, and more so if intangible capital is high.

### **2.3.1 Why Does Intangible Capital Matter So Much?**

In our last set of panel results, we use sample-split analysis to better understand why intangible capital is an economically important determinant of corporate cash holdings. In particular, we examine both financial and real investment frictions, which are the key ingredients of our model. If firms with more intangible capital hold more cash because of financing frictions, we would expect that the relation between intangible and cash should be stronger among firms for which financing frictions are more severe. As for investment frictions, the basic insight of the vast literature on real options (e.g., Abel and Eberly (1994), Bertola and Caballero (1994)) is that fixed adjustment costs lead firms to make large, lumpy investments. Thus, if intangible capital makes it more difficult to raise external finance, these real frictions may lead firms with more intangible capital to accumulate even more cash to finance their large investments.

Panel A of Table 4 shows evidence supporting the role of financial frictions. We follow the standard approach in the literature (e.g., Hennessy and Whited (2007)) and in every year over the sample period we rank firms based on five ex-ante indicators of their financial constraint status, which include firm size, dividend payer status, the WW-Index by Whited and Wu (2006), a measure of asset liquidation value by Berger, Ofek, and Swary (1996), and an index of industry asset redeployability by Balasubramanian and Sivadasan (2009). We assign to the financially constrained (unconstrained) groups those firms in the bottom (top) quartile of the annual distribution of each of these measures in turn, except for the financial constraints index, for which the order-

ing is reversed. Consistently across specifications and irrespective of which indicator of ex-ante financing status is chosen, we find that the economic significance of the coefficient on intangible capital is much stronger in the sub-samples of firms that are more likely to face financial frictions. For example, the OLS coefficient in Column (1) more than triples when we go from the top to the bottom quartile of the firm size distribution (Rows [1] and [2]).

Panel B splits the sample between bottom and top quartiles of the following five (time-invariant) proxies of investment frictions: (4-SIC) industry frequency of investment inaction and an indicator for whether there are investment spikes in the industry, which are both defined following Cooper and Haltiwanger (2006); time-series skewness and kurtosis of annual aggregate industry investment, both based on Caballero (1999); and the time-series standard deviation of aggregate industry operating costs. The intuition underling these proxies is that, due to technological differences, the extent to which firms face fixed costs varies across industries. Thus, industries where fixed cost are higher are those where firms are more likely to adjust investment infrequently, and, conditional on adjusting, by a proportionally larger amount. In addition, in these industries fixed costs lead to a time-series distribution of aggregate investment that is sharply right-skewed and fat-tailed. Thus, we assign to the high (low) investment friction groups those firms in the top (bottom) quartile of the distribution of each of these measures in turn, except for the variability of operating costs, for which the ordering is reversed. Consistently across specifications and irrespective of the indicator chosen, the economic significance of the coefficient on intangible capital is much stronger in the sub-samples of firms that are more likely to face investment frictions. For example, the OLS coefficient in Column (1) about doubles for firms that are in industries with investment spikes compared to those without such spikes (Rows [3] and [4]).

### **3 A Structural Model of Corporate Cash Management**

This section develops a stylized dynamic model in which illiquidity of productive assets and financial market frictions interact with each other to determine firms' optimal liquidity management policies. Our general equilibrium framework allows us to derive the ergodic joint distribution of capital stock, financial assets/liability and idiosyncratic technology of heterogeneous firms, which is then used to construct the exact moments of endogenous quantities in a simulation-free



environment. Thus, the general equilibrium framework avoids any sampling biases stemming from Monte-Carlo style simulations. Furthermore, our comparative statistic analysis incorporates any endogenous feedbacks of market prices in general equilibrium. In our description of the model economy, we will focus on the firm problem. The definition of stationary equilibrium and the numerical method can be found in the Appendix.

### 3.1 Firms

#### 3.1.1 Technology

Firms combine labor and capital to produce and sell output in a competitive market. They use two different types of capital: tangible ( $K_T$ ) and intangible ( $K_N$ ). In particular, the production technology takes the following Decreasing-Returns-to-Scale (DRS) Cobb-Douglas form:

$$Y = Z^{1-(1-\alpha)\xi} [\Phi(K_T, K_N; \theta, \rho)^\alpha N^{1-\alpha}]^\xi - F_o, \quad 0 < \xi < 1 \quad (2)$$

where  $Z$  is an idiosyncratic technology shock,  $N$  is labor hours, and  $\Phi(K_T, K_N; \theta, \rho)$  is a capital aggregator that combines the two types of capital and transforms them into *capital services*. Production is subject to fixed operation costs, denoted by  $F_o$ , which make it possible for the firm to incur operating losses ex post. The idiosyncratic technology shock follows a  $N_z$ -state Markov Chain process with a transition function denoted by  $Q(Z, dZ')$ .<sup>13</sup>

We specify the capital aggregator as a linearly homogeneous function of the two capital stocks (see Epstein (1983)). More specifically, we adopt the following CES form:

$$\Phi(K_T, K_N; \theta, \rho) = \left[ \theta \left( \frac{K_T}{\theta} \right)^{-\rho} + (1 - \theta) \left( \frac{K_N}{1 - \theta} \right)^{-\rho} \right]^{-1/\rho} \quad (3)$$

where the elasticity of substitution is given by  $1/(1 + \rho)$ . We consider two different implementations of this model setup: first, a baseline formulation that makes additional parametric assumptions to preserve tractability while at the same time developing intuition about the main forces at work in the model; second, a more general formulation that explores the consequences of weak-

---

<sup>13</sup>The Markov Chain process is adopted to facilitate our analysis of ergodic distribution of firms' balance sheets in general equilibrium. Later, we generalize this process by a continuous Markov process.

ening some of the parametric assumptions of the first setup.

With this technology, a static profit maximization can be stated as:

$$\Pi(K_T, K_N; \theta, \rho) = \max_N \left\{ Z^{1-(1-\alpha)\xi} [\Phi(K_T, K_N; \theta, \rho)^\alpha N^{1-\alpha}]^\xi - wN \right\}.$$

It is straightforward to show that profits are equivalent to

$$\begin{aligned} \Pi(K_T, K_N; \theta, \rho) &= \eta(w) Z \Phi(K_T, K_N; \theta, \rho)^\gamma, \\ \text{where } \eta(w) &\equiv [1 - (1 - \alpha)\xi] \left[ \frac{(1 - \alpha)\xi}{w} \right]^{\frac{(1-\alpha)\xi}{1-(1-\alpha)\xi}}, \quad \gamma \equiv \frac{\alpha\xi}{1 - (1 - \alpha)\xi}. \end{aligned} \quad (4)$$

### 3.1.2 Capital Accumulation

To motivate firms' cash holdings, it is essential to introduce illiquidity of long-lived capital assets. To that end, we assume that all capital expenditures are only partially reversible (Abel and Eberly (1996)). We denote initial purchase prices and liquidation values by  $p_i^+$  and  $p_i^-$  for  $i = T, N$ . The partial irreversibility can be formally expressed as  $0 \leq p_i^- \leq p_i^+$  for  $i = T, N$ . Since the desire to hold cash arise from the imperfect resalability of capital assets, we immediately make a simplifying assumption: the initial purchase prices of two capitals are identical, i.e.,  $p_i^+ = p^+$  for  $i = T, N$ .

In addition, we also assume that adjustment of capital is costly in either direction because it involves fixed adjustment costs. We assume that the both types of capital face the same amount of fixed costs of adjustment, which we denote by  $F_k$ . Combining these two assumptions about the illiquidity of capital assets, we can express the adjustment cost of capital as

$$\Gamma(K'_i, K_i) = p_i(K'_i, K_i) [K'_i - (1 - \delta_i)K_i] + F_k \cdot \mathbf{1}[K'_i \neq (1 - \delta_i)K_i] \quad (5)$$

where the price of capital  $p_i(K'_i, K_i)$  is given by

$$p_i(K'_i, K_i) = \begin{cases} p^+ & \text{if } K'_i \geq (1 - \delta_i)K_i \\ p_i^- & \text{if } K'_i < (1 - \delta_i)K_i \end{cases} \quad (6)$$

for  $i = T, N$  with  $0 \leq p_N^- \leq p_T^- \leq p^+$ .  $\delta_i$  measures the depreciation rate of type  $i$  capital stock.

### 3.1.3 Financing Frictions

Firms have three financing options: (i) internal funds, including operating income and cash holdings; (ii) debt financing; and (iii) equity issuance. We consider capital market frictions that make the capital structure of the firm deviate from the Modigliani-Miller theorem. Next, we detail the debt and equity market frictions in turn.

**Debt Market Friction** It is well-established in the literature that more tangible capital assets support more debt (see Shleifer and Vishny (1992), Hart and Moore (1994) and Rampini and Viswanathan (2010) for theoretical arguments, and Sibilkov (2009) for empirical evidence). This is because intangible capital, by its very own nature, is difficult to verify in quality or quantity. In fact, it often embodies the human capital of developers, which cannot be easily transferred to a third entity in its entirety. As a consequence, intangible capital is rarely pledged as collateral in debt contracts. To capture this feature, we assume that the firm cannot commit to transfer the technology embodied in the intangible capital stock to creditors upon default. Since embodied human capital cannot be transferred, intangible capital cannot be liquidated for a positive value by a third party.<sup>14</sup>

Furthermore, in the spirit of Hart and Moore (1994) we assume that the firm's output is observable, but not verifiable by a court. Hence, no debt contract can be written on the outcome of the firm's output. Under this circumstance, as shown by Kiyotaki and Moore (1997), the only possible form of debt contract is a risk-free debt contract collateralized by capital assets. We differ from Kiyotaki and Moore (1997) in that only tangible capital assets constitute eligible collateral. The resulting risk-free debt contract is subject to the following borrowing constraint:

$$B' \leq B^{\max}(K'_T; p_T^-) \equiv p_T^- \frac{(1 - \delta_T)K'_T}{1 + r(1 - \tau_i)} \quad (7)$$

where  $r(1 - \tau_i)$  is after-tax interest rate. For later reference, we define the financial slack of the firm as  $B^{\max}(K'_T; p_T^-) - B'$ . A natural interpretation of  $B^{\max}(K'_T; p_T^-)$  is as collateralized line of

---

<sup>14</sup>However, we allow the firm to have downsizing option, i.e., the firm can partially liquidate intangible capital stock by incurring the liquidation cost  $1 - p_N^-$ . An implicit assumption is that the firm, as long as it operates as a going concern, commits itself to deliver the human capital to the entity that is obtaining the liquidated part of intangible capital.

credit arrangement. Note that the constraint is an occasionally binding one.

Financial slack can be decomposed into two parts as follows:

$$B^{\max}(K'_T; p_T^-) - B' = \underbrace{B^{\max}(K'_T; p_T^-) - \underbrace{\max\{0, B'\}}_{\text{Debt}}}_{\text{Unused line of credit}} + \underbrace{[-\min\{0, B'\}]}_{\text{Cash}}. \quad (8)$$

The second term on the right-hand side can be interpreted as debt while the last term is cash. The difference between the first and the second term is equivalent to the unused line of credit.

In our stylized setting, firms never hold debt and cash at the same time. In the case when a firm finds it optimal to have strictly positive cash balances, the firm's financial (liquidity) facility is composed of two terms: option to borrow up to the debt capacity given by  $B^{\max}(K'_T; p_T^-)$  and the cash holdings given by  $-\min\{0, B'\}$ . When the firm finds it optimal to carry debt, the firm's remaining liquidity facility is given by  $B^{\max}(K'_T; p_T^-) - \max\{0, B'\}$ , the unused line of credit. Our general equilibrium analysis will show how the tangibility of capital assets affect the economy-wide utilization rate of the line of credit as well as cash holdings via precautionary savings arising from financial market friction.

**Equity Market Friction** If there were no equity market frictions, the debt market friction would play no role since the firm could undo it at no cost by issuing new equity. Thus, to create a scope for active risk management policies, we assume that raising outside equity reduces the value of existing shareholders more than the notional amount of equity issuance (this assumption follows seminal contributions on corporate risk management such as Froot, Scharfstein, and Stein (1993) and Bolton, Chen, and Wang (2009)). We denote equity issuance and ex-dividend value of the firm by  $E$  and  $W$ , respectively. The assumption of costly equity financing implies that the share of the existing owners after the issuance of new shares is less than  $W/(W + E)$ . We capture the loss to existing shareholders using a "dilution" function,  $\varphi(E)$ , which takes the following parametric form:

$$\varphi(E) \equiv \varphi_0(K_T + K_N) \cdot \mathbf{1}(E \geq 0) + \varphi_1 \cdot \max\{0, E\}. \quad (9)$$

In words, the firm incurs fixed costs when issuing new equity, which are proportional to its size. In addition, the firm also incurs linear costs that are proportional to the amount issued. This

parametric choice is standard in the literature and facilitates comparison with the results of Bolton, Chen, and Wang (2009), who show that fixed costs of equity issuance significantly strengthen firms' precautionary demand for cash.

### 3.1.4 Value Maximization Problem

For our baseline implementation of the model, we adopt a limiting case,  $\rho = \infty$ : tangible capital and intangible capital are not substitutable at all.<sup>15</sup> In this limiting case, the capital aggregator converges to a Leontief function:

$$\Phi(K_T, K_N; \theta, \rho) = \min \left\{ \frac{K_T}{\theta}, \frac{K_N}{1-\theta} \right\}. \quad (10)$$

We define the total capital stock as  $K \equiv K_T + K_N$ .<sup>16</sup> Since the Leontief assumption requires  $K_T/\theta = K_N/(1-\theta)$ , then the capital services can be expressed as

$$\Phi(K_T, K_N; \theta, \rho) = \frac{K_T}{\theta} = \frac{K_N}{1-\theta} = K.$$

Substituting this expression in (4) yields the conventional expression for the profit function,  $\Pi(K) = \psi(w)ZK^\gamma$ . We make another simplifying assumption: the depreciation rate of the two types of capital is identical and denoted by  $\delta$ .

The flow of funds constraint facing the firm can be expressed as

$$D = (1 - \tau_c) [\Pi(K_T, K_N; \theta, \rho) - F_0] - \sum_{i=T,N} [\Gamma(K'_i, K_i) - \tau_c \delta K_i] - [1 + r(B)]B + B' + E - \varphi(E) \quad (11)$$

where  $D$  denotes the dividends payout,  $\tau_c$  is a flat rate corporate income tax.<sup>17</sup> We allow  $B'$  to be negative, in which case  $B'$  is investment in liquid assets (cash accumulation). We assume that the interest income tax rate,  $\tau_i$ , is lower than corporate income tax rate,  $\tau_c$ , which creates scope for the firm to accumulate debt. We also assume that when the firm invest in liquid assets – i.e., when it accumulates cash, it earns a return that is strictly less than risk-free after tax return,  $r(1 - \tau_i) - \kappa$ .

<sup>15</sup>In fact, while we take this case for tractability reasons, we view this case more realistic than other alternatives.

<sup>16</sup>Under our simplifying assumption,  $p_T^+ = p_N^+ = p^+$ , we do not need define tangible capital ratio using nominal prices of heterogeneous capital stocks.

<sup>17</sup>For simplicity, we assume no dividend taxation.

We interpret the gross  $\kappa$  as agency cost of cash holdings (see Bolton, Chen, and Wang (2009)). Hence, after-tax interest rate can be expressed as

$$r(B) = \begin{cases} r(1 - \tau_c) & \text{if } B \geq 0 \\ r(1 - \tau_i) - \kappa & \text{if } B < 0 \end{cases} \quad (12)$$

Despite the tax advantage of debt, the firm may optimally choose to hold cash. In order to preserve tractability,<sup>18</sup> we do not introduce frictions, such as transaction costs, that make frequent refinancing of debt costly. These additional frictions may lead the firm to simultaneously hold debt and liquid assets, an issue that is not central to the main logic of our model.

The firm problem can be defined recursively as the maximization of the value of equity by choosing  $K'$ ,  $B'$ ,  $D$  and  $E$ ,

$$\begin{aligned} V(K, B, Z) = \min_{\lambda, \psi} \max_{K', B', D, E} & \left\{ (1 + \lambda)D - E + \psi \left[ \frac{p_T^-(1 - \delta)\theta}{1 + r(1 - \tau_i)} K' - B' \right] \right. \\ & \left. + \frac{1}{1 + r(1 - \tau_i)} \int V(K', B', Z') Q(Z, dZ') \right\} \quad (13) \\ \text{s.t. (11)} \end{aligned}$$

where  $\lambda$  and  $\psi$  are the Lagrangian multipliers associated with the nonnegativity constraint for dividends and the collateralized borrowing constraint, respectively. Note that the firm discounts the continuation value with after-tax risk free rate. While we adopt a general equilibrium framework, we solve for a stationary equilibrium without aggregate shocks. For this reason, we do not use the stochastic discounting factor of the household.

## 4 Financial and Investment Policies of the Individual Firm

In this subsection, we qualitatively characterize the properties of optimal investment and financial policies before we turn to the quantitative analysis. The presence of non-convex costs of equity issuance and capital adjustment complicates the analytic characterization of the problem at hand. However, we show that conventional variational tools can be applied to handle the issue along the line of Abel and Eberly (1994). For the discussion below, the following property of the model

---

<sup>18</sup>Technically, to consider this case we would need to introduce an additional state variable.

is useful. Using Benveniste-Scheinkman's formula, one can derive the marginal effect of debt on equity value as

$$V_B(K, B, Z) = -(1 + \lambda)[1 + r(B)] = \begin{cases} -(1 + \lambda)[1 + r(1 - \tau_c)] & \text{if } B \geq 0 \\ -(1 + \lambda)[1 + r(1 - \tau_i) - \kappa] & \text{if } B < 0 \end{cases} \quad (14)$$

or equivalently

$$\lambda = -\frac{V_B}{1 + r(B)} - 1. \quad (15)$$

This condition says that the shadow value of internal funds is determined by the difference between the slope of the equity value function with respect to debt/cash and 1. In a Miller-Modigliani world, the slope should be always equal to  $-[1 + r(B)]$  regardless of the net-debt position of the firm, leaving the shadow value always equal to 0. However, as will be shown, the slope of the equity value function is not always equalized to  $-[1 + r(B)]$  when the marginal change in the net-debt position reduces the equity value more than  $1 + r(B)$ , a sign of financial distress, which then has important consequences for the dynamics of risk management and investment strategies.

#### 4.1 Equity Issuance Policy

The equity issuance cost function  $\varphi(E)$  is everywhere differentiable except at  $E = 0$ . Let  $\varphi'(0)^+$  and  $\varphi'(0)^-$  denote right hand side and left hand side derivatives of  $\varphi(E)$  at  $E = 0$ , respectively. Then the efficiency conditions for financial policies can be summarized as follows:

$$E : \begin{cases} 1 = (1 + \lambda)[1 - \varphi'(E)] & \text{if } \lambda < \lambda^- \text{ or } \lambda \geq \lambda^+ \\ E = 0 & \text{if } \lambda^- \leq \lambda < \lambda^+ \end{cases} \quad (16)$$

where

$$\lambda^- \equiv \varphi'(0)^- / [1 - \varphi'(0)^-]$$

and

$$\lambda^+ \equiv \varphi'(0)^+ / [1 - \varphi'(0)^+].$$

and  $\varphi'(E) = \varphi_1 \cdot 1(E > 0)$ .

Using (9), it is straightforward to verify that  $\lambda^- = 0$  and  $\lambda^+ = \varphi_1/(1 - \varphi_1)$ . Suppose that the firm has an interior solution, i.e.,  $E > 0$ . Since  $\varphi'(E) = \varphi_1 \cdot 1(E > 0)$  and  $1 = (1 + \lambda)[1 - \varphi'(E)] = (1 + \lambda)(1 - \varphi_1)$ , the interior solution implies  $1 + \lambda > 1$ . In words, the firm issues new shares only if the shadow value of internal funds  $\lambda$  is strictly greater than 0. However, the second line of the efficiency conditions (16) shows that the converse is not true: the shadow value of internal funds can be greater than 0 even when the firm does not issue new shares. The presence of fixed costs of issuance makes it optimal for the firm to postpone issuance until the liquidity condition becomes dire enough in the sense of  $\lambda \geq \lambda^+$ . Or equivalently, using (15), equity financing is warranted if and only if

$$-\frac{V_B}{1 + r(B)} \geq 1 + \lambda^+ = \frac{1}{1 - \varphi_1}.$$

Otherwise, it is optimal neither to pay out dividends nor to issue new equity, something that can be dubbed *inaction in financial policy*.

## 4.2 Debt/Cash Policy

The efficiency condition for the debt/cash policy is given by

$$B' : 0 = 1 + \lambda - \psi + \frac{1}{1 + r(1 - \tau_i)} \int V_B(K', B', Z') Q(Z, dZ'). \quad (17)$$

Using (14), we can transform the efficiency condition into an Euler equation.

### 4.2.1 Investment in Liquid Assets

When the firm invests in liquid assets – i.e., when it accumulates cash, the collateral constraint becomes slack,  $\psi = 0$  since  $B' < 0$ . Hence, by combining the efficiency condition (17) with (14), we obtain

$$1 + \lambda = \int (1 + \lambda') \frac{1 + r(1 - \tau_i) - \kappa}{1 + r(1 - \tau_i)} Q(Z, dZ') \quad (18)$$

The left-hand side of the above expression can be thought of as the marginal cost of investment in liquid assets whereas the right-hand side is the marginal benefit. Based on this Euler equation, we can make several observations.

First, it is never optimal to issue new shares and invest in liquid assets simultaneously. To



see this formally, assume that the firm issues new shares today. As shown in the discussion of the efficiency condition for equity issuance, equity issuance is optimal if and only if  $\lambda \geq \lambda^+ = \varphi_1/(1 - \varphi_1)$ . The first order condition for equity issuance  $1 = (1 + \lambda)[1 - \varphi'(E)]$  and the functional assumption for the issuance cost (9) imply that  $\lambda$  is bounded above by  $\varphi_1/(1 - \varphi_1)$ . Hence it must be the case that  $\lambda = \varphi_1/(1 - \varphi_1)$  (since the firm issues new shares) and  $\lambda' \leq \varphi_1/(1 - \varphi_1)$  (since the shadow value is bounded). However, (18) cannot be satisfied in this case because the present value of the return on liquid asset is less than or equal to 1, i.e.,  $1 - \kappa/[1 + r(1 - \tau_i)] \leq 1$  unless the agency cost of cash holdings is strictly negative. Intuitively, the firm invests in cash to avoid raising external financing in the future. Hence, it is suboptimal to use external financing to invest in cash today, and even more so when there is a strictly positive agency cost of cash holdings.

Second, while it is never optimal to issue shares and invest the proceeds in cash, it is rational to stop paying dividends and accumulate cash within the firm. This is the case when  $\lambda > 0$ , but  $\lambda < \lambda^+ = \varphi_1/(1 - \varphi_1)$ . The Euler equation (18) suggests that this is more likely to be the case when the firm expects tomorrow's liquidity condition to be tight such that strictly positive realizations of  $\lambda'$  are given greater probability weights. Otherwise, (18) may not be satisfied. For an example, consider the extreme case where the firm assigns essentially zero weight to the event associated with  $\lambda' > 0$ . In this case, (18) cannot be satisfied since the left hand side is greater than or equal to 1 whereas the right hand side is strictly less than 1 due to the agency cost of cash holding. This suggests that the firm is unlikely to carry liquid assets to tomorrow if the firm's liquidity constraint is expected to be loose. Conversely, the firm is more likely to invest in cash if it expects the liquidity condition to be tight either because of investment opportunities or operating losses.

Third, it is conceivable, but not highly likely that the firm pays out dividends and save some resources in cash. This is the case of  $\lambda = 0$ . Since  $0 \leq \lambda' \leq \lambda^+ = \varphi_1/(1 - \varphi_1)$ , to satisfy (18) requires that the agency cost should be strictly positive. If there are no agency costs at all, the financing mode of paying out dividends and maintaining a positive retention simultaneously makes sense only in the extreme case when the firm is certain about  $\lambda' = 0$ . Otherwise, the marginal benefit of cash holdings (the right hand side) may be strictly greater than the marginal cost of cash holdings (the left side), and the firm may have insatiable liquidity demand. With nonzero agency costs of holding cash, however, the firm finds it optimal to disburse at least some

portion of financial slack to shareholders as dividends. A small agency cost of cash holdings ensures that the problem is stationary. In our baseline calibration, we specify a strictly positive, but very small agency cost.<sup>19</sup>

#### 4.2.2 Debt Issuance

In this case, the collateral constraint becomes relevant and the Euler equation for  $B'$  takes the following form:

$$1 + \lambda - \psi = \int (1 + \lambda') \frac{1 + r(1 - \tau_c)}{1 + r(1 - \tau_i)} Q(Z, dZ'). \quad (19)$$

The left hand side measures the marginal benefit of debt financing whereas the right hand side measures the marginal cost of debt. The first thing to note is that the present value of return is now replaced by  $[1 + r(1 - \tau_c)]/[1 + r(1 - \tau_i)] \approx 1 - r\Delta\tau < 1$  where  $\Delta\tau \equiv \tau_c - \tau_i$ . (19) can then be used to make a few observations.

First, the firm never issues equity before it uses up its borrowing capacity, hence the ‘pecking order’ obtains. To see this, suppose that this is not the case, i.e., the firm issues new shares while keeping the collateral constraint slack. This would be the case with  $\lambda = \varphi_1/(1 - \varphi_1)$  or equivalently  $1 + \lambda = 1/(1 - \varphi_1)$ , but  $\psi = 0$  (since the borrowing constraint is a slack). Since  $1 - r\Delta\tau < 1$  and  $1 + \lambda' \leq 1 + \lambda$ , (19) cannot be satisfied. Conversely, if  $\lambda = \varphi_1/(1 - \varphi_1)$ , it must be the case that the collateral constraint binds, i.e.,  $\psi > 0$  to satisfy (19). Intuitively, there is no reason for the firm to use equity finance when debt financing is still available and tomorrow’s debt capacity is independent of the amount of unused line of credit today.

Second, it is perfectly rational, though it may sound imprudent, to borrow funds and use the proceeds to pay out dividends, an issue that has recently attracted a fair deal of criticism in the media. However, this is simply a consequence of tax distortions: if  $\Delta\tau = 0$ , such a policy cannot satisfy (19) under uncertainty since  $1 + \lambda = 1 \leq 1 + \lambda'$ . In fact, it may be even optimal to borrow up to the limit, i.e.,  $\psi > 0$  if the tax differential is sufficiently large and the likelihood of financial distress tomorrow is low (i.e.,  $\lambda' > 0$  is a low probability event). Using computation, we show that this is indeed typical for firms that lack growth options due to either overcapacity or low expected

---

<sup>19</sup>Unfortunately, we realized this the hard way: Initially, we worked with  $\kappa = 0$  in our dynamic programming, and realized that there were some states in which cash holdings were unstable in the sense that the policy function  $g_B$  stays below 45 degree line on  $(B, B')$  diagram, which means that the firm ever wants to decrease the level of  $B$ . In contrast, if the agency cost of cash holdings is too high, the firm may never want to hold any cash in its balance sheet.

profitability, which means a very small likelihood of the firm facing liquidity problems tomorrow.

Third, it is also completely rational to stop paying dividends without issuing new shares ( $0 < \lambda < \varphi_1/(1 - \varphi_1)$ ) and use up the borrowing capacity ( $\psi > 0$ ). Two very different situations can be consistent with this financing mode: if the firm has a good investment opportunity, it may be optimal to use up all of its financial slack including unused borrowing capacity to exercise the investment option; Even when the firm lacks an investment opportunity, such a financing mode may be necessary if the firm inherits a debt overhang problem from the past, in which case, debt financing today simply reflects a poor balance sheet condition rather than aggressive investment policy.

Finally, it is possible for the firm to borrow today, but not to use up its borrowing capacity ( $\psi = 0$ ). The firm may or may not pay dividends, i.e.,  $0 \leq \lambda < \varphi_1/(1 - \varphi_1)$ , although issuing new shares ( $\lambda = \varphi_1/(1 - \varphi_1)$ ) in this situation is inconsistent with slack in the borrowing capacity as shown above ('peking order'). This is the case in which the firm uses the unused line of credit as a risk management tool. Since today's borrowing affects tomorrow's liquidity condition, the firm may have an incentive to preserve some slacks in borrowing capacity despite the forgone tax benefits in anticipation of investment opportunity tomorrow.

### 4.3 Investment Policy

The adjustment cost function  $\Gamma(K', K)$  is everywhere differentiable except at  $\Gamma((1 - \delta)K, K)$ . Following Abel and Eberly (1994), we define  $\Gamma_{K'}((1 - \delta)K, K)^+$  and  $\Gamma_{K'}((1 - \delta)K, K)^-$  as the right-hand side and left-hand side derivatives of  $\Gamma(K', K)$ . We also define Tobin's marginal  $q$  as<sup>20</sup>

$$q^M \equiv \frac{1}{1 + r(1 - \tau_i)} \int V_K(K', B', Z') Q(Z, dZ'). \quad (20)$$

We can then derive the efficiency condition as

$$K' : \begin{cases} (1 + \lambda)\Gamma_{K'}(K', K) - \psi \frac{p_T^-(1 - \delta)\theta}{1 + r(1 - \tau_i)} = q^M & \text{if } q^M < q^- \text{ or } q^M > q^+ \\ K' = (1 - \delta)K & \text{if } q^- \leq q^M \leq q^+ \end{cases} \quad (21)$$

<sup>20</sup>Note that the presence of the non-convex adjustment cost makes  $V_K$  discontinuous in some situations. However, such situations are measure zero events, and thus  $V_K$  is still integrable.

where

$$q^- \equiv (1 + \lambda)\Gamma_{K'}((1 - \delta)K, K)^- - \psi \frac{p_T^-(1 - \delta)\theta}{1 + r(1 - \tau_i)}$$

and

$$q^+ \equiv (1 + \lambda)\Gamma_{K'}((1 - \delta)K, K)^+ - \psi \frac{p_T^-(1 - \delta)\theta}{1 + r(1 - \tau_i)}.$$

Without financial frictions, i.e.,  $\lambda = \psi = 0$  always, (21) implies that there are two investment targets, one for expansion when  $K' > (1 - \delta)K$ , the other for contraction when  $K' < (1 - \delta)K$ . Between these two targets, there exists an inaction region where neither expansion nor contraction are warranted. This is because investment fundamentals as measured by  $q^M$  are neither good enough nor bad enough.

However, owing to the financial market frictions, there can be continua of investment and disinvestment targets. To see this, consider the case of expansion:

$$(1 + \lambda)p^+ - \psi \frac{p_T^-(1 - \delta)\theta}{1 + r(1 - \tau_i)} = q^M$$

where we use the fact  $\Gamma_{K'}(K', K) = p^+$  if  $K' > (1 - \delta)K$ . The left-hand side measures the marginal cost of investment while the right-hand side measures the marginal benefit. It is evident that costly equity financing increases the cost of investment to  $(1 + \lambda)p^+ \geq p^+$ . The collateral constraint, however, decreases the marginal cost of investment, since increasing production capacity increases debt capacity. Note that the higher is the tangible capital ratio,  $\theta$ , the greater is the reduction in marginal cost of borrowing. Thus, as production becomes more intangible capital intensive (as  $\theta$  goes down), investment becomes more sensitive to internal funds. In other words, the sensitivity of investment to internal funds is a decreasing function of the tangible capital ratio,  $\theta$ .

## 5 Results

### 5.1 Calibration

To characterize optimal policies, we rely on numerical analysis. We choose the following baseline calibration. The elasticity of the profit function with respect to capital service ( $\gamma$ ) is set equal to

0.6 as in previous studies (for instance, Hennessy and Whited (2007)). We set the depreciation rate equal to 0.10. We set the resale value of capital  $p^- = p_T^- = p_N^- = 0.95$ . This is a small discount, especially compared to 0.8 of Ramey and Shapiro (2001). However, such a small discount is large enough to generate substantial amount of saving in liquid asset holdings.<sup>21</sup> To parametrize the fixed cost of investment, we follow Cooper and Haltiwanger (2006), who estimate the fixed cost of investment as about 0.01 of installed capital. In our adaptation, we set this value proportional to the steady state level of capital accumulation in the frictionless benchmark. The fixed cost of operation ( $F_O$ ) is set equal to 0.05 following Gilchrist, Sim, and Zakrajsek (2010). This value helps to match dividend payout ratio in the data given other parameters of the model. To calibrate the idiosyncratic technology shock process, we set  $\rho_z = 0.8$  and  $\sigma_z = 0.3$ , which is roughly in line with the estimates of Gourio (2008) regarding the transitory part of idiosyncratic shock process using Compustat data. As for the tangible-to-intangible capital ratio  $\theta$ , we provide an extensive set of comparative statistics.

The risk free rate is calibrated as 0.06, such that the after tax annual interest rate is about 0.04. We choose the fixed cost of equity issuance to be 1.5 percent of the steady state level of capital stock in a frictionless model. This is slightly higher than in Bolton, Chen, and Wang (2009), for example. For the linear cost of equity issuance, there is a range of estimates/calibrations in the literature from 0.06 (Gomes (2001)) to 0.30 (Cooley and Quadrini (2001)). We choose a value of 0.15 to be on the conservative side of the middle range. Finally, we set the corporate income tax and interest income tax rates as 0.35 and 0.30, respectively. As will be shown, this difference is large enough to create a substantial incentive to accumulate debt without the need to make additional assumptions on firms' discounting factor or death probability. Finally, we specify a very small agency cost of cash holdings, 5bps. This small value is sufficient to circumvent the issue of nonstationarity of cash holdings discussed above.

---

<sup>21</sup>We have tried a range of resale value between 0.60 and 0.95. While a lower resale value of capital generates more cash holdings, we have found that this is not a first order effect. In fact, we choose 0.95 to shut down this additional channel.

## 5.2 Properties of the Real and Financial Policies

### 5.2.1 Financial Frictions, Investment Options, and Dynamic Risk Management

We start with a characterization of the financial and real investment policies of the firm in the baseline formulation of the model in partial equilibrium. By way of summary, in this section we consider financial (cash and debt) and investment policy functions,  $B' = g_B(K, B, Z)$  and  $K' = g_K(K, B, Z)$ , respectively. We ask the following three questions: how do firms' growth options,  $Z$ , given  $(K, B)$ , affect investment and risk management strategies?; how do firm's financial conditions, measured by  $B$ , given  $(K, Z)$ , affect a firm's liquidity demand?; and how does the technological parameter  $\theta$ , given  $(K, B, Z)$ , affect a firm's liquidity management decisions?

Figure 3 displays (i) optimal choice of cash/debt ( $B'$ , cash when negative and debt when positive, top panels), (ii) usage of line of credit  $(1 - \max\{0, B'\} / B^{\max}(K'_T; p_T^-))$ , middle panels) and (iii) capacity choice ( $K'$ , bottom panels) as functions of current level of installed capital ( $K$ , horizontal axis) for two different levels of technology ( $Z$ ) and for a given financial condition ( $B$ ). We consider deviations of the technology level from its steady state of 30% below (blue solid lines) and 30% above (black dash-dotted lines). We set the current net-debt outstanding at its unconditional mean level in our stochastic simulation with  $T = 200$  periods and  $N = 10,000$  firms, i.e., we fix  $B$  at  $\bar{B} \equiv 1 / (TN) \sum_{it} B_{it}$ . To highlight the properties of liquidity demand, we set  $\theta = 0.4$ , a very low level of tangible capital ratio, and hence, a very low level of pledgeability of production assets. In fact, this value of  $\theta$  is associated with large average net financial asset holdings as a ratio to total assets (the sum of book value of capital and liquid asset holdings),  $1 / (TN) \sum_{it} B_{it} / A_{it} = -0.23$  in our simulation with fixed cost of investment. The panels to the left ((a), (c) and (e)) show results for the model with only partial irreversibility, which we contrast with results for the model that adds fixed adjustment cost of investment to partial irreversibility shown in the panels to the right ((b), (d) and (f)).

First, consider the case of partial irreversibility. The most striking feature of the optimal financial policy is that cash hoarding is associated with the low technology draw while leverage build-up is associated with the high technology draw (panel (a)). When the current technology is low, the growth option of the firm is 'in the money' for a substantial range of production capacity, and the firm finds it optimal to accumulate a large amount of liquid assets in order to preserve its

future investment options and prepare for next expansion. Note that cash accumulation is costly since the firm forgoes the tax advantage of debt.<sup>22</sup>

These features of firms' financial policies hinge crucially upon the assumption that the firm has no overcapacity problem. If this assumption is not met, the financial strategy can take a dramatic turn: pay out all surplus cash flow as dividends and repurchases, and issue new debt to exploit the tax benefits. In the region where the capital accumulation level is over 0.5 in panel (a), the growth option associated with the low technology is so deep 'out of the money' that the firm assesses the probability of unexpected large cash needs to be very small. As a result, the firm starts running down its cash balances, and eventually accumulates a positive amount of debt. In panel (c), investment is indeed inactive in this region, approximately  $[0.5, 1.0]$ .

Furthermore, the firm starts liquidating capital despite the discount  $(1 - p^-)$  once its capacity hits a boundary level of about 1. The vertical difference between  $(1 - \delta)k$  (grey-thin-solid line) and flat level of blue line in panel (e) measures the amount of disinvestment in the region with capital accumulation level greater than 1. By contrast, when current capacity is very low, as, for instance, in the region below a capital accumulation level of 0.5, the marginal productivity of capital is so high that strictly positive investment is warranted despite the low current technology. In this situation, the firm partially decreases its cash holdings to finance its capital expenditure, although some portion of its cash holdings is still carried into the next period. In this region, investment increases linearly as the gap between the  $(S, s)$  target and the currently installed capital becomes greater.

Panel (c) shows how the firm operates its line of credit as another risk management tool. By construction, the area of zero usage of line of credit coincides with the area associated with positive cash holdings. When the firm issues a strictly positive amount of debt to exploit corporate income tax shield, it is still optimal to maintain a certain amount of unused line of credit to cover future investment opportunities or operating losses. In the figure, one can see that the firm withdraws its line of credit in the area with capital accumulation level greater than 1, but keeps more than

<sup>22</sup>To see this, consider that the firm earns  $1 + r(1 - \tau_i)$  by investing liquid assets. Since the discount factor of the firm is also  $1 + r(1 - \tau_i)$ , cash earns nothing in terms of present value. However, debt creates immediate financial profits given by  $1 - [1 + r(1 - \tau_c)]/[1 + r(1 - \tau_i)]$  owing to the differential tax treatment of debt in the U.S. tax code. Hence, without financial market frictions that makes outside equity costly to raise, the firm would not hoard cash. It would not only distribute any financial surplus to the shareholders, but also issue debt to distribute additional financial gains from tax benefits to the shareholders, expecting that it will be able to raise additional fundings from the shareholders if needed.

half of its borrowing capacity unused.

The firm's financial policy takes a very different form when the technology level is high, the case of black, dash-dotted lines in the figure. Since the growth option is deep 'out of the money' in this case, the firm disburses all of its resources to finance a large scale expansion of productive capacity especially when capital accumulation level is approximately below 1.3. Furthermore, it issues new debt in the entire state space and uses the proceeds for capacity expansion when capital accumulation level is below 1.3, and for tax benefits when capital accumulation level is above 1.3. In panel (e), one can see that investment expenditures increase linearly as we move from the current capacity level of 1.3 to the left, since the gap between target capacity and actual capacity grows.

However, near the capacity level of 0.3, the investment function is kinked. This is the effect of costly equity financing. At this level of current capacity, the amount of financing that can be raised through internal funds and drawdown of unused line of credit is not sufficient to cover investment expenditures that would have been chosen without financial frictions. As a result, the capacity target itself becomes a function of firm's financial conditions, which include the current capacity given its current net debt position, a feature that does not exist for a nonconvex adjustment cost model without financial frictions: in contrast to the frictionless case, there exists a continuum of expansion targets corresponding to a firm's financial condition.

When the firm's overcapacity problem is severe enough, even a high level of technology does not warrant capacity expansion and investment is inactive in the region where the current capacity level is greater than 1.3. The financial policy in this case is simply decrease cash holdings by paying out dividends and build up leverage to exploit tax benefits. Panel (c) shows that the usage of debt capacity takes a dramatically different form: when the capital accumulation level is above 1.6, the firm completely uses up its borrowing capacity for maximum tax benefits. This is in stark contrast to the case of the low technology. The firm views a positive investment as not warranted not only for today, but also for the near future. Again, mean reversion plays an important role here: owing to mean reversion and its current, unusually high technology, the firm's expected profitability is declining.

When the adjustment of capital involves fixed costs, investment and financial policies have broadly similar contours to those of the pure irreversibility case. However there are important



differences. First, investment involves a much wider inaction region (panel (f)). Second, investment also involves ‘burst’ episodes. For instance, investment at around  $K = 0.3$  (blue solid line) or  $K = 0.8$  (black, dash-dotted line) disproportionately jumps up, and investment (blue solid line) jumps down at around  $K = 1.7$ . These jumps are about as large as 30% of existing capacity, which is what Cooper and Haltiwanger (2006) classify as (dis)investment “spikes” or “lumpy investment.” In fact, lumpy investment is what the firm wants to insure itself against by holding extra cash. Comparing panel (a) and (b), one can see that the firm’s optimal liquidity holdings increase substantially when there are fixed costs of investment. Note that as in the case of pure irreversibility, investment functions are kinked around low levels of capital accumulation due to the financial friction, which generates convex adjustment like dynamics even though there are no such convex adjustment costs in the model.<sup>23</sup>

### 5.2.2 Investment Predictability: Cash vs. Tobin’s Q

The configuration of dynamic risk management under financial frictions and investment dynamics under nonconvex adjustment frictions implies that cash and Tobin’s Q may have predictive power, not for current investment, but for future investments. To explore this possibility, we first define Tobin’s (average) Q in our context as

$$q^A \equiv \frac{1}{1 + r(1 - \tau_i)} \int \frac{W(K', B', Z')}{K'} Q(Z, dZ')$$

where the total value of firm  $W$  is defined as

$$W(K, B, Z) \equiv V(K, B, Z) + [1 + r(B)]B.$$

Note that in an empirical context the term  $[1 + r(B)]B$  should be interpreted as the market value of *net debt* position, i.e., the market value of ‘total debt minus cash and cash equivalents’. This means that for some firms, the total value of the firm ( $W$ ) may be *less* than the value of equity ( $V$ ) as the

---

<sup>23</sup>This is one reason why ‘structural’ estimates from simulation based estimators may overstate the role of convex adjustment friction and simultaneously understate nonconvex adjustment frictions if the underlying modes lack proper financial structures.

firm has become *net creditor*.<sup>24</sup> The top panels of figure 4 show how Tobin's Q responds to changes in capital accumulation with the left panel displaying the case of pure irreversibility and the right panel the case of mix of irreversibility and fixed costs of adjustment. We assume the same financial conditions used in figure 3, and we also consider the same two levels of idiosyncratic technology with blue solid line showing the case of 30 percent lower than the steady state level and the black, dash-dotted line the case of 30 percent higher.

A few observations are immediate. First, Tobin's Q is non-monotonic with respect to installed capital,  $k$ . Second, Tobin's Q may not even be continuous. For instance, consider panel (b) together with (d), which shows gross investment,  $I = K' - (1 - \delta)K$  with 0 implying inaction. Tobin's Q is discontinuous exactly at the action/inaction boundaries. Third, Tobin's Q is negatively correlated with investment when we vary the level of technology holding  $(B, K)$  constant, while it is positively correlated with investment when we vary the level of installed capital holding  $(B, Z)$  constant, with both aspects roughly offsetting each other, thus likely to generate a zero contemporaneous correlation between Tobin's Q and investment. Fourth, Tobin's Q for the case of low technology is higher (lower) than the one of high technology exactly when net-debt policy  $g_B(K, B, Z_{low})$  is placed lower (higher) than  $g_B(K, B, Z_{high})$  in figure 3, suggesting that the ordering of Tobin's Q might be driven by the same mechanism behind the opposite ordering of net-debt policy. To put it more simply, Tobin's Q is higher when the firm's liquidity demand, including unused line of credit, is higher. As shown in the previous section, firms tend to hoard more cash *in anticipation of* the arrival of investment opportunities. If so, the market value of the firm should increase at the time when the firm saves in liquid assets, not because of the direct contribution of cash and equivalents to firm value, but because the market value reflect the value of growth option. If investment is currently postponed, but expected in the near future, Tobin's Q should be unusually high. In contrast, right after the adjustment of capital stock, Tobin's Q should be lower because the firm has already exercised the growth option and the denominator of Tobin's Q has just expanded substantially in a lumpy fashion. This is why in figure 4, Tobin's Q jumps down right after a positive lumpy adjustment and jumps up right after a negative lumpy adjustment. Such considerations suggest that both cash holdings and Tobin's Q should convey the same

---

<sup>24</sup>We did not use the total value of the firm, but the value of equity when we define the marginal Q (20). This is because the marginal effects of capital on the firm value and the equity value are identical.

information regarding future investments. We will verify this prediction using our simulation.

### 5.2.3 Financial Frictions and Debt/Cash Dynamics

In this subsection, we show how past financial conditions affect the dynamics of risk management. To that end, we consider hypothetical firms with an identical level of technology (at its steady state). In the upper panels of figure 5, we show how firms' liquidity demand changes as their initial financial condition changes. More specifically, we consider three levels of  $B$  that would imply net debt ratios relative to the steady state level of total assets (book value of capital plus cash,  $B / \bar{A}$ ) of -0.3 (blue, solid line), 0.0 (black, dash-dotted line), and 0.30 (red, dashed line), respectively. The first can be considered as the case of so called *cash cow* firm, a special case with ample financial slack that allows the firm to behave like a financially frictionless firm in most of the state space. The third can be thought of as the case of the firm with weak balance sheet condition, which are potentially subject to financial distress. Roughly, this case matches the net-debt structure of the firms in the 75 percentile of net-leverage distribution in 2012Q4 of Compustat. The second is an intermediate case. For each of these cases, we are holding all else equal, most importantly, firm's technological fundamentals, i.e., current technology level and the ratio of tangible asset at  $\theta = 0.4$ .

The key takeaway here is that there is a tremendous amount of *inertia* in firm's financial position: firms that have net financial assets (positive net debt) today are more likely to hold net financial assets (positive net debt) tomorrow. In a frictionless world with no adjustment costs of financial assets/liabilities, there is no reason to expect such inertia since equity markets should provide perfect shock absorption. Equity frictions are responsible for making financial variables slow moving. Thus, the inertial dynamics of firms' balance sheet is an indicator of financial frictions.

This is also related to the phenomenon known as cash sensitivity to cashflow in the literature (see Almeida, Campello, and Weisbach (2004)). A poor balance sheet condition is likely to lead to a poor cashflow, and under frictional financial markets, such poor cashflow condition is likely to lead to a poor balance sheet condition tomorrow. What is surprising in our results is that it is not only the firms with positive net debt position that exhibit sensitivity to cashflow in their cash/debt policy, but it is also the firms with ample financial slacks that show sensitivity to current finan-

cial conditions. This is because the seemingly unconstrained firms have obtained such financial slack to insure themselves against future financial constraints in a forward looking manner in our model. These firms would have not obtained such cash positions without financial market friction to begin with.

The lower panels show the same phenomenon from a different angle in  $(B, B')$  diagrams, where grey, solid line show 45 degree lines, which indicate fixed points  $B' = g_B(K, B, Z)$ . To show the relationship between  $B$  and  $B'$ , we consider two fixed levels of capacity, 65 percent (denoted as low capacity) and 100 percent (denoted as high capacity) of the stochastic steady state of capital accumulation. In both cases, we set the technology level equal to the steady state, 1.

Consider the irreversibility case, the lower left panel. The net-debt function associated with the low capacity stays above the 45 degree line while the one with high capacity stays below the 45 degree line. One can perform a thought experiment where the firm starts with  $B = -0.3$  today. The red arrowed line shows the dynamic adjustment process of  $B' = g_B(K_{low}, B, Z)$ , holding everything else constant. The fact that the policy function (blue, solid line) cuts the 45 degree line at a strictly positive level implies that the firm wants to reduce the current liquid asset holdings. In fact, the fixed point is found above zero, meaning that the firm wants to change the current position of net financial asset holdings to a net debt position. This is due to the fact that its current capacity is so low that the firm wants to invest, and thus use up all cash holdings to purchase investment goods, and furthermore, wants to withdraw its line of credit to finance investment.

However, as shown by the red, arrowed line, this process involves a few gradual steps. This is because the firm wants to set aside some extra liquidity capacity to prepare for unexpected losses or even greater investment opportunities, again, a feature of *precaution* that would not exist without financial frictions. In contrast, when the firm has a greater capacity, shown by black, dash-dotted line in the panel (the case of  $B' = g_B(K_{high}, B, Z)$ ), the fixed point is found at a negative level, implying that a hypothetical firm with a positive net debt holdings wants to accumulate positive cash holdings due to lack of investment opportunities given its higher capacity level, simply preparing for operating losses or arrivals of higher technology. It is easy to see that such a transition is gradual given the positive slope of the policy function. In this case the gradualism is a direct consequence of the inability to invest a large amount resources in financial assets in a short period of time, which would cause the dividend constraint to bind.

In the bottom right panel, we consider the same capacity levels for the case with the fixed adjustment cost. In contrast to the pure irreversibility case, both policy functions with the two capacity levels have fixed points at negative levels. This because the fixed cost of adjustment make the firms want to postpone investment and hoard liquid assets for the next expansion. Again, as indicated by the positive slopes, the adjustment process of balance sheet conditions is gradual due to the financial market friction.

#### 5.2.4 Asset Tangibility and Risk Management

Our last exercise in this section analyzes the effect of technological change on the firm's optimal liquidity management strategy. Figure 6 considers three different values of the tangible capital ratio,  $\theta = 0.3, 0.5$  and  $0.8$  for which we show the corresponding optimal  $B'$  policies (upper panels), the usage of line of credit (middle panels), and the value of the option to invest in liquid financial assets (bottom panels, will be defined more formally below). We also contrast the case of partial irreversibility (left) to the case of combined irreversibility and fixed costs (right). We set the initial net debt position such that the net leverage relative to total asset is equal to  $-0.3$  and the technology level at its steady state. As expected, higher tangibility leads to more debt: the light blue line ( $\theta = 0.8$ ) is higher than the red line ( $\theta = 0.5$ ), which is in turn higher than the blue line ( $\theta = 0.3$ ). The key novel result of our model is that tangibility also affects liquidity management: since intangible capital reduces firm's financial buffer, the firm compensates for the foregone financial flexibility by holding more liquid assets. Furthermore, as shown by the middle panel, the firm keeps a greater portion of its line of credit unused. This is another manifestation of the precautionary motive with equity frictions, since the firm wants to avoid issuing relatively more costly equity. Importantly, real frictions magnify the effect of financial frictions as more inflexibility in the adjustment of physical capacity makes the firm's liquidity management strategy even more sensitive to technological change.

In the bottom panels of the figure, we compare model implied firm value for two cases: first, the case when firms have the option to invest in liquid assets; and second, the case when firms are precluded from this option, which we implement by introducing the nonnegativity constraint,  $0 \leq B' \leq B^{\max}(K'_T; p_T^-)$ . We denote firm value in the first case by  $V^C$  and in the latter by  $V^O$ . By

construction,  $V^C \geq V^O$ . We then define the value of liquidity as  $100 \times \log(V^C / V^O)$ : the percentage change in firm value from having the option to invest in liquid assets. This is equivalent to the *willingness to pay* to obtain the option to invest in liquid assets. Panels (c) and (d) show that the option can increase the value of equity as much as more than 5 percent. Moreover, the value of liquidity is much higher when firm's production assets are less liquid. Interestingly, liquidity is valuable even for firms that almost use up their financial slack, although a sudden increase in liquidity needs is unlikely for these firms.

Figure 7 reproduces the same exercise for a firm with net leverage ratio of 0.30. With the poor balance sheet condition, as shown by the upper and middle panels, the line of credit plays a more important role in firms' risk management strategy since accumulating liquid assets in a short period of time is costly. In the middle panels, one can see that the unused line of credit is close to zero in most of state space, except around the area right before an execution of lumpy investment. What is remarkable in figure 7 is that the value of liquidity can reach as high a level as 10 percent of the value of equity. This is a somewhat paradoxical result in that these firms cannot afford to invest in liquid assets even when allowed because of their poor current financial condition. However, such poor financial condition also implies that these firms have greater potential to improve their equity values substantially over time by adopting proper financial policies and the dynamic programming (13) captures such potential.

### 5.3 Comparative Statistics in General Equilibrium

We present the results of stationary general equilibrium in Table 6. For this baseline results, we assume the presence of fixed adjustment cost of investment as well as partial irreversibility. The table considers 6 different levels of asset tangibility, starting from  $\theta = 0.8$  and going down to  $\theta = 0.3$ , roughly covering the range of the data since 1970s.

The first panel summarizes the model-generated moments regarding net-leverage choice of the firms in stationary equilibrium. The first row of the first panel shows how average cash-to-total assets ratio responds to changes in asset tangibility.<sup>25</sup> As tangibility goes down from 0.8 to 0.3, the cash ratio increases from 0.02 to 0.18 percent, confirming our argument that firms try to

---

<sup>25</sup>Total assets are composed of after-tax profits, depreciation allowances, book value of tangible and intangible assets, and cash holdings.

compensate for the forgone financial flexibility brought about by technological change by accumulating more liquid assets. The first row computes the economywide average using firm-size weights because small firms tend to hoard more cash in the model since they have more investment opportunities.

The second row reports the unweighted average of the cash holding ratios. Figure 1 reports intangible-to-tangible capital ratio whereas  $\theta$  in the model is defined as the tangible to total capital ratio. Hence, if we convert the data to the same metric of  $\theta$ , the range of changes of the tangible-to-total capital ratio in the data is equivalent to a change from  $\theta = 0.80$  to  $0.53$  over the last 40 years. During this overall change, the unweighted cash ratio in the data has gone up from  $0.08$  to  $0.23$ . The second row shows that the model generates changes of similar magnitude with the unweighted cash ratio going up from  $0.04$  to  $0.23$  when the tangible capital ratio changes from  $\theta = 0.8$  to  $0.5$ . However, the cash ratio shown in 1 is defined as the total cash and equivalents relative to tangible asset. The fifth row shows the exact model counterpart to this: the unweighted cash-to-tangible assets ratio increases from  $0.05$  to  $0.41$ . These model-implied moments suggest that the model has the potential to provide a quantitative account of the key stylized facts in the data.

Finally, the seventh row of the panel shows that the model is also very successful in replicating the secular downward trend in net-leverage ratio shown in figure 1. Figure 8 shows how the joint distribution of capital and net-debt position responds to the decline in the tangible capital ratio from  $\theta = 0.8$  (blue bars) to  $0.5$  (red bars) to  $0.3$  (light blue bars). One can clearly see that the distribution moves to the left such that more probability mass is allocated to the negative portion of the support on the net-debt dimension as the tangible capital ratio declines. In fact, with  $\theta = 0.3$ , the stationary distribution allocates more probability mass to the negative support than to the positive support, suggesting that the corporate sector becomes a net creditor and the household sector becomes a net borrower in our closed economy setting. The seventh row of the first panel confirms this result.

The second panel of table 6 reports how the information content of cash changes in response to changes in the tangible asset ratio. The first row of the second panel confirms our theoretical prediction that the sensitivity of investment to cashflow goes up with the decline in the tangible asset ratio. This is because the decline in the pledgeable portion of productive assets reduces borrowing

capacity. While firms try to offset this tendency by accumulating liquid assets, it appears that they cannot fully undo this tendency and, as a result, the investment sensitivity to cashflow goes up. The second row shows that the sensitivity of cash to cashflows also goes up substantially with the decline in the tangible asset ratio. As we pointed out in our theoretical discussion, this also suggests that cash dynamics becomes more sluggish as the initial financial condition becomes more important for today's decision of how much to invest in liquid assets.

The third row indicates that the information content of lagged cash for today's investment linearly increases as the tangible asset ratio declines. Without financial market frictions, such feature is puzzling since holding cash is costly due to both forgone tax benefits and agency costs. In fact, the fifth row of the second panel shows that the correlation between investment in liquid assets and Tobin's Q converges to 1 as the tangible asset ratio declines toward 0.3. Combining this near perfect correlation between current cash holdings and Tobin's Q (the fifth row) on the one hand and the correlation between investment and lagged cash holdings (the third row) on the other confirms our prediction that Tobin's Q would have information for future investments, not for current investment. Indeed, the forth row shows that their contemporaneous correlation is actually slightly negative.

The last panel of table 6 shows the macroeconomic consequences of technological change. The key macroeconomic aggregates are mostly insulated from the transformation of the financial sector and the technological change behind it. Capital accumulation, shown in the first row, does go down by about 2 percent. However, the effect on output and consumption is almost nil up to rounding errors.<sup>26</sup> While we do not view it as a first order phenomenon, we report that that the dispersion of capital allocation, as shown in the seventh row, tends to decline as the tangible asset ratio declines, creating a small increase in total factor productivity in the context of decreasing-returns-to-scale technology, partially offsetting the tendency of output to decline when aggregate factor inputs decline. Another way of looking at this phenomenon is to check what happens to the total value of the firm in the sixth row: while the indebtedness of the corporate sector declines monotonically and the sector eventually becomes a net creditor, aggregate wealth holdings of the household sector are not affected greatly by this change as the increase in the value of equity

---

<sup>26</sup>We are currently performing a battery of robustness checks in terms of labor supply elasticity and the degree of wealth effects on labor supply.



almost completely offsets the decline in wealth due to increasing borrowing position of the household sector. Overall, based on these results, we conclude that technological change appears to be neutral for aggregate consumption and wealth accumulation in stationary equilibrium.<sup>27</sup>

#### **5.4 Alternative Specification: A General CES Case**

The baseline model we have analyzed so far is based on the special case of CES capital aggregator:  $\rho = \infty$  or zero substitutability of heterogeneous capital inputs. It is a legitimate question how much of our conclusion owe to this special assumption. To address this question, we now consider the case of a general CES capital aggregator. A problem with this specification is the curse of

current technology level  $Z$ , and solve the following 'normalized' value maximization problem:

$$v(k_T, k_N, b) = \min_{\lambda, \psi} \max_{\tilde{k}'_T, \tilde{k}'_N, \tilde{b}', d, e} \left\{ (1 + \lambda)d - e + \psi \left[ p_T^- \frac{(1 - \delta_T)\tilde{k}'_T}{1 + r(\tilde{b}')} - \tilde{b}' \right] \right. \\ \left. + \frac{1}{1 + r(1 - \tau_i)} \int \exp(\epsilon') v \left( \frac{\tilde{k}'_T}{\exp(\epsilon')}, \frac{\tilde{k}'_N}{\exp(\epsilon')}, \frac{\tilde{b}'}{\exp(\epsilon')} \right) dF(\epsilon') \right\} \quad (22)$$

s.t.

$$d = (1 - \tau_c)[\pi(k_T, k_N) - F_0] - \sum_{i=T,N} [\Gamma(\tilde{k}'_i, k_i) - \tau_c \delta_i k_i] \quad (23)$$

$$- [1 + r(b)]b + \tilde{b}' + e - \varphi(e) \\ \pi(k_T, k_N) = \eta(w) \left[ (1 - \theta) \left( \frac{k_T}{1 - \theta} \right)^{-\rho} + \theta \left( \frac{k_N}{\theta} \right)^{-\rho} \right]^{-\gamma/\rho} \quad (24)$$

where  $k_T \equiv K_T/Z$ ,  $k_N \equiv K_N/Z$ ,  $b \equiv B/Z$ ,  $\tilde{k}'_T \equiv K'_T/Z$ ,  $\tilde{k}'_N \equiv K'_N/Z$ , and  $\tilde{b}' \equiv B'/Z$ .

Even with the normalization, solving for  $v(k_T, k_N, b)$  requires tremendous computing resources. For this reason, we do not solve for a stationary general equilibrium, but solve for the individual firm's problem, and then simulate the model economy with a set random draws for idiosyncratic technology shocks in partial equilibrium setting with 250 periods and 10,000 firms.<sup>28</sup> While this is not ideal, the results on the baseline indicate that we do not lose much insight by adopting a partial equilibrium setting.

Before we report our results, it is useful to remind ourselves of some properties of the CES aggregator. Figure 9 displays two case of CES aggregators normalized by total capital stock, i.e.,  $\Phi(K_T, K_N; \theta, \rho)/K = \Phi(K_T/K, K_N/K; \theta, \rho)$ . The upper panel shows the case of  $\rho = 10$ , and the lower panel shows the case of  $\rho = -0.3$ . As can be seen in the figure, the case of  $\rho = 10$  is already very close to the case of Leontief and the marginal effect from deviating from the technological benchmark ratio  $\theta$  is so big that firms almost never want to deviate from the benchmark rate. In contrast, the case of  $\rho = -0.3$ , which implies slightly higher substitutability than the Cobb-Douglas aggregator, displays much greater room for changing capital ratios. In our simulation, we set  $\rho = -0.3$  to see how robust our findings in the baseline case are. Owing to the computational burden, we only report the cases of  $\theta = 0.8, 0.5$ , and  $0.3$ . We keep all other parameters of the baseline model unchanged except for  $\sigma_\epsilon$ , for which we choose 0.05. This is a much smaller value

<sup>28</sup>When computing moments, we delete the initial 50 periods.

than in the baseline. However, the random walk specification implies that the amount of variance grows linearly with time. Hence, this is not an overly optimistic parametrization.

Table 7 reports a few moments from this simulation exercise. We only report unweighted moments in the table as the extended model becomes effectively size-free. In interpreting these results, it is important to keep in mind that the value of  $\theta$  is no longer identical to the tangible-to-total capital ratio since firms can now freely deviate from this value. The idea of the exercise is to see if the firms still react to changes in  $\theta$  in the same way they did in our baseline results. With more flexible technology, firms may not have as strong an incentive to hoard liquid assets.

The first and second rows show the impact of technological change on cash-to-total assets and cash-to-tangible assets. We can see that firms do not hold liquid assets when  $\theta = 0.8$ . This is because firms in the simulation can use the more flexible technology as a de facto risk management tool: when facing investment opportunities, firms may want to choose a higher ratio of tangible-to-intangible capital ratio to expand their borrowing capacity despite a lower technological efficiency.  $\rho = -0.3$  means that the marginal cost of deviating from the technologically efficient ratio is not big and, as a result, it reduces the amount of liquidity demand. However, as  $\theta$  goes down to 0.5 and to 0.3, liquidity demand picks up again since the efficiency loss required to make firms adopt more tangible capital ratios for borrowing capacity becomes too high and, as a result, firms are led to hold more liquid assets. As in the baseline case, net leverage ratios, shown in the third and fourth rows, decline monotonically as  $\theta$  goes down. This, together with the results on cash ratios confirms that our baseline results are not driven by the Leontief assumption. The extended model also shows that the information content of Tobin's Q and cash holdings is almost identical as these variables are nearly perfectly correlated (the fifth row).

Finally, the last row of the table reports the correlation between net leverage and tangible asset ratios. This correlation increases as  $\theta$  goes down. This result shows that when firms find it optimal to choose higher leverage ratio they tend to choose higher levels of tangible capital ratios. In the model, causation runs in both direction. They can borrow more because they have more tangible capital as collateral. However, at the same time, more vulnerable balance sheet conditions also lead firms to hold more pledgeable assets in their balance sheets since these assets expand borrowing capacity for a long period of time and since it is costly to strengthen their balance sheet conditions by holding liquid assets in a short period of time.

## 6 Conclusion

We have presented new evidence and theory which support the hypothesis that the rise in intangible capital can explain the secular increase in US corporate cash holdings over the last four decades. Our empirical evidence shows that intangible capital is a key empirical determinant of cash holdings. In addition, the evidence suggests that both financial and real frictions contribute to explain why intangible capital matters so much. Next, we built a structural dynamic corporate finance model where intangible capital matters for firms' cash management decisions because of the interplay between financial and investment frictions. All else equal, our model generates an outsized increase in the demand for corporate cash in response to an increase in intangible capital. We conclude that intangible capital is a crucial ingredient to providing a satisfactory analytic account of key stylized facts in corporate finance, which to date had eluded standard explanations.

## References

- ABEL, A. B., AND J. C. EBERLY (1994): "A Unified Model of Investment Under Uncertainty," *The American Economic Review*, 84(5), pp. 1369–1384.
- (1996): "Optimal Investment with Costly Reversibility," *The Review of Economic Studies*, 63(4), pp. 581–593.
- ALMEIDA, H., M. CAMPELLO, AND M. S. WEISBACH (2004): "The Cash Flow Sensitivity of Cash," *Journal of Finance*, 59(4), 1777–1804.
- BALASUBRAMANIAN, N., AND J. SIVADASAN (2009): "Capital Resalability, Productivity Dispersion, and Market Structure," *The Review of Economics and Statistics*, 91(3), 547–557.
- BATES, T. W., K. M. KAHLE, AND R. M. STULZ (2006): "Why Do U.S. Firms Hold So Much More Cash Than They Used To?," NBER Working Papers 12534, National Bureau of Economic Research, Inc.
- BERGER, P. G., E. OFEK, AND I. SWARY (1996): "Investor valuation of the abandonment option," *Journal of Financial Economics*, 42(2), 257–287.
- BERTOLA, G., AND R. J. CABALLERO (1994): "Irreversibility and Aggregate Investment," *The Review of Economic Studies*, 61(2), pp. 223–246.
- BOLTON, P., H. CHEN, AND N. WANG (2009): "A Unified Theory of Tobin's  $q$ , Corporate Investment, Financing, and Risk Management," NBER Working Papers 14845, National Bureau of Economic Research, Inc.
- CABALLERO, R. J. (1999): "Aggregate investment," in *Handbook of Macroeconomics*, ed. by J. B. Taylor, and M. Woodford, vol. 1 of *Handbook of Macroeconomics*, chap. 12, pp. 813–862. Elsevier.

- COOLEY, T. F., AND V. QUADRINI (2001): "Financial Markets and Firm Dynamics," *The American Economic Review*, 91(5), pp. 1286–1310.
- COOPER, R. W., AND J. C. HALTIWANGER (2006): "On the Nature of Capital Adjustment Costs," *The Review of Economic Studies*, 73(3), pp. 611–633.
- CORRADO, C., C. HULTEN, AND D. SICHEL (2009): "Intangible Capital And U.S. Economic Growth," *Review of Income and Wealth*, 55(3), 661–685.
- CORRADO, C. A., AND C. R. HULTEN (2010): "How Do You Measure a 'Technological Revolution'?" *American Economic Review*, 100(2), 99–104.
- EISFELDT, A. L., AND D. PAPANIKOLAOU (2013): "Organization Capital and the Cross-Section of Expected Returns," *The Journal of Finance*, pp. n/a–n/a.
- EPSTEIN, L. G. (1983): "Aggregating Quasi-Fixed Factors," *The Scandinavian Journal of Economics*, 85(2), pp. 191–205.
- FAULKENDER, M., M. J. FLANNERY, K. W. HANKINS, AND J. M. SMITH (2012): "Cash flows and leverage adjustments," *Journal of Financial Economics*, 103(3), 632–646.
- FROOT, K. A., D. S. SCHARFSTEIN, AND J. C. STEIN (1993): "Risk Management: Coordinating Corporate Investment and Financing Policies," *The Journal of Finance*, 48(5), pp. 1629–1658.
- GILCHRIST, S., J. SIM, AND E. ZAKRAJSEK (2010): "Uncertainty, Financial Frictions, and Investment Dynamics," Discussion paper.
- GOMES, J. F. (2001): "Financing Investment," *The American Economic Review*, 91(5), pp. 1263–1285.
- GOURIO, F. (2008): "Estimating Firm-Level Risk," mimeo, Boston University.
- GOURIO, F., AND J. MIAO (2010): "Firm Heterogeneity and the Long-Run Effects of Dividend Tax Reform," *American Economic Journal: Macroeconomics*, 2(1), 131–68.
- GREENWOOD, J., Z. HERCOWITZ, AND G. W. HUFFMAN (1988): "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 78(3), 402–17.
- HALL, B. H., A. B. JAFFE, AND M. TRAJTENBERG (2000): "Market Value and Patent Citations: A First Look," NBER Working Papers 7741, National Bureau of Economic Research, Inc.
- HALL, R. E. (2001): "The Stock Market and Capital Accumulation," *American Economic Review*, 91(5), 1185–1202.
- HART, O., AND J. MOORE (1994): "A Theory of Debt Based on the Inalienability of Human Capital," *The Quarterly Journal of Economics*, 109(4), 841–879.
- HENNESSY, C. A., AND T. M. WHITED (2007): "How Costly Is External Financing? Evidence from a Structural Estimation," *The Journal of Finance*, 62(4), pp. 1705–1745.
- JOVANOVIC, B., AND P. L. ROUSSEAU (2005): "General Purpose Technologies," in *Handbook of Economic Growth*, ed. by P. Aghion, and S. Durlauf, vol. 1 of *Handbook of Economic Growth*, chap. 18, pp. 1181–1224. Elsevier.
- KIYOTAKI, N., AND J. MOORE (1997): "Credit Cycles," *Journal of Political Economy*, 105(2), 211–48.

- LEMMON, M. L., M. R. ROBERTS, AND J. F. ZENDER (2008): "Back to the Beginning: Persistence and the Cross-Section of Corporate Capital Structure," *Journal of Finance*, 63(4), 1575–1608.
- LEV, B. (2001): *Intangibles: Management, measurement, and reporting*. Brookings Institution Press, Washington, DC.
- LEV, B., AND S. RADHAKRISHNAN (2005): "The Valuation of Organization Capital," in *Measuring Capital in the New Economy*, NBER Chapters, pp. 73–110. National Bureau of Economic Research, Inc.
- MCGRATTAN, E. R., AND E. C. PRESCOTT (2007): "Technology capital and the U.S. current account," Discussion paper.
- OPLER, T., L. PINKOWITZ, R. STULZ, AND R. WILLIAMSON (1999): "The determinants and implications of corporate cash holdings," *Journal of Financial Economics*, 52(1), 3–46.
- RAMEY, V. A., AND M. D. SHAPIRO (2001): "Displaced Capital: A Study of Aerospace Plant Closings," *Journal of Political Economy*, 109(5), 958–992.
- RAMPINI, A. A., AND S. VISWANATHAN (2010): "Collateral, Risk Management, and the Distribution of Debt Capacity," *The Journal of Finance*, 65(6), 2293–2322.
- RIDDICK, L. A., AND T. M. WHITED (2009): "The Corporate Propensity to Save," *Journal of Finance*, 64(4), 1729–1766.
- SHLEIFER, A., AND R. W. VISHNY (1992): "Liquidation Values and Debt Capacity: A Market Equilibrium Approach," *Journal of Finance*, 47(4), 1343–66.
- SIBILKOV, V. (2009): "Asset Liquidity and Capital Structure," *Journal of Financial and Quantitative Analysis*, 44(05), 1173–1196.
- STOKEY, N. L., E. C. PRESCOTT, AND R. E. LUCAS (1989): *Recursive methods in economic dynamics* / Nancy L. Stokey and Robert E. Lucas, Jr., with Edward C. Prescott. Harvard University Press Cambridge, Mass.
- WHITED, T. M., AND G. WU (2006): "Financial Constraints Risk," *Review of Financial Studies*, 19(2), 531–559.

Table 1: Stylized Facts on Intangible Capital, Firm Financing, and Corporate Investment

Firm Financing					Investment & Firm Dynamics: Difference Between Cash Rich and Cash Strapped Firms			
Panel A: Time-Series Stylized Facts, by Decade								
	Cash		Net Debt		Investment		Sales Growth	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
1970s	0.09	0.05	0.18	0.19	0.04	0.02	0.03	0.02
1980s	0.13	0.06	0.15	0.17	0.07	0.04	0.07	0.06
1990s	0.17	0.07	0.11	0.14	0.08	0.05	0.08	0.08
2000s	0.21	0.11	0.05	0.06	0.06	0.03	0.05	0.05
Panel B: Cross-sectional Stylized Facts, by Quartile of Intangible Capital								
	Cash		Net Debt		Investment		Sales Growth	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Intangible Capital, Q1	0.08	0.04	0.28	0.29	0.04	0.03	0.05	0.05
Intangible Capital, Q2	0.10	0.05	0.20	0.21	0.04	0.03	0.07	0.06
Intangible Capital, Q3	0.13	0.08	0.10	0.11	0.05	0.03	0.09	0.07
Intangible Capital, Q4	0.23	0.12	-0.07	-0.10	0.13	0.06	0.11	0.08
Panel C: Time-Series Stylized Facts for Innovative Firms (R&D>0)								
	Cash		Net Debt		Investment		Sales Growth	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
1970s	0.09	0.05	0.16	0.18	0.04	0.02	0.04	0.03
1980s	0.15	0.07	0.10	0.12	0.08	0.04	0.08	0.07
1990s	0.21	0.11	0.01	0.04	0.09	0.05	0.10	0.09
2000s	0.27	0.19	-0.06	-0.06	0.07	0.03	0.06	0.05
Panel D: Cross-sectional Stylized Facts for Innovative Firms (R&D>0)								
	Cash		Net Debt		Investment		Sales Growth	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Intangible Capital, Q1	0.08	0.04	0.26	0.27	0.03	0.02	0.06	0.06
Intangible Capital, Q2	0.10	0.05	0.18	0.20	0.04	0.02	0.08	0.07
Intangible Capital, Q3	0.14	0.08	0.08	0.10	0.05	0.03	0.10	0.08
Intangible Capital, Q4	0.31	0.23	-0.10	-0.14	0.14	0.06	0.12	0.09

Note: a. The table reports means and medians for various sub-samples of all US nonfinancial firms (excluding Utilities) in Compustat from 1970 to 2010 [176,877 observations for 18,535 unique firms]. b. Firm financing facts refer to cash (ratio of the sum of cash and short-term marketable securities to book assets) and net debt (ratio of total debt net of cash holding to book assets). Investment and firm dynamics facts refer to total investment (the ratio of the sum of capital expenditures and R&D to net book assets) and sales growth (annual change in log sales). The reported figures are mean and median differences between cash rich and cash strapped firms, which are defined as those firms in the top and bottom quartiles of the distribution of year-prior cash holdings, respectively. c. Panels A and C report time-series evidence by decades for the entire sample and the sub-sample of firms that report positive R&D, respectively. Panels B and D report cross-sectional sorts based on intangible capital, which is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D); it is normalized by net book assets. d. Detailed variable definitions are provided in the Appendix.

Table 2: Panel Evidence on Intangible Capital and Firm Financing

Whole Sample	R&D>
--------------	------



Table 3: Panel Evidence on Intangible Capital, Corporate Investment, and Firm Dynamics

	Whole Sample				R&D>0 Firms			
<i>Panel A: Sensitivity to Cash Conditions</i>								
	Investment		Sales Growth		Investment		Sales Growth	
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CDF(Cash <sub><i>t</i>-1</sub> )	0.071*** (0.000)	0.059*** (0.000)	0.145*** (0.001)	0.125*** (0.001)	0.076*** (0.000)	0.059*** (0.000)	0.166*** (0.001)	0.132*** (0.001)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R <sup>2</sup>	0.459	0.595	0.105	0.295	0.390	0.515	0.102	0.291
<i>Panel B: Sensitivity to Cash Conditions By Quartiles of Intangible Capital</i>								
	Investment		Sales Growth		Investment		Sales Growth	
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Q1	0.049*** (0.001)	0.045*** (0.001)	0.145*** (0.001)	0.109*** (0.001)	0.054*** (0.001)	0.059*** (0.001)	0.145*** (0.001)	0.106*** (0.001)
Q2	0.055*** (0.001)	0.053*** (0.001)	0.151*** (0.001)	0.118*** (0.001)	0.055*** (0.000)	0.061*** (0.000)	0.155*** (0.000)	0.148*** (0.000)
Q3	0.062*** (0.000)	0.059*** (0.000)	0.165*** (0.000)	0.130*** (0.000)	0.062*** (0.000)	0.069*** (0.000)	0.190*** (0.000)	0.160*** (0.000)
Q4	0.096*** (0.000)	0.078*** (0.000)	0.280*** (0.000)	0.268*** (0.000)	0.106*** (0.000)	0.089*** (0.000)	0.303*** (0.000)	0.283*** (0.000)

Note: a. The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. b. Panel A reports estimates from panel regressions of total corporate investment (capex + R&D) and annual sales growth on the empirical cumulative distribution function (CDF) of lagged cash to book assets ratio for OLS and firm fixed effects specifications. Reported coefficients are the change in the dependent variable associated with a change from the lowest to the highest values of lagged cash. Columns (1)-(4) and (5)-(8) are for the entire sample and for the subsample of firms with positive R&D, respectively. c. Panel B reports estimates of the same regressions as in Panel A for different sub-samples based on quartiles of the distribution of intangible capital. d. Year dummies as well as firm-level controls for standard determinants of corporate investment are included in all regressions. p-values are in parentheses and are clustered at the firm level. e. Detailed variable definitions are in the Appendix.

Table 4: Why does Intangible Capital Matter? Panel Evidence on Financial and Real Frictions

<i>Panel A: Financial Frictions</i>						<i>Panel B: Real Frictions</i>					
		Whole Sample		R&D>0 Firms				Whole Sample		R&D>0 Firms	
		OLS	FE	OLS	FE			OLS	FE	OLS	FE
		(1)	(2)	(3)	(4)			(5)	(6)	(7)	(8)
By Firm Size						By Industry Frequency of Investment Inaction					
[1]	Q1	0.102	0.112	0.120	0.120	[1]	Q1	0.024	0.031	0.030	0.036
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
[2]	Q4	0.030	0.028	0.037	0.039	[2]	Q4	0.137	0.112	0.162	0.133
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
By Dividend Payer Status						By Investment Spikes in the Industry					
[3]	No	0.100	0.075	0.124	0.090	[3]	No	0.049	0.048	0.061	0.049
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
[4]	Yes	0.028	0.034	0.033	0.035	[4]	Yes	0.095	0.079	0.120	0.081
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
By WW-Index						By Time-Series Skewness of Industry Investment					
[5]	Q4	0.104	0.090	0.126	0.107	[5]	Q1	0.044	0.043	0.060	0.047
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
[6]	Q1	0.055	0.050	0.065	0.058	[6]	Q4	0.100	0.079	0.145	0.104
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
By Asset Liquidation Value						By Time-Series Kurtosis of Industry Investment					
[7]	Q1	0.145	0.109	0.152	0.115	[7]	Q1	0.048	0.046	0.065	0.051
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
[8]	Q4	0.051	0.049	0.059	0.054	[8]	Q4	0.092	0.078	0.133	0.093
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
By Degree of Asset Redeployability						By Time-Series Variability of Operating Costs					
[9]	Q1	0.199	0.126	0.207	0.132	[9]	Q4	0.038	0.040	0.054	0.050
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)
[10]	Q4	0.062	0.048	0.084	0.059	[10]	Q1	0.102	0.080	0.133	0.096
		(0.000)	(0.000)	(0.000)	(0.000)			(0.000)	(0.000)	(0.000)	(0.000)

Note: a. The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates from panel regressions of cash holdings to book assets on intangible capital for several sub-sample splits based on ex-ante proxies for the severity of financial (Panel A) and investment (Panel B) frictions faced by firms. b. Reported coefficients are the change in the dependent variable associated with a one-standard deviation change in intangible capital, which is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by net book assets. c. Columns (1)-(2) and (5)-(6) report results for the whole sample, while Columns (3)-(4) and (7)-(8) are for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions and regressions with firm fixed effects. Controls are as in Table 2. d. In Panel A, the sample is split between bottom and top quartiles of (year-prior) values of: firm size (Rows [1] to [2]), Whited and Wu (2006) WW-Index (Rows [5] to [6]), Berger et al. (1996) asset liquidation value (Rows [7] to [8]), and Balasubramanian and Sivadasan (2009) index of industry asset redeployability (Rows [9] to [10]), and by dividend payer status (Rows [3] to [4]). p-values clustered at the firm level are in parentheses. e. In Panel B, the sample is split between bottom and top quartiles of: (4-SIC) industry frequency of investment inaction -  $|\text{Capex}/\text{book assets}| < .01$  (Rows [1] to [2]), and whether in the industry there are investment spikes -  $|\text{Capex}/\text{book assets}| > .2$  (Rows [3] to [4]), all based on Cooper and Haltiwanger (2006); time-series skewness (Rows [5] to [6]) and kurtosis (Rows [7]

to [8]) of annual aggregate industry investment (Capex/book assets), based on Caballero (1999); and the time-series standard deviation of aggregate industry operating costs (Rows [9] to [10]). f. Detailed variable definitions are in the Appendix.

Table 5: Baseline Calibration

Description	Calibration
<i>Parameters of Technology and Preferences</i>	
Returns-to-scale	$\xi = 0.83$
Value-added share of capital	$\alpha = 0.30$
Depreciation	$\delta = 0.10$
Elasticity of substitution between capital inputs	$\rho = \infty, -0.3$
Purchase price of capital	$p^+ = 1.00$
Partial irreversibility	$p^- = 0.95$
Fixed cost of adjustment	$F_k = 0.01k^*$
Fixed cost of operation	$F_0 = 0.05k^*$
Persistence of technology shock	$\rho_z = 0.80$
Constant relative risk aversion	$\sigma = 1.00$
Volatility of technology shock	$\sigma_z = 0.30$
Inverse of Frisch elasticity of labor supply	$\phi = 1.00$
<i>Financial Parameters</i>	
Risk-free rate	$r = 0.06$
Agency Cost of Cash Holdings	$\kappa = 5 \text{ bps}$
Fixed cost of issuance	$\varphi_0 = 0.015k^*$
Linear cost of issuance	$\varphi_1 = 0.15$
Interest rate income tax rate	$\tau_i = 0.30$
Corporate income tax rate	$\tau_c = 0.35$

Note:  $k^*$  is the steady state level of capital accumulation in a frictionless model.

Table 6: Comparative Statics: Macroeconomic Effects of Asset Tangibility

Tangible Capital Ratio, $\theta$	.8	.7	.6	.5	.4	.3
<i>Net Leverage Ratios</i>						
Cash-to-total assets (weighted)	0.02	0.04	0.07	0.10	0.14	0.18
Cash-to-total assets (unweighted)	0.04	0.09	0.15	0.23	0.30	0.40
Debt-to-total assets (weighted)	0.39	0.31	0.25	0.18	0.12	0.08
Cash-to-tangible assets (weighted)	0.02	0.05	0.10	0.17	0.26	0.37
Cash-to-tangible assets (unweighted)	0.05	0.13	0.23	0.41	0.65	1.06
Debt-to-tangible assets (weighted)	0.48	0.42	0.36	0.30	0.22	0.15
Net debt-to-total assets (weighted)	0.34	0.25	0.16	0.08	-0.02	-0.10
<i>Cashflow Sensitivity of Cash and Investment</i>						
Corr(Investment, Cashflow)	0.28	0.30	0.30	0.30	0.31	0.33
Corr(Cash, Cashflow)	0.49	0.62	0.69	0.77	0.76	0.75
Corr(Investment, Lagged Cash)	0.09	0.11	0.14	0.15	0.19	0.20
Corr(Investment, Tobin's Q)	-0.20	-0.19	-0.20	-0.21	-0.20	-0.20
Corr(Cash, Tobin's Q)	0.60	0.76	0.84	0.88	0.89	0.91
<i>Macroeconomic Aggregates</i>						
Capital accumulation	0.99	0.99	0.99	0.97	0.97	0.97
Consumption	0.56	0.56	0.56	0.55	0.56	0.56
Output	0.65	0.65	0.65	0.65	0.65	0.65
Hours	0.47	0.47	0.47	0.47	0.47	0.47
Wage	0.80	0.80	0.80	0.80	0.80	0.80
Total value of firm (V+B)	1.96	1.96	1.96	1.96	1.96	1.97
Dispersion of capital (std)	0.42	0.43	0.42	0.40	0.40	0.40
Tobin's Q	1.63	1.61	1.61	1.62	1.62	1.61

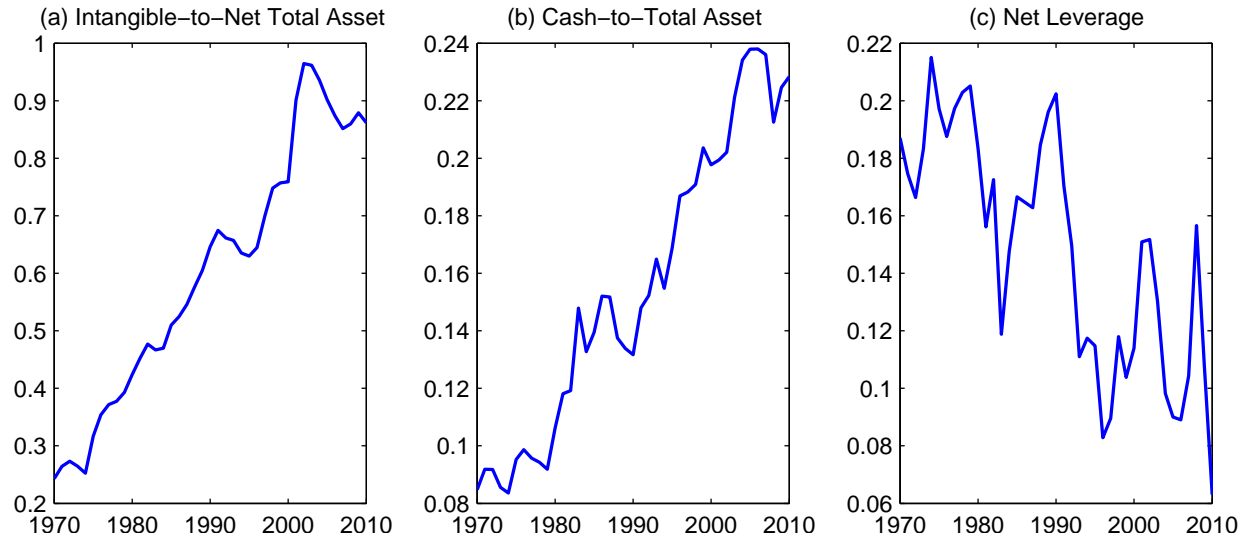
Note: The table shows the moments of endogenous variables in the economy with irreversibility and fixed adjustment cost, using stationary distribution. The stationary distribution  $\mu^*(K, B, Z)$  is discretized on a space (50,50,5).

Table 7: Comparative Statics: the Case of CES

Technological parameter, $\theta$	.8	.5	.3
Cash-to-total assets	0.000	0.072	0.142
Cash-to-tangible assets	0.000	0.115	0.250
Net debt-to-total assets	0.339	-0.042	-0.138
Net debt-to-tangible assets	0.457	-0.039	-0.232
Corr(Cash, Tobin's Q)	n/a	0.937	0.970
Corr(Net leverage ratio, Tangible asset ratio)	0.330	0.414	0.589

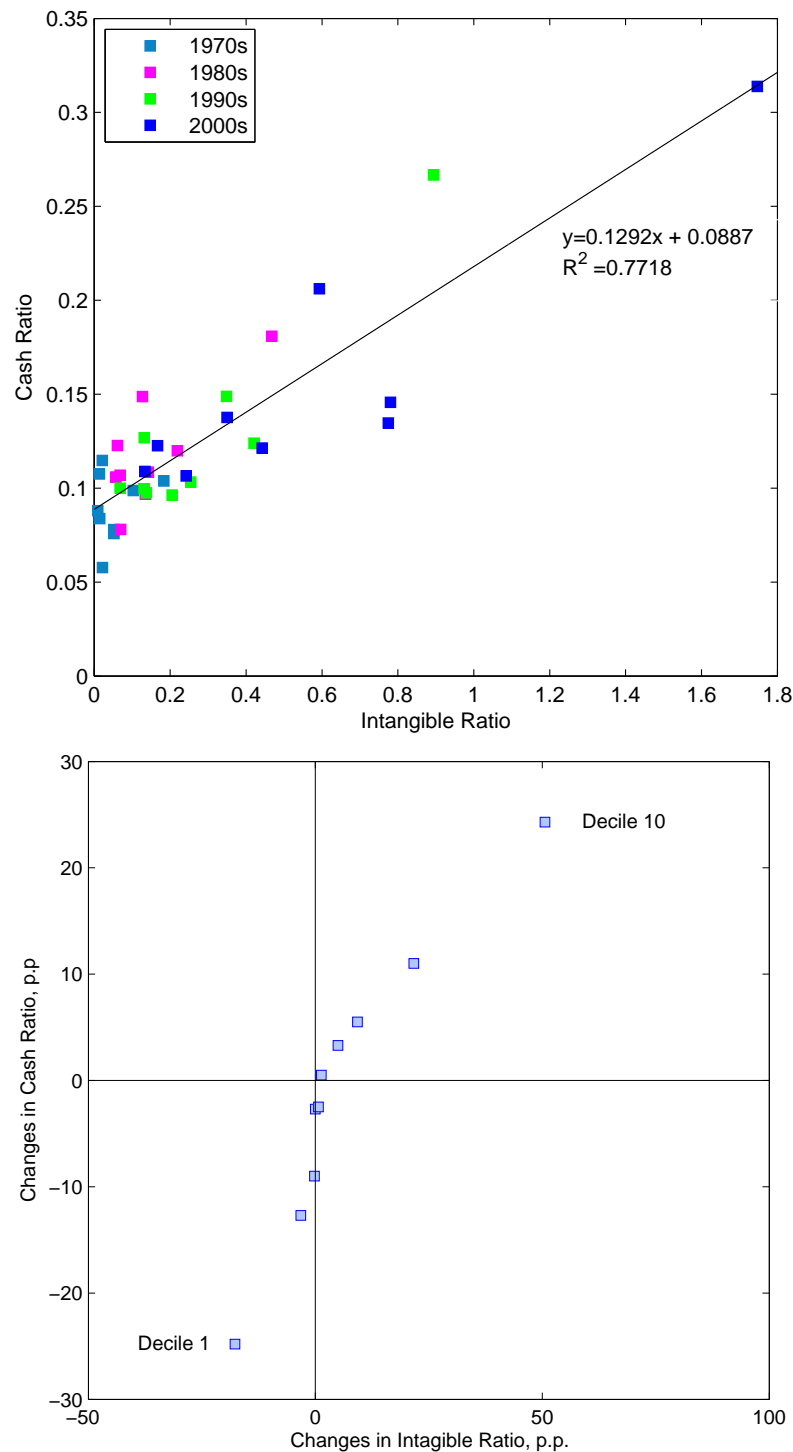
Note: The table shows the moments of endogenous variables in the economy with irreversibility and fixed adjustment cost, using actual simulation of size T=200 and N=10,000. The Markov Chain in the baseline is replaced with a Gauss-Hermite quadrature with same number of grids.

Figure 1: Intangible Capital, Cash Hoardings and Leverage



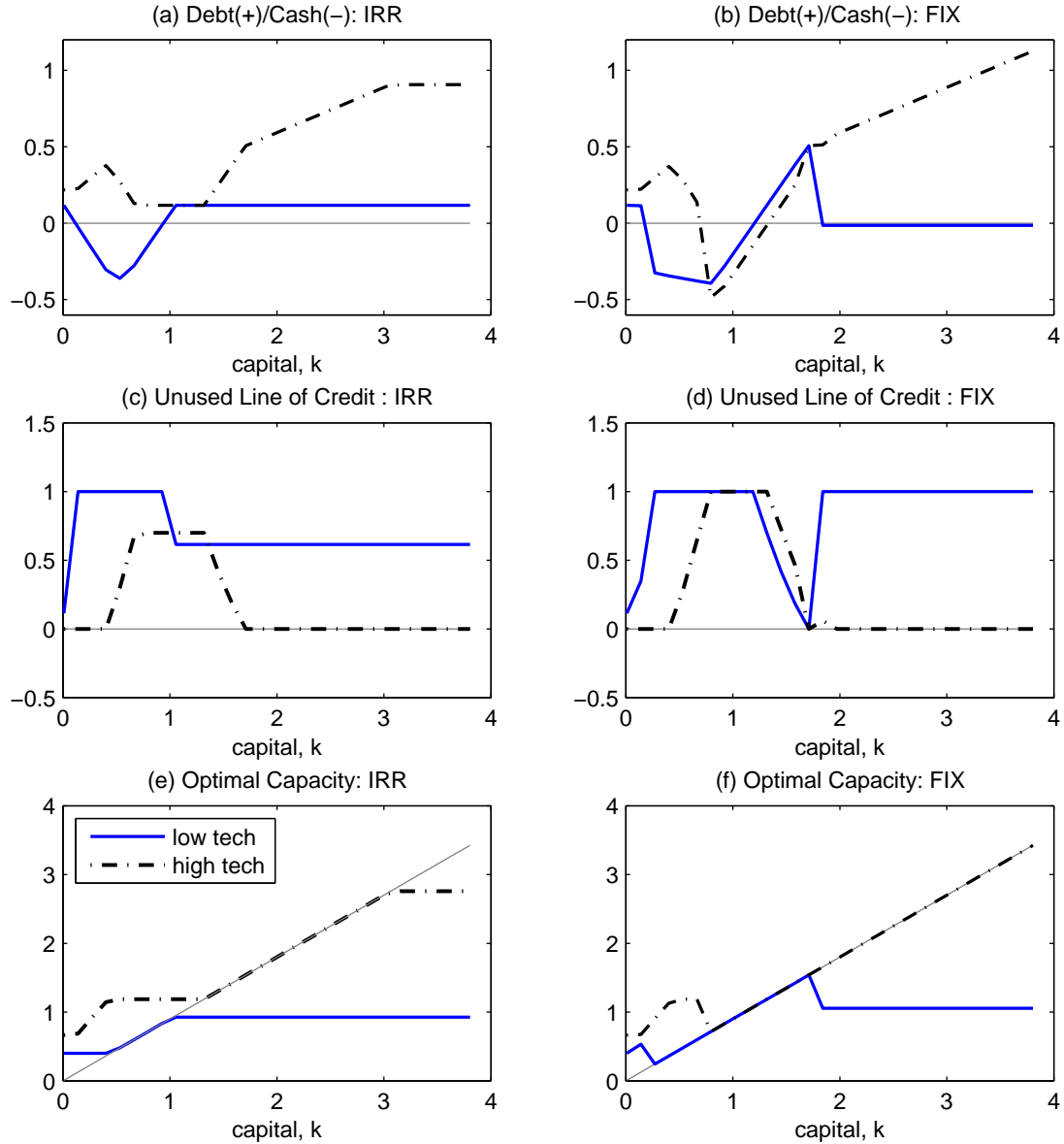
Note: Panel (a), (b) and (c) show intangible capital ratio relative to total (tangible) assets, cash-to-total (tangible) assets and net-debt-to-total (tangible) assets, respectively. The sample includes all Compustat firm-year observations from 1970 to 2010 with positive values for the book value of total assets and sales revenue for firms incorporated in the United States. Financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999) are excluded from the sample, yielding a panel of 176,877 observations for 18,535 unique firms. Variable definitions are provided in the Appendix.

Figure 2: Changes in Intangible Capital and Cash: Cross-Industry, Cross-Firm Variations



Note: The sample includes all Compustat firm-year observations from 1970 to 2010 with positive values for the book value of total assets and sales revenue for firms incorporated in the United States. Financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999) are excluded from the sample, yielding a panel of 176,877 observations for 18,535 unique firms. Variable definitions are provided in the Appendix.

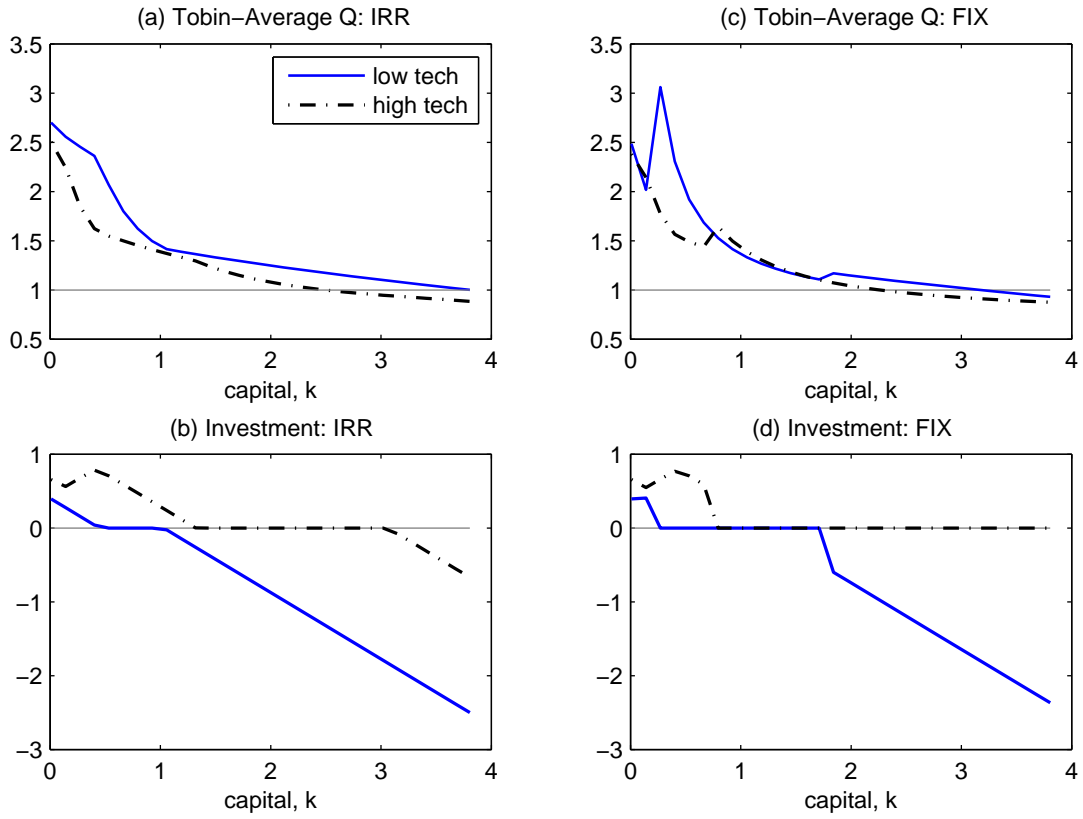
Figure 3: Cash, Debt, and Line of Credit: Impact of Technology and Capital



Note: Blue solid line is the case with a technology level 30 percent lower than the steady state level and black, dash-dotted line is the case with a 30 percent higher technology level. In all cases, we set the current financial balances (b) equal to the stochastic steady state of the debt/cash balances, i.e.,  $E(b)$ , which is equivalent to -35 percent of total capital stock in the steady state with  $\theta = 0.4$  and fixed costs of adjustment.

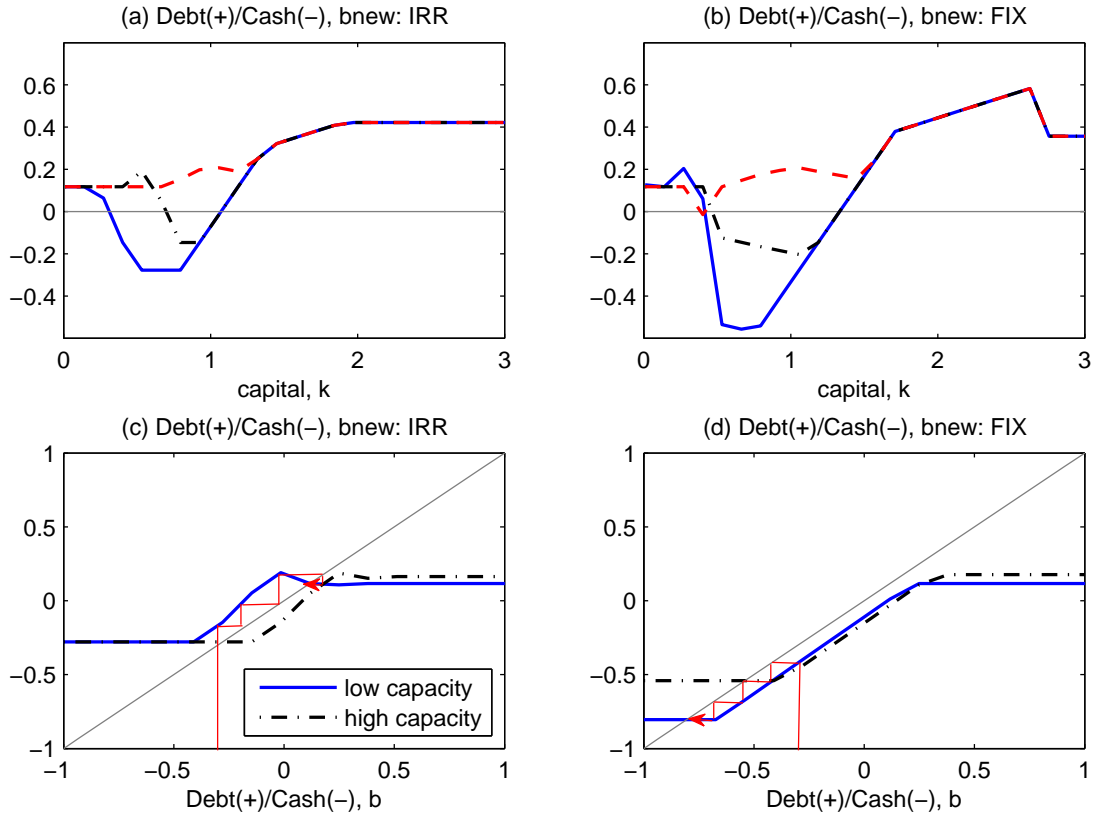


Figure 4: Tobin's Q, Investment, Real and Financial Frictions



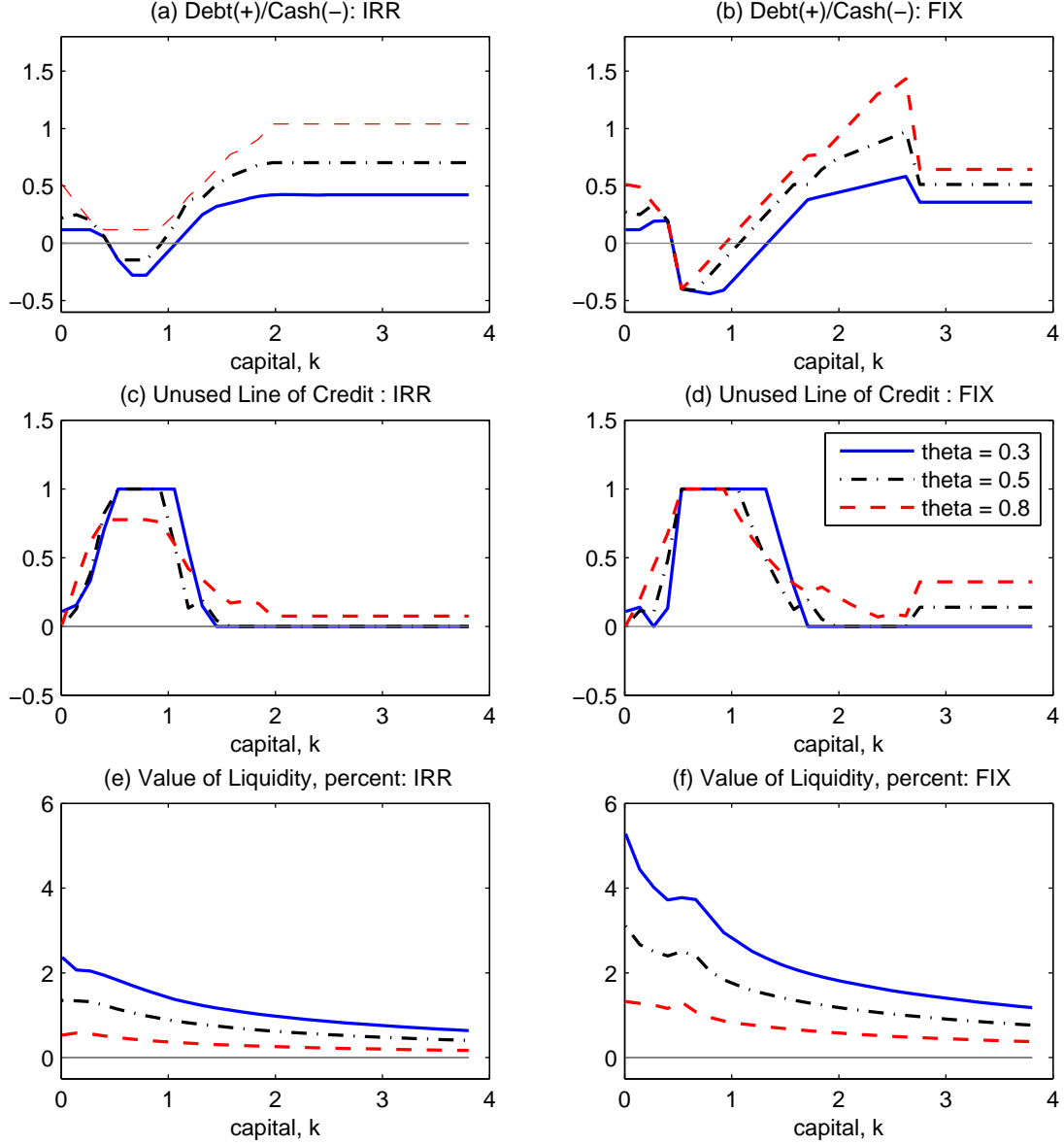
Note: Blue solid line is the case with a technology level 30 percent lower than the steady state level and black, dash-dotted line is the case with a 30 percent higher technology level. In all cases, we set the current financial balances (b) equal to the stochastic steady state of the debt/cash balances, i.e.,  $E(b)$ , which is equivalent to -35 percent of total capital stock in the steady state with  $\theta = 0.4$  and fixed costs of adjustment.

Figure 5: Debt Dynamics, Capacity and Debt Overhang



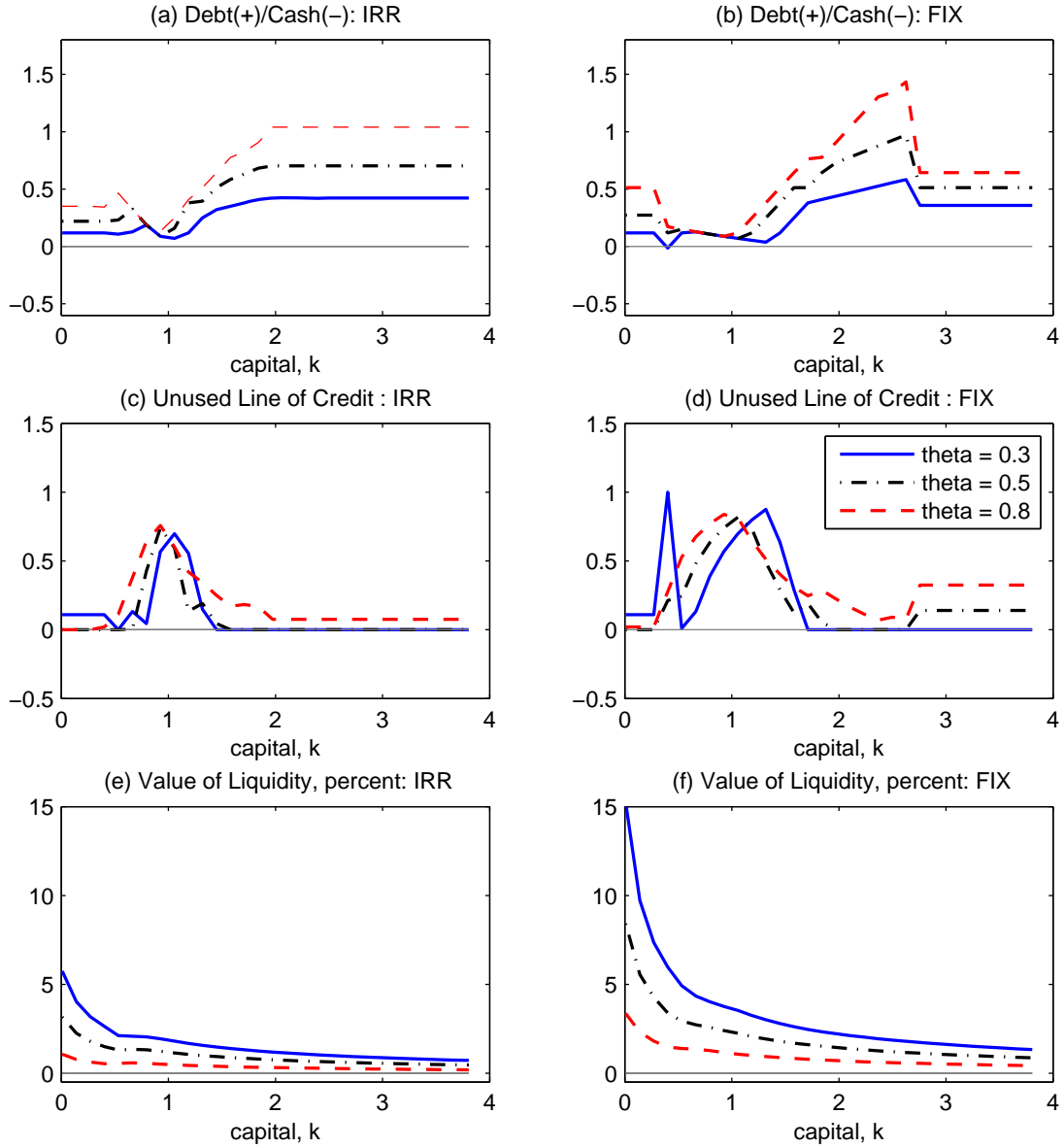
Note: Blue solid, black solid-dotted and red dashed lines are the cases with  $b = -0.5, -0.2$  and  $0.15$ . All cases are considered with idiosyncratic shock 30 percent higher than its steady state level with  $\theta = 0.4$  and fixed costs of adjustment. Note that the stochastic steady state of  $b$ , i.e.,  $E[b]$  is equal to  $-0.35$ .

Figure 6: Asset Tangibility, Value of Liquidity and Cash Hoarding: Strong Balance Sheet



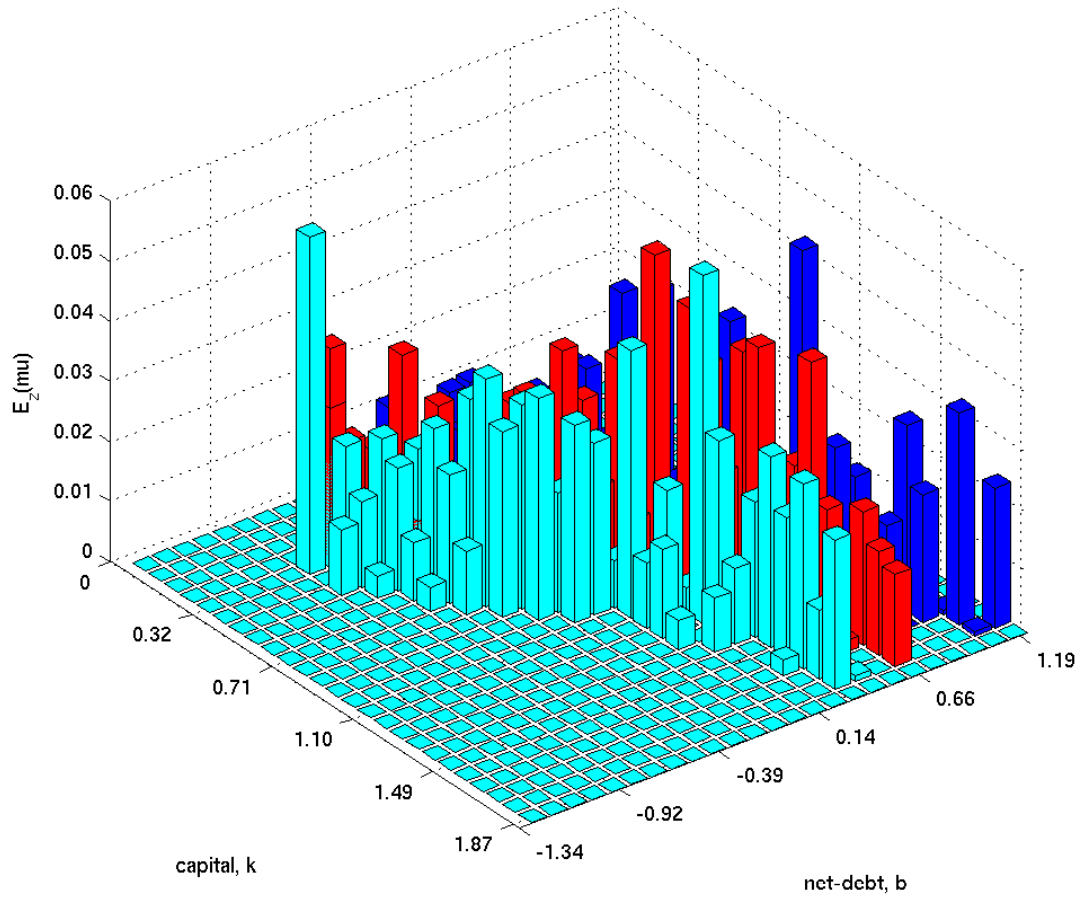
Note: Blue solid, black dash-dotted and red dashed lines are the cases with  $\theta = 0.3, 0.5$  and  $0.8$ , respectively. In all cases, we set the current financial balances (b) equal to the stochastic steady state of the debt/cash balances, i.e.,  $E(b)$ , which is equivalent to -35 percent of total capital stock in the steady state. The idiosyncratic technology shock is set equal to its steady state level..

Figure 7: Asset Tangibility, Value of Liquidity and Cash Hoarding: Weak Balance Sheet



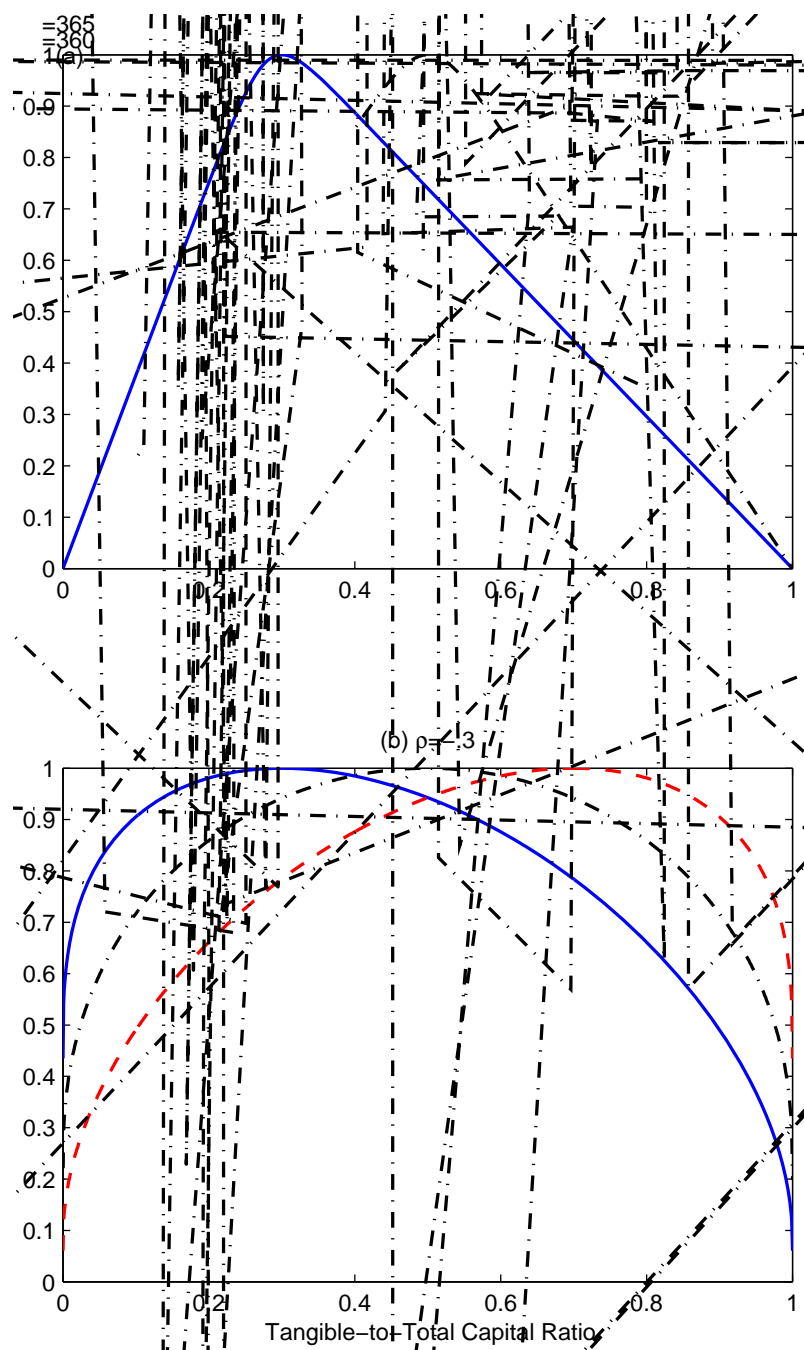
Note: Blue solid, black dash-dotted and red dashed lines are the cases with  $\theta = 0.3, 0.5$  and  $0.8$ , respectively. In all cases, we set the current financial balances (b) equal to the stochastic steady state of the debt/cash balances, i.e.,  $E(b)$ , which is equivalent to -35 percent of total capital stock in the steady state. The idiosyncratic technology shock is set equal to its steady state level..

Figure 8: Asset Tangibility and Stationary Distribution of Capital and Net-Debt



Note: Blue, red and cyan bars are the cases with  $\theta = 0.8, 0.5$  and  $0.3$ , respectively.  $E_z[\mu]$  is the marginal distribution of  $(K, B)$ .

Figure 9: Ratio of CES Capital Aggregator Relative to Total Capital



# Appendices

## A Stationary Equilibrium

The model economy consists of a continuum of firms that combine capital and labor to produce final outputs, and a continuum of households that provide labor hours to firms to earn market wages, consume final outputs and invest in firm's shares and debts to accumulate wealth. For the description of the firm problem, see the main text.

### A.1 Stationary Distribution

The presence of persistent idiosyncratic shocks, DRS production technology and financial market friction implies a non-degenerate joint distribution of technology, capital accumulation and financial balances. We denote the joint distribution by  $\mu(K, B, Z)$ . At any point in time, the joint distribution satisfies the following law of motion<sup>29</sup>:

$$\mu'(\mathbf{K} \times \mathbf{B} \times \mathbf{Z}) = \int \mathbf{1}(g_k(K, B, Z; \mu) \in \mathbf{K}) \cdot \mathbf{1}(g_b(K, B, Z; \mu) \in \mathbf{B}) \cdot Q(Z, \mathbf{Z}) \mu(dK, dB, dZ) \quad (25)$$

where  $g_k(K, B, Z; \mu)$  and  $g_b(K, B, Z; \mu)$  are the optimal capital and financial policies that solve the program (13). Note that the distribution next period  $\mu'$  is determined by today's optimal policies, which then depends on today's distribution  $\mu$  via market clearing wage. The stationary distribution is the fixed point solution to the above functional equation:  $\mu' = \mu = \mu^*$ . The stationary distribution can be used to compute exact moments of any order as well as *aggregates*.<sup>30</sup>

### A.2 Households

Since our focus is on firms' investment and financial policies, we assume the existence of a representative agent for the household sector. The household is assumed to maximize the expected present value of utility flows discounted at  $\beta < 1$ :  $\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t)$ . The utility flow is strictly increasing and concave in consumption, and is strictly decreasing and concave in labor hours. For ease of interpretation of general equilibrium effects, we adopt a utility form that is nonseparable in consumption and hours following Greenwood, Hercowitz, and Huffman (1988). More specifically, we specify

$$u(C, N) = \frac{1}{1-\sigma} \left[ \left( C - \frac{\zeta}{1+\phi} N^{1+\phi} \right)^{1-\sigma} - 1 \right]. \quad (26)$$

Such specification abstracts from wealth effects on labor supply, thus making it straightforward to interpret the effects of technological changes on capital accumulation.

<sup>29</sup>See Stokey, Prescott, and Lucas (1989) for theoretical discussion, and Gourio and Miao (2010) for a computational example.

<sup>30</sup>In principle, it is conceivable that the firm may want to exit owing to the presence of fixed costs of operation. For this reason, we allow the firms to have an exit option during our simulation such that the value of equity is truncated below by a certain threshold value  $\bar{V}$ . This can be achieved by replacing  $V(K', B', Z')$  with  $\max\{\bar{V}, V(K', B', Z')\}$  in the continuation value term. However, exit does not occur in our simulation with baseline calibration of the model in which we set  $\bar{V} = 0$ . If, however, the outside option of the firm,  $\bar{V}$  is substantially greater than zero the firms may want to exit in certain circumstances. For simplicity, we adopt an implicit assumption that the sunk costs of entry are given such that the value of outside option remains at a low value, and the value of new firm entry is no greater than the required gross return on the costs of entry, i.e.,  $\mathbb{E}[V(0, 0, Z_0)] - [1 + r(1 - \tau_i)]F_S \leq 0$ , where  $Z_0$  is an initial draw from the ergodic distribution of  $Z$  and  $F_S$  is the sunk entry costs, which can be interpreted as a natural entry barrier.

The household earns competitive market wage  $w$  per work hour, and saves by investing in shares and debt issued by the firms. The budget constraint of the household is given by

$$C + \int (P_S S' + B') \mu(dK, dB, dZ) = wN + T_G + T_F + \int \{(D + \tilde{P}_S)S + [1 + r(1 - \tau_i)]B\} \mu(dK, dB, dZ). \quad (27)$$

where  $P_S$  is the (ex-dividend) value of equity today,  $\tilde{P}_S$  is the (ex-dividend) value today of existing shares outstanding yesterday.  $S$  and  $S'$  are the number of shares outstanding yesterday and today, respectively. We assume that the proceeds of interest and corporate income taxes are transferred to the household in a lump sum, denoted by  $T_G$ . We also assume that all fixed costs of operation and investment are transferred to the household in the same way, denoted by  $T_F$ . The two value terms  $P_S$  and  $\tilde{P}_S$  are linked to each other by an accounting identity,

$$P_S S' = [\tilde{P}_S + E - \varphi(E)]S \quad (28)$$

This identity simply says that the total value of equity today is the sum of the total value of shares outstanding yesterday and the value of new shares issued today. Substituting (28) in (27) and imposing stock market clearing condition  $S = S' = 1$  yields

$$C + \int B' \mu(dK, dB, dZ) = wN + T_G + T_F + \int \{D - [E - \varphi(E)] + [1 + r(1 - \tau_i)]B\} \mu(dK, dB, dZ). \quad (29)$$

A few remarks are in order. First, by substituting (11) in (29), one can see that the term  $E - \varphi(E)$  vanishes. This makes it clear that the costs of issuing equity take the form of discount sales of new shares such that the dilution costs to the old shareholders are exactly offset by the gains of new shareholders in general equilibrium, thus leaving the resource constraint of the economy intact. Second, we use the same notation  $B$  to denote the debt issued by a firm and held by the household. When  $B$  is positive, this means that the household has a financial claim on a firm. When  $B$  is negative, this implies that the household owes money to a firm. Finally, we assume that the differential tax treatment of interest incomes and expenses applies only to the firms, but not to the household. This implies that the after-tax interest rate is equalized to the time discount rate of the household in the stationary equilibrium,  $1 + r(1 - \tau_i) = \beta^{-1}$ .

### A.3 Government

The government follows a balanced budgeting rule, collecting taxes and then transferring them to the household. The budget constraint is given by

$$T_G + T_F = \int [\tau_c [\Pi(K, Z) - F_0] - \tau_c \delta K - (\tau_c - \tau_i) \max\{0, B\}] \mu(dK, dB, dZ) \quad (30)$$

When a firm holds a strictly negative financial balance  $B$ , the taxes on interest incomes and the deduction on interest expenses of the household are offset.

### A.4 Stationary Equilibrium

The stationary equilibrium consists of a constant market wage  $w$ , the stationary distribution  $\mu^*$ , the individual policy rules of the firms,  $K' = g_K(K, B, Z; \mu^*)$ ,  $B' = g_B(K, B, Z; \mu^*)$ ,  $E = g_E(K, B, Z; \mu^*)$ ,



$D = g_D(K, B, Z; \mu^*)$ ,  $H^D = H^D(K, Z, w; \mu^*)$ ,  $I = p(g_K(K, B, Z; \mu^*), K) \cdot [g_K(K, B, Z; \mu^*) - (1 - \delta)K] \equiv g_I(K, B, Z; \mu^*)$ , the policy rules of the representative household,  $C = C(w; \mu^*)$ , and  $H^S = H^S(w; \mu^*)$  such that labor and goods markets clear<sup>31</sup>:

$$H^S(w; \mu^*) = \int H^D(K, Z, w; \mu^*) \mu^*(dK, dB, dZ) \quad (31)$$

$$C(w; \mu^*) = \int [Y(K, Z, w; \mu^*) - g_I(K, B, Z; \mu^*) + \kappa \min\{0, g_B(K, B, Z; \mu^*)\}] \mu^*(dK, dB, dZ). \quad (32)$$

## B Details of Variable Definition

The variables used in the analysis are defined as follows:

- Cash to book asset – our main dependent variable – is defined cash and marketable securities (data item #1) divided by book assets (#6)
- Other cash measures (robustness): Cash to Net Book Assets is cash and marketable securities (#1) divided by book assets (#6) minus cash and marketable securities (#1); Cash to Market Value of Assets is cash and marketable securities (#1) divided by long-term debt (#9) plus debt in current liabilities (#34) plus market value of equity.
- Net-Leverage is the ratio of long-term debt (#9) plus debt in current liabilities (#34) minus cash and marketable securities (data item #1) to book assets (#6).
- Industry sigma (cash flow risk) is the standard deviation of industry cash flow to book assets. Standard deviation of cash flow to book assets is computed for every firm-year using data over the previous ten years. We then average these cash flow standard deviations over 2SIC industries and each year.
- Market-to-book ratio is the ratio of the book value of assets (#6) minus the book value of equity (#60) plus the market value of equity (#199 \* #25) to the book value of assets (#6).
- Firm size is the natural logarithm of book assets (#6) in 1990 dollars (using CPI).
- Cash flow is earnings after interest, dividends, and taxes before depreciation divided by book assets ((#13 – #15 – #16 – #21) / #6).
- Capital expenditures is the ratio of capital expenditures (#128) to book assets (#6).
- Dividend is a dummy variable equal to one in years in which a firm pays a common dividend (#21). Otherwise, the dummy equals zero.
- Acquisitions is the ratio of acquisitions (#129) to book assets (#6).
- Net working capital is the ratio of net working capital (#179) minus cash (#1) to book assets (#6).
- Leverage is the ratio of long-term debt (#9) plus debt in current liabilities (#34) to book assets (#6).
- Net debt (equity) issuance is annual total debt (equity issuance minus debt retirement (equity repurchases), divided by book assets.
- R&D (flow) is the ratio of R&D expenditures (#46) to book assets (#6).
- Asset Tangibility is the ratio of net PPe (#8) to book assets (#6) minus cash and marketable securities (#1).

---

<sup>31</sup>The last term in the goods market clearing condition is due to the agency cost of cash holdings, which we view as an efficiency loss to the economy. The goods market clearing conditions can be derived by adding up three flow of funds constraints of the firms, the representative household and the government.

- High-tech industries are defined following Loughran and Ritter (2004) as SIC codes 3571, 3572, 3575, 3577, 3578, 3661, 3663, 3669, 3674, 3812, 3823, 3825, 3826, 3827, 3829, 3841, 3845, 4812, 4813, 4899, 7370, 7371, 7372, 7373, 7374, 7375, 7378, and 7379.
- WW-Index is based on Whited and Wu (2006) and is as follows:  $WW\text{-Index} = -0.091 * \text{CashFlow} - 0.062 * \text{Dividend} + 0.021 * \text{Leverage} - 0.044 * \text{Size} + 0.102 * \text{Industry Growth} - 0.035 * \text{Growth}$ , where Industry Growth is the 4-SIC industry sales growth, Growth is own-firm real sales growth, and the other variables are as defined above.
- Asset liquidation value is based on Berger et al. (1996) and is the sum of  $0.715 * \text{Receivables}(\#2)$ ,  $0.547 * \text{Inventory}(\#3)$ , and  $0.535 * \text{Capital}(\#8)$ .
- Industry asset redeployability index is based on Balasubramanian and Sivadasan (2009) and is the fraction of total capital expenditures in an industry accounted for by purchases of used (as opposed to new) capital, computed at 4-digit SIC level and constructed using hand-collected US Census Bureau data. Since these data are available only once every 5 years and not for more recent years, we compute a time-invariant index by averaging the available quinquennial indices at the 4-SIC level. This measure is only available for a restricted sample of manufacturing firms.
- Investment inaction, small investments, and investment spikes are defined at the firm level based on Cooper and Haltiwanger (2006) as those firm-year observations corresponding to  $|\text{Capex/book assets}| < .01$ ,  $|\text{Capex/book assets}| \geq .01$ , and  $|\text{Capex/book assets}| > .2$ , respectively. Industry is 4-SIC. In each industry-year, we compute frequency as number of observations involving investment inaction (small investment) to total number of observations in the industry. This procedure results in a time-invariant cross-sectional ranking of 4-SIC industries.
- Time-series skewness and kurtosis of annual aggregate industry investment are based on Caballero (1999) and calculated as the skewness and kurtosis of average annual Capex to book assets ratios in each (4-SIC) industry. In every year, we calculate annual averages in each industry as industry-year means of individual firm-year Capex to book asset ratios. This procedure results in a time-invariant cross-sectional ranking of 4-SIC industries.
- Time-series standard deviation of aggregate industry operating costs is calculated after aggregating firm-level operating costs by taking annual means at the 4-SIC industry level. For each industry, the measure is the standard deviation of these annual industry means of operating costs. Operating costs are costs of goods sold (#41). This measure gives a time-invariant cross-sectional ranking of 4-SIC industries.