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

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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 and that its importance increases monotonically with firms' financial constraint status and investment inflexibility. On average, our measure accounts for almost as much of the secular increase in cash since the 1970s as all other determinants together. We then develop a new dynamic model of corporate cash holdings with two productive assets, tangible and intangible capital. The interplay of real and financial frictions in the model leads firms with growth options to optimally hold cash in anticipation of (S,s)-type adjustments in physical capital because they want to avoid raising costly external finance. Since only tangible capital can be pledged as collateral, a shift toward intangible capital shrinks the debt capacity of firms and leads them to hold more cash in order to preserve financial flexibility. This mechanism is quantitatively important, as our model predicts an increase in cash holdings in line with the data in response to a realistic increase in intangible capital. We also consider alternative hypotheses, such as declining interest rates and rising equity issuance costs. Overall, our results suggest that technological change has contributed significantly to recent changes in corporate liquidity management.

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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[1] represents a big outstanding challenge for both empirical and theoretical research in corporate finance.

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, & Stulz (2009)). 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 explores a new hypothesis. We ask whether 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 show that it explains almost as much of the secular increase in cash since the 1970s as all other standard determinants together. The economic significance of the relation between intangible capital and corporate cash holdings

[1] 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)).

is higher than any of the other firm-level determinants and is even bigger for firms that have less financial slack and face more inflexible investment adjustments.

In order to better understand these stylized facts, we develop a new structural dynamic model of corporate cash holdings which builds on Bolton, Chen, and Wang (2011) and Riddick and Whited (2009) and features two distinct productive assets, physical and intangible capital. A motive for cash holdings arises in our model because of the interplay between real and financial frictions: especially when they have growth options, firms optimally hold cash since they anticipate having to make large (S,s)-type adjustments in physical capital and want to avoid raising costly external finance to fund these investments. Since only tangible capital can be pledged as collateral, a shift toward intangible capital shrinks the debt capacity of firms and leads them to hold more cash. In line with our empirical findings, the effect of rising intangible capital is even larger for firms that have more inflexible investment, since these firms anticipate having to make larger investments and, thus, want to hold an even large cash buffer. As a result of this mechanism, the level of cash holdings predicted by the model is up to an order of magnitude higher than the standard benchmark, thus offering a potential resolution of the quantitative puzzle in the literature. Overall, we conclude that intangible capital is a critical ingredient to providing a satisfactory analytical account of key stylized facts of US 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. While the previous literature has found a positive relation between some of these investments – e.g., R&D – and cash, we show that this relation is generally weak economically, as it is the case for other routinely employed measures of asset tangibility based on property, plant, and equipment. 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 intangibles 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 nonfinancial firms in Compustat between 1970 and 2010. Our measure is defined as the sum of three main components: the stock of innovative (R&D) capital, and the stock of human and organizational capital, and the stock of information technology (IT) capital. The stock of innovative capital is constructed by capitalizing R&D expenditures using a standard perpetual inventory method (e.g., Hall (1993)), for the stock of human and organizational capital we capitalize SG&A expenditures, and for IT we capitalize expenditures in computer software from the BEA.

Our empirical analysis shows that intangible capital is an important economic determinant of corporate cash holdings. We document a strong link between intangible capital and cash both in the cross-section and in the time-series using a wide range of specifications, that include standard OLS estimates (Opler et al. (1999)), as well as median regressions, regressions in changes rather than levels and a specification with firm fixed effects, and, finally, an instrumental variable specification that exploits R&D taxes as a source of plausibly exogenous variation in intangible capital.

Robustly across thee specifications, intangible capital emerges as the most important firm-level determinant of cash. In order to gauge its economic significance, for example, our OLS estimates imply that a one standard deviation increase in intangible capital leads to an increase in cash of almost 9 percentage points, which is larger than half of the mean level of cash holdings in the sample.

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, & Stulz (2009). 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 we can attribute to the rise in intagible capital up to a 5 percentage point increase in cash. This effect is economically significant as it corresponds to almost half of the overall predicted increase in cash holdings. Finally, suing sample split analysis and a battery of standard proxies for financial slack (which include firm size and dividend payer status, the KZ-Index by Kaplan and Zingales (1997), the WW-Index by Whited and Wu (2006), a measure of asset liquidation value by Berger et al. (1996), and an index of industry asset redeployability by Balasubramanian and Sivadasan (2009)) as well as new proxies for investment flexibility ((4-SIC) industry frequency of investment inaction, of small investments, and an indicator for whether there are investment spikes in the industry, which are all defined following Cooper and Haltiwanger (2006); time-series skewness and kurtosis of annual aggregate industry investment, based on Caballero (1999); and the time-series standard deviation of aggregate industry operating costs), we show that the economic importance of intangible capital is even larger form firms that have less financial slack and less investment flexibility.

In order to better understand the economic forces that drive the empirical link between intangible capital and cash holdings, we next develop a new structural dynamic model of optimal investment, capital structure, and liquidity management decisions that build on Bolton, Chen, and Wang (2011) and 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 and intangible capital, as well as cash, debt, and equity financing 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. In addition, the model predicts an increase in cash holdings in response to an increase in intangible capital whose magnitude is in line with the data.

Our paper contributes to the literature along three broad 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 showing that it helps to explain key stylized facts of US 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 (2011), Riddick and Whited (2009); see also Froot, Scharfstein and Stein (1993) for a seminal contribution) 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, a task we plan to undertake in future work.

2 Data

In order to explore the link between the rise in intangible capital and the secular trend in corporate cash, we construct a new comprehensive firm-level measure of intangible capital using standard accounting data from Compustat between 1970 and 2010. Our sample consists of all Compustat firms incorporated in the United States for the period 1970 to 2010. As is standard in the literature, we exclude financial firms (SIC codes 6000-6999), regulated utilities (SIC codes 4900-4999),[2] and firms with missing or non-positive book value of assets and sales in a given year. This selection

[2]The reason for these exclusions is due to the fact that cash holdings of firms in these industries can be subject to regulatory supervision.

process results in a final set of 176,877 firm-year observations for 18,535 unique firms. Following Bates, Kahle, and Stulz (2009), the dependent variable in our main analysis is the cash ratio defined as cash and marketable securities divided by book assets. In robustness analysis, we consider different definitions that divide cash and marketable securities by book assets net of cash and by market value of assets. Next, we detail how our measure of intangible capital is constructed.

2.1 Intangible Capital

Our key explanatory variable is a measure of intangible capital for each firm-year. Our aim is to construct a proxy for the amount of capital accumulated by past investments in intangible assets. In contrast to physical (tangible) capital such as property, plant, and equipment, intangible capital is hard to measure since investments in intangible assets are typically reported as an expense and capital that is created by such investments is not captured on firms' balance sheets. At the same time, investment in intangibles is substantial. Using aggregate NIPA accounts, Corrado, Hulten, and Sichel (2005) estimate that roughly $1 trillion of intangible investment is excluded from NIPAs annually over the period 2000 to 2003.

Our measure of intangible capital is constructed using annual data on expenses in three broad categories 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. First, the stock of knowledge capital from past R&D expenses is constructed using the perpetual inventory method as follows:

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

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 $\delta_{R\&D} = 15\%$ following Hall, Jaffe, and Trachtenberg (2001).[3] 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.

[3]If R&D expenditures are constant (in real terms), the stock of knowledge capital is $G_t = \sum_{s=0}^{\infty} (1-\delta)^s\, R\&D_{t-s} = \frac{R}{\delta}$.

Second, investments in organizational capabilities represent expenditures on enhancing the value of brand names and other knowledge embedded in firm-specific human and structural resources. Lev and Radhakrishnan (2004) argue that sales, general, and administrative (SG&A) expenses represent a proxy for investments in organizational capital since they reflect most of the expenditures that generate organizational capital, such as employee training costs, brand enhancements, payments to management and strategy consultants, and distribution systems (Papanikolau and Eisfeldt (2011) also construct a measure of organizational capital based on SG&A). We construct the stock of organizational capital from past SG&A expenses using perpetual inventory method as in (1) with $\delta_{SG\&A} = 20\%$ following Lev and Radhakrishnan (2004).[4]

Third, we construct a measure of each firm's stock of computerized information and software. Unfortunately, these expenses are not reported separately in firms' financial statements. However, these investments are reported at the (2-SIC) industry level in Bureau of Economic Analysis (BEA) Fixed Reproducible Tangible Wealth (FRTW) data. To obtain stocks, we apply the perpetual inventory method with a depreciation rate of 31% as in the BEA data. This data allows us to construct the stock of computerized information and software for each year at the industry level. We then construct a multiple of this stock to tangible capital stock at the industry level (stock of computerized information relative to tangible capital stock) and apply that multiple to each firm's tangible capital stock (PPE) to derive a firm-level computerized information and software stock.[5]

Intangible capital is defined as the sum of the stocks of investments in these three categories divided by net book assets. Since SG&A expenditures include a multitude of other expenses unrelated to investments in organizational capabilities, we follow Corrado, Hulten, and Sichel (2005) and only weigh the stock of organizational capital by 0.2.[6] Our resulting estimate for average intangible to tangible capital is about 1.2, which is comparable to the estimate in Corrado, Hulten, and Sichel (2005) based on aggregate NIPA accounts.

Table 1 provides summary statistics for our sample. We report the means, medians, and standard deviations of cash ratios as well as of intangible capital and of the main control variables, which are standard. The Appendix provides sources and detailed definitions of these variables.

[4]Missing values of SG&A are interpolated.

[5]Our results are little changed if we do not include this stock in our measure of intangible capital.

[6]In robustness analysis we have explored alternative weights in a wide (+/- 50%) range, which leave our results qualitatively unchanged.

Overall, our sample is comparable to those used in related studies (see Opler, Titman, and Stulz (1999) and Bates, Kahle, and Stulz (2009)). The bottom four rows of Table 1 report summary statistics of cash ratios for each quartile of the distribution of intangible capital in our sample. In the entire sample, mean (median) 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%) for firms in the top quartile of intangible capital.

3 Intangible Capital and the Rise in US Corporate Cash Holdings: The Evidence

This section studies the empirical link between the rise in intangible capital and the secular trend in corporate cash holdings. 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 and the rise in cash holdings in our large panel of US corporations over the 1970 to 2010 period. Finally, we use sample split analysis to investigate the importance of financing and investment frictions as potential forces behind this relation.

3.1 Stylized Facts

We begin our analysis by considering basic stylized facts of the evolution of corporate cash holdings over time. Figure 1 shows the sample average ratio of cash holdings to book assets (top panel) and of intangible capital to net book assets (bottom panel) over the sample period. Consistent with Bates, Kahle, and Stulz (2009), mean (median, not shown) cash holdings display a pronounced secular upward trend from about 8% (5%) in 1970 to about 20% (13%) by 2010. The rise was not concentrated in any particular decade, but rather has been steady. In additional graphical analysis,[7] we have divided the sample into terciles each year by size and age, high-tech and

[7]Detailed results are available upon request.

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. The bottom panel plots annual average intangible capital as a ratio to book assets net of cash over the same period. Our data replicates the finding of Corrado, Hulten, and Sichel (2009) that there was a substantial increase in intangible capital, with the intangible ratio rising tenfold over the last decades from about 5% of net book assets in 1970 to about 60% in 2010.

The fact that intangible capital has increased substantially suggests that it has the potential to provide an analytic account of the trend in cash, which constitutes a significant challenge for the existing literature. For example, Bates, Kahle, & Stulz (2009) emphasize that the rise in idiosyncratic uncertainty over the 1980s and 1990s may have contributed to the rise in cash due to firm's precautionary motive for holding cash. However, Brandt, Brav, Graham, and Kumar (2008) show that volatility fell back significantly after 2001, suggesting that volatility cannot explain the continued upward trend in cash over the last decade. Determinants related to other prominent explanations, such as retained profits or agency problems related to managerial private benefits of control, also have limited explanatory power since there has been no obvious trend in firm profits or firm governance quality. Finally, while repatriations are plausibly a significant part of the story, tax related explanations also can't be the main driver of the secular trend, since cash holdings have increased also for firms with no foreign subsidiaries (Faulkender and Petersen (2011)).

As a first step toward probing the relation between intangible capital and cash, we explore cross-industry 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 increases have 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 0.13) even in traditional industries such as retail (Shops). Figure 2 shows the corresponding distribution of average industry cash ratios. Sectors in the top panel are sorted by the average intangible capital ratio in the 2000s and the bars show average cash ratios for each decade by industry. While cash ratios have increased over time in all industries, the most notable increases were posted in industries that had the most intangible capital in the last decade. In fact, for the pooled industry-decades observations in the bottom panel, there is a strong correlation between intangible capital and cash ratios, with a regression coefficient of about 0.13 and an R^2 of more than 75%.

Next, we consider cross-firm variation. We stratify the sample into terciles each year according to each firm's year-prior intangible capital ratio. The top panel of Figure 3 plots average cash ratios for each tercile over the sample period. While cash ratios increased on average in all terciles, they roughly tripled for firms in the highest tercile of intangible capital but only went up by about 50% for firms in the lowest tercile. Since these annual averages pool across many potentially different firms, changes in composition of the sample over time may be driving the trend. To address this concern, the bottom panel of Figure 3 considers time-series variation within firms. We compute, for each firm, the change in average intangible capital ratio before and after 1990 and divide the sample into deciles according to these firm-level changes in intangible capital. The figure plots the corresponding average change in cash ratios before and after 1990 for each decile of the distribution of these firm-level changes in intangible capital. Firms in the lower deciles have declines in intangible capital, while firms in the top deciles correspond to the largest increases. Changes in cash line up quite well along the diagonal, with firms that experienced a decline in intangible capital also seeing their cash ratios decline, while firms for which intangible capital rose the most also experiencing the greatest increases in cash.

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

3.2 Main Regression Analysis

In the first part of our empirical analysis, we use standard panel regression techniques to examine whether intangible capital is an economically important determinant of corporate cash holding decisions. To that end, we regress cash holding ratios on our measure of intangible capital, while controlling for a set of standard determinants of cash holdings (e.g., Opler et al. (1999) and Bates et al. (2009)). We consider several different variations of the following baseline model:

$$Cash_{it} = \alpha_t + \beta * Intangible\ Capital_{it-1} + \delta * X_{it-1} + \varepsilon_{it} \quad (2)$$

where $Cash_{it}$ is the ratio of firm i cash holdings to book assets in year t. The main explanatory variable is the intangible capital ratio and X_{it-1} is a vector of time-varying 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. We report standardized coefficients to facilitate comparison and interpretation, which are, for each reported coefficient, the change in the dependent variable associated with a one-standard deviation change in the determinant. We include year effects, α_t, 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 null hypothesis is that β equals zero.

We report results separately for the overall sample and for the subset of firms that report positive R&D in any given year in order to address the concern that results for the overall sample may simply reflect spurious differences in average cash holdings between non-innovative vs. innovative firms.[8] We complement our baseline OLS estimates (and small variations that replace time dummies with a linear time trend or add net working capital and leverage to the set of controls), with the following additional tests: first, median regressions that address the concern that outliers firm-year observations with very high levels of cash may be driving the OLS estimates; second, OLS estimates for a specification in changes, rather then levels, and for a specification in levels but with firm fixed-effects,[9] which control for time-invariant unobserved heterogeneity across firms thus allowing to exploit within-firm variation in cash over time.

We also present 2SLS estimates that treat intangible capital as an endogenous variable and achieve identification by using R&D user cost as a plausibly exogenous instrument (see Bloom et al (2010) for another paper using this identification strategy).[10] This specification addresses the

[8]This is the case since intangible capital is non-zero for those non-innovative firms that have zero R&D stock but have investments in brand equity or distribution systems.

[9]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.

[10]We do not report results for the entire sample since R&D tax credit is a meaningful source of exogenous variation

important potential concern that OLS estimates may be biased by the endogeneity of intangible capital, if, say due to financial constraints, firms with more cash are in better position to invest in intangible capital, making the latter an outcome, rather than a determinant, of cash. It is unlikely that R&D tax policy should be systematically related to cash holdings. However, to the extent that R&D expenses respond to tax incentives, we would expect R&D tax credits to have predictive power for the R&D stock. Following Hall (1992), we use the Federal rules to construct a measure of R&D tax credit for each firm, which has a firm-specific component since the definition of what qualifies as allowable R&D for tax purposes depends on a firm-specific "base" (see Appendix for details on construction of the instrument).

Table 2-A presents the results of these different specifications for the overall sample (Columns (1) to (6)) and for the subset of firms that report positive R&D in any given year (Columns (7) to (11)). The coefficient on intangible capital is robustly positive and statistically significant across the two samples and all specifications. Signs and statistical significance of coefficients on most control variables are also unchanged across specifications[11] and 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. In all, our finding that intangible capital is a statistically significant determinant of corporate cash holdings is neither due to outliers in cash, nor to unobserved firm heterogeneity, nor to reverse-causality.[12]

Irrespective of sample and specification, intangible capital is not only statistically, but also economically significant, and in fact it is more important than any of the other determinants of cash, including firm cash flows and industry risk. 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%. While coefficients on most other determinants decline markedly in the specifications

in intangible capital only for firms that report positive R&D.

[11] With the exception of dividends, which changes sign, and industry cash flow volatility, which becomes insignificant in the fixed effects specification (Coumns (6) and (10)), consistent with evidence in Brav et al. (2008) of no secular trend in idiosyncratic volatility over our sample period.

[12] As expected, the first stage results for the IV specification in Column (11), which are omitted for brevity, show that R&D tax credit increases R&D expenditures. The F-tests indicate that the instrument has considerable power.

in changes (Column (4)) and with firm fixed effects (Column (5)), the estimates for intangible capital decline by only about 2 and 1/2%, suggesting that intangible capital not only picks up cross-sectional variation, but is also an economically significant determinant of the time-series evolution of cash holdings. Finally, robustly across specifications, intangible capital coefficients for firms with positive R&D (Columns (7)-(11)) are even larger than those for the entire sample, which suggests that our baseline OLS result is not spurious and that, possibly also because there is less measurement error in the intangible capital variable (leading to lower attenuation bias), intangible capital is an even more important economic determinant of cash holdings for innovative firms.

Table 2-B shows that our findings have important implications for the measurement of leverage. We replicate our battery of 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 the two samples and all specifications. Irrespective of sample and specification, intangible capital is also economically significant. For example, for the baseline OLS specification in Column (1), one standard deviation increase in intangible capital is associated with about 11 % decrease in the cash ratio, which is almost as large as the sample mean value of net leverage ratio 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.

3.2.1 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. To ease comparison and gauge the relative contribution of intangible capital compared to other standard determinants, we use the approach in Bates et al. (2009) and augment the OLS specification with additional financial controls (Column (3) of Table 2) with net debt and equity issuance, which are included in their specification. The intuition for this exercise is as follows: sample average intangible capital was 0.42 in 1980 and 0.75 in 2000. The (unscaled) coefficient on intangible capital in Column (3) of Table 2 is 0.087. Thus, we infer 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*0.42) in 1980 to 6.5 percentage points (=0.087*0.75) in 2000.

Table 3 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 regression specification of Column (3) of Table 2 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. Consistent with our earlier discussion of economic significance, 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) (Columns (1) and (2) of Table 3). Except for the next most important determinant, net working capital, changes in all other standard determinants have quite limited explanatory power for the rise in cash.

3.2.2 Implications for the Empirical Literature on the Determinants of Corporate Cash Holdings and Robustness Checks

While our measure of intangible capital is new to the corporate finance literature, there have been at least two related measures routinely employed in previous studies of corporate cash and capital structure: R&D expenditures (flows) and asset tangibility measured as the ratio of property, plants, and equipment to book assets. Standard findings are that there is a positive relation between R&D flows and cash holdings and between asset tangibility and leverage ratios (e.g., Lemmon, Roberts, and Zender (2008)). Row [1] of Table 4 shows that, if we replace intangible capital with R&D expenditures in our regressions, we also find a positive coefficient. However, the statistical significance of R&D expenditures is not robust across specifications and their economic significance is small even in the baseline OLS specification (Column (1) of Table 4).

Row [2] shows results for a specification that includes both intangible capital and R&D expenditures. Robustly across samples and specifications, the inclusion of R&D expenditures leaves the coefficient on intangible capital little changed. However, the sign of the coefficient on R&D expenditures now becomes negative, suggesting that, much like capital expenditures and acquisitions, firms use their cash holdings to pursue investment in research and development. Row [4] shows that replacing intangible capital with a standard measure of asset tangibility (PPE to net book assets) leads again to coefficients that are not robustly significant, whose signs change across specifications, and have generally very weak economic significance.

The last four rows of Table 4 show that our main result is robust to using different definitions of cash ratios (Rows [5] and [6]) and does not reflect changes in sample composition due to entry of new firms or increased importance of high-tech sectors, which is a valid concern since new entrants and firms in high technology sectors have both more intangible capital and more cash. Row [7] shows that the coefficient of intangible capital remains robustly positive and economically significant across all specifications when we restrict our sample to exclude entrants (i.e., firms that are not present in every year of the sample period) and Row [8] shows that this is the case also if we exclude firms in high technology sectors.

3.3 Why Does Intangible Capital Matter So Much?

In the second part of our empirical analysis, 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. First, we consider financial frictions. A well-established literature (e.g., Hart and Moore (1994)) emphasizes that intangible assets may limit external (debt) financing and favor internal finance (cash) because such assets complicate contractibility problems by lowering the value that can be captured by creditors in default states. Thus, 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. Second, we consider real frictions. There is a vast literature on real options in finance (e.g., Abel et al (1996)) and on non-convex adjustment costs of investment in macroeconomics (Caballero (1999) is a comprehensive survey). The basic insight of these studies 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 in order to be able to finance their large investments.

Table 5 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 six ex-ante indicators of their financial constraint status, which include firm size (Rows [1] to [2]), the KZ-Index by Kaplan and Zingales (1997) (Rows [5] to [6]) and the WW-Index by Whited and Wu (2006) (Rows [7] to [8]), a measure of asset liquidation value by Berger et al. (1996) (Rows [9] to [10]), and an index of industry asset redeployability by Balasubramanian and Sivadasan (2009) (Rows [11] to [12]), as well as dividend payer status (Rows [3] to [4]). 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 two financial constraints indices, for which the ordering 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]).

Table 6 shows evidence on the role of investment frictions. We now split the sample between bottom and top quartiles of the following (time-invariant) proxies of investment frictions: (4-SIC) industry frequency of investment inaction (Rows [1] to [2]), of small investments (Rows [5] to [6]), and an indicator for whether there are investment spikes in the industry (Rows [3] to [4]), which are all defined following Cooper and Haltiwanger (2006); time-series skewness (Rows [7] to [8]) and kurtosis (Rows [9] to [10]) of annual aggregate industry investment, based on Caballero (1999); and the time-series standard deviation of aggregate industry operating costs (Rows [11] to [12]). 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 industry measures in turn, except for the frequency of small investments and 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 where there are investment spikes compared to those that are in industries that have no such spikes in investment (Rows [3] and [4]).

3.4 Intangible Capital and Cash Dynamics

In our final set of tests, we further probe the role of intangible capital in driving the time-series dynamics of corporate cash management. We do so by adding a lagged dependent variable into 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 (there is a vast literature on partial adjustment in leverage ratios – e.g., 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 et al. (2012) for more details on this intuition).

Because there is an ongoing debate in the literature about the proper estimation procedure of SOA, Table 7 reports results for a wide battery of SOA estimators. Row [1] shows that the annual SOA of cash ranges between 0.27 and 0.54, 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. Rows [2] to [5] shows results when we estimate SOAs separately for firms in each quartile of the sample distribution of intangible capital. 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 time larger than for firms in the bottom quartile. These results are consistent with the hypothesis that intangible capital increases adjustment costs of cash.

4 Intangible Capital, Debt Capacity, and Cash Holdings: A Structural Model

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. We consider a firm that produces and sells output in a competitive market by combining labor and capital. The firm uses 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:

$$Y = Z^{1-(\alpha_n+\alpha_k)} N^{\alpha_n} \Phi(K_T, K_N)^{\alpha_k} - F_0(K_T + K_N), \quad \alpha_n + \alpha_k < 1 \tag{3}$$

where Z is an idiosyncratic technology shock, n is labor hours, and $\Phi(K_T, K_N)$ is a capital aggregator that combines the two capitals and transforms them into *capital services*. We will discuss the properties of the aggregator $\Phi(K_T, K_N)$ in detail later.

Production is subject to fixed operation costs, which we assume are proportional to the size of the firm given by $K_T + K_N$. The proportional fixed cost F_0 plays an important role: given that the capital inputs are quasi-fixed, the fixed cost makes it possible for the firm to incur an operating loss ex post. The idiosyncratic technology shock follows a Markov process given by

$$\log Z = \rho_z \log Z_{-1} + \sigma_z \epsilon - 0.5\sigma_z^2, \quad \epsilon \sim N(0,1). \tag{4}$$

The firm static optimization problem is to maximize profits before tax and fixed costs:

$$\begin{aligned} \Pi(K_T, K_N; \omega) &= \max_N \{ Z^{1-\alpha_n} N^{\alpha_n} \Phi(K_T, K_N)^{\alpha_k} - \omega N \} \\ &= \phi(\omega) Z^{1-\gamma} \Phi(K_T, K_N)^{\gamma} \end{aligned} \tag{5}$$

where τ_c is a flat tax rate on corporate income, $\phi(\omega) \equiv (1-\alpha_n)(\alpha_n/\omega)^{\alpha_n/(1-\alpha_n)}$ and $\gamma \equiv \alpha_k/(1-\alpha_n)$.

To motivate liquid asset 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)). Denoting initial purchase prices and liquidation values by p_i^+ and p_i^- for $i = T, N$, partial irreversibility can be formally expressed as $p_i^- \leq p_i^+$ for $i = T, N$. In addition, we also assume that adjustment of capital is costly in either direction because it involves fixed adjustment costs. Fixed costs are proportional to capital in place, with the proportionality factor denoted by F_k for both capital types (Cooper and Haltiwanger (2006)). Combining these two assumptions regarding the illiquidity of capital assets, we can express the adjustment cost of capital as

$$G(\mathbf{X}, \mathbf{K}) = \sum_{i=T,N} \{[p_i^+ \cdot 1(X_i > 0) + p_i^- \cdot 1(X_i < 0)]X_i + F_k K_i \cdot 1(X_i \neq 0)\} \tag{6}$$

where X_i satisfies the laws of motion for capital: $K_i' = (1 - \delta_i)K_i + X_i$ for $i = T, N$.

4.1 Financing Frictions

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

4.1.1 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.[13]

[13]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.

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:

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

where $r(B')$ 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 a collateralized line of credit arrangement.

Note that we allow B' to be negative, in which case b' is investment in liquid assets. We assume that the interest income tax rate, τ_i, is lower than corporate income tax rate, τ_c, which creates scope for the firm to accumulate debt. Hence, after-tax interest rate can be expressed as

$$r(B') = \begin{cases} r(1-\tau_c) & \text{if } B' \geq 0 \\ r(1-\tau_i) & \text{if } B' < 0 \end{cases} \tag{8}$$

Despite the tax advantages of debt, the firm may optimally choose to hold liquid assets. In order to preserve tractability,[14] 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.

4.1.2 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 simply 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

[14]Technically, to consider this case we would need to introduce an additional state variable.

Wang (2011)). 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:

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

In words, the firm incurs fixed costs when issuing new equities, 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 (2011), who show that fixed costs of equity issuance significantly strengthen firms' precautionary demand for liquid assets.

Finally, the flow of funds constraint faced by the firm is given by:

$$\begin{aligned} D &= (1-\tau_c)\left[\Pi(K_T, K_N; \omega) - F_0 \sum_{i=T,N} K_i\right] \\ &\quad + \tau_c \sum_{i=T,N} \delta_i K_i - (1 + r(B))B - g(\mathbf{X}, \mathbf{K}) + B' + E \end{aligned} \tag{10}$$

where d is the dividend payout. Note that the depreciation of capitals is tax deductible in our setup.

4.2 Firm Value Maximization Problem

To close the model, we need to specify the capital aggregator. We assume that the aggregator is linear homogenous (see Epstein (1983)). In particular, we assume a Constant-Elasticity-of-Substitution (CES) aggregation function:

$$\Phi(K_T, K_N) = [(1-\theta)K_T^{-\rho} + \theta K_N^{-\rho}]^{-1/\rho} \tag{11}$$

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 weakening some of the parametric assumptions of the first setup. Next, we describe these two cases in turn.

4.2.1 Baseline Model

For our baseline analysis, we adopt additional parametric assumptions that make the model more tractable, but do not come at the cost of shutting down any of the main forces at work in the model. First, we assume that tangible and intangible capital have the same depreciation rate and purchase/liquation values (Symmetry): $\delta_T = \delta_N = \delta$, $p_T^+ = p_N^+ = 1$ and $p_T^- = p_N^- = p_K < 1$. Second, we assume that the elasticity of substitution between the two capital is zero, i.e., that the capital aggregator takes the following Leontief form ($\rho = \infty$):

$$\Phi(K_T, K_N) = \min\{(1-\theta)K_T, \theta K_N\}$$

These assumptions make the model more tractable by eliminating the need to track two state variables separately for tangible and intangible capital stocks – i.e., we need to track only one state, total physical assets, $K \equiv K_T + K_N$. To see why this is the case, consider that under these assumptions the technological constraint implies that (over any equilibrium path taken by the firm) $(1-\theta)K_T = \theta K_N$, or equivalently, $K_N = \frac{1-\theta}{\theta} K_T$. Furthermore, since $p_T^{\pm} = p_N^{\pm}$ and defining the tangible asset ratio as $\theta = K_T/K$, we can rewrite the collateral constraint as

$$B' \leq B^{\max}(K'; p_K, \theta) \equiv \frac{p_K \theta (1-\delta) K'}{1 + r(B')}$$

It transpires from this expression for the collateral constraint that this formulation allows us to analyze in a very parsimonious way the key intuition of the model that a higher tangible asset ratio implies greater debt capacity. Thus, by varying θ parametrically, this formulation turns out to be an effective and parsimonious way to fulfill the main goal of our model, which is is to develop a quantitative analysis of the effect of the asset tangibility on firms' optimal investment, hedging, and liquidity management choices.

Under the baseline assumptions, we can express the firm's optimization problem as follows:

$$\begin{aligned} V(K,B,Z) &= \min_{\lambda,\mu} \max_{B',X,D,E} \Bigg\{ (1+\lambda)D - [E+\varphi(E)] + \mu \left[\frac{p_K \theta(1-\delta)}{1+r_b(B')} K' - B' \right] \\ &\qquad + \frac{1}{1+r(1-\tau_i)} \int \max\{\bar{V}, V(K',B',Z')\} Q(Z,dZ') \Bigg\} \\ &\quad \text{s.t} \\ D &= (1-\tau_c)[\Pi(K_T,K_N;\omega) - F_0 K] + \tau_c \delta K - (1+r(B))B \\ &\quad -G(X,K) + B' + E \\ K' &= (1-\delta)K + X \end{aligned} \tag{12}$$

where λ and μ are multipliers for the dividend ($D \geq 0$) and the collateral constraints, respectively.

4.2.2 Alternative Formulation

We also consider robustness of our conclusions to an alternative formulation that lessens the strong parametric assumptions of our baseline analysis. In this alternative setting, we replace the Leontief assumption with a general CES aggregator. We also allow for different depreciation rates for tangible and intangible capital.[15] This alternative formulation achieves tractability by exploiting the linear homogenous structure of the problem. Since the profit function and the constraint correspondences of the problem are linearly homogeneous in Z, K_T and K_N, we can define the firm problem in terms of maximization of firm value per unit of tangible capital (normalizing factor). To see this, note that the profit function can be normalized as

$$\pi(z,k) \equiv \phi(\omega) z^{1-\gamma} (1-\theta+\theta k^{-\rho})^{-\gamma/\rho}.$$

where z is defined as technology-to-tangible capital ratio (Z/K_T) and k is defined as intangible-to-tangible capital ratio (K_N/K_T). Likewise, the normalized adjustment cost function $g(\mathbf{x},k)$ can be expressed as

$$g(\mathbf{x},k) = F_k[1 \cdot 1(x_T \neq 0) + k \cdot 1(x_T \neq 0)] + \sum_{i=T,N} [1 \cdot 1(x_i > 0) + p_K \cdot 1(x_i < 0)] x_i$$

[15] Note that we keep the symmetry assumption about the purchase and resale prices of capital, since this assumption is unlikely to alter our main conclusions as long as these prices are held constant.

where $x_i \equiv X_i / K_T$. The dilution cost also can be normalized as

$$\varphi(e) = \varphi_0(1+k) \cdot 1(e>0) + \varphi_1 \cdot \max\{0, e\}$$

We use lower case letters to denote ratios relative to tangible capital stock in place. We denote the variables that are predetermined at the beginning of the next period, but are still normalized by today's tangible capital stock, using '$\sim$'. For instance, $k'_N \equiv K'_N / K'_T$, and $\tilde{k}'_N \equiv K'_N / K_T$. Finally, to preserve homogeneity of the value function, we assume that the outside option of the firm is proportional to the size of the firm, i.e., $\bar{V} = \bar{v}K$.

The "scaled" firm problem is given by

$$\begin{aligned} v(k,b,z) &= \min_{\lambda,\mu} \max_{\tilde{b}',x_T,x_N,d,e} \Bigg\{ (1+\lambda)d - [e+\varphi(e)] + \mu \left[\frac{p_K(1-\delta_T)}{1+r_b(b')} \tilde{k}'_T - \tilde{b}' \right] \\ &\quad + \frac{1}{1+r(1-\tau_i)} \tilde{k}'_T \int \max\{\bar{v}(1+k'), v(k',b',z')\} Q(z,dz') \Bigg\} \\ &\quad \text{s.t.} \\ d &= (1-\tau_c)\left[\pi(z,k) - F_0(1+k)\right] + \tau_c(\delta_T + \delta_N k) - (1+r(b))b \\ &\quad -g(\mathbf{x},k) + b' + e \\ \tilde{k}_T &= (1-\delta_T) + x_T \quad \text{and} \quad \tilde{k}_N = (1-\delta_N)\,k + x_N \end{aligned} \tag{13}$$

In contrast to our baseline formulation, now the parameter θ does not directly enter the collateral constraint as the firm is free to choose any technological combination of the two capitals. However, the technological parameter θ affects the debt capacity of the firm also in this alternative formulation, though indirectly as the marginal productivity of intangible capital determines the optimal debt capacity chosen by the firm. An interesting feature of this alternative implementation of our setup is that the substitutability between the two types of capital allows the firm to trade-off the marginal efficiency of intangible capital against the convenience yield of tangible capital as collateral asset, the marginal effect of which is given by $\mu \cdot p_K(1-\delta_T)/1 + r_b(b')$.

Despite this margin, the firm cannot indefinitely postpone investment in intangible capital. For very low levels of k, the marginal productivity of intangible capital is so high that the firm may find it optimal to invest in intangible capital even though it does not provide the convenience yield of

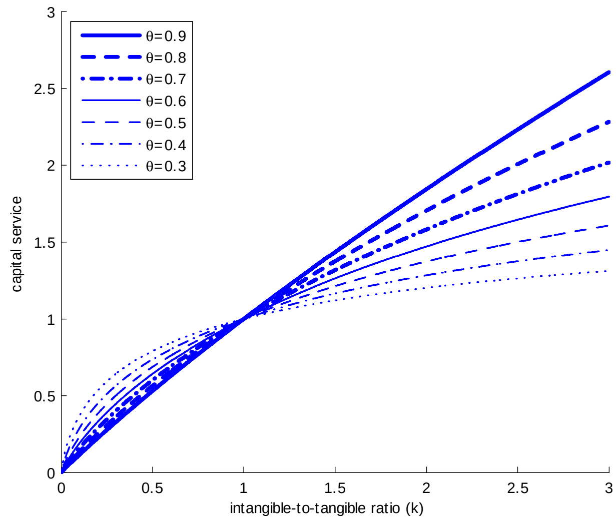

Figure 1: Intangible-to-Tangilble Capital Ratio and Capital Service

expanding debt capacity. If the current technology does not warrant any expansion of productive capacity, the firm can achieve the same effect of increasing its financial slack by investing in liquid assets in order to keep its investment options alive. Only as the level of k becomes relatively high, the firm may want to invest in tangible capital, raising the marginal efficiency of existing intangible capital and expanding its debt capacity at the same time. In all these decisions, θ plays an important role since, for any given elasticity of substitutability $1/(1+\rho)$ and state (k, b, z), it determines the marginal productivity of intangible capital. In future analysis, we plan to further explore the implications of this alternative setup.

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 (γ) 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. Following Ramey and Shapiro (2001), we set the resale value of capital at 0.8. To parametrize the fixed cost of investment, we follow Cooper and Haltiwanger (2006), who estimate that the fixed cost of investment as about 0.01 of installed capital. The fixed cost of operation (F_O) is set equal to 0.30 so that about 1/3 of the simulation sample generates negative operating

Table 1: Baseline Calibration

Description	Calibration
Technological parameters	
Profit function curvature	$\alpha = 0.60$
Depreciation	$\delta = 0.10$
Partial irreversibility	$p_k = 0.80$
Fixed cost of adjustment	$F_k = 0.01$
Fixed cost of operation	$F_0 = 0.30$
Persistence of technology shock	$\rho_z = 0.80$
Volatility of technology shock	$\sigma_z = 0.30$
Financial parameters	
Risk-free rate	$r = 0.06$
Fixed cost of issuance	$\varphi_0 = 0.01$
Linear cost of issuance	$\varphi_1 = 0.15$
Interest rate income tax rate	$\tau_i = 0.30$
Corporate income tax rate	$\tau_c = 0.35$

income (earnings after interests, dividends, and taxes before depreciation), which is in line with Compustat data. 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 θ, 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 follow Bolton, Chen, and Wang (2011) to choose the fixed cost of equity issuance to be 1 percent of total capital assets in place. 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.

5.2 Properties of the Optimal Real and Financial Policies

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

Figure 2 displays the firm's optimal choice of cash/debt (B', upper panels) and investment (X, lower panels) as a function of capital accumulation (K) for two different levels of technology (Z) and for a given financial condition (B). We set the current net-debt outstanding at its unconditional mean level in our stochastic simulation with $T = 100$ periods and $N = 1,000$ firms, i.e., we fix B at $\bar{B} \equiv 1/(TN)\Sigma_{it}B_{it}$. To highlight the properties of liquidity demand, we set $\theta = 0.3$, a very low level of tangible capital ratio, and hence, a very low level of pledgeability of production assets. In fact, this value of θ 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), $1/(TN)\Sigma_{it}B_{it}/A_{it} = 0.29$ in our simulation. We consider deviations of the technology level from its steady state of 30% below (blue solid lines) and 30% above (red dotted). The panels to the left ((a) and (c)) 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) and (d)).

First, consider the case of partial irreversibility. The most striking feature of the optimal financial policy is that cash hoarding is associated with low technology while leverage build-up is associated with high technology (panel (a)). When the current technology is low, the growth option of the firm is 'in the money' in 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.[16]

These features of firms' financial policies hinge crucially upon the assumption that the firm has

[16]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.

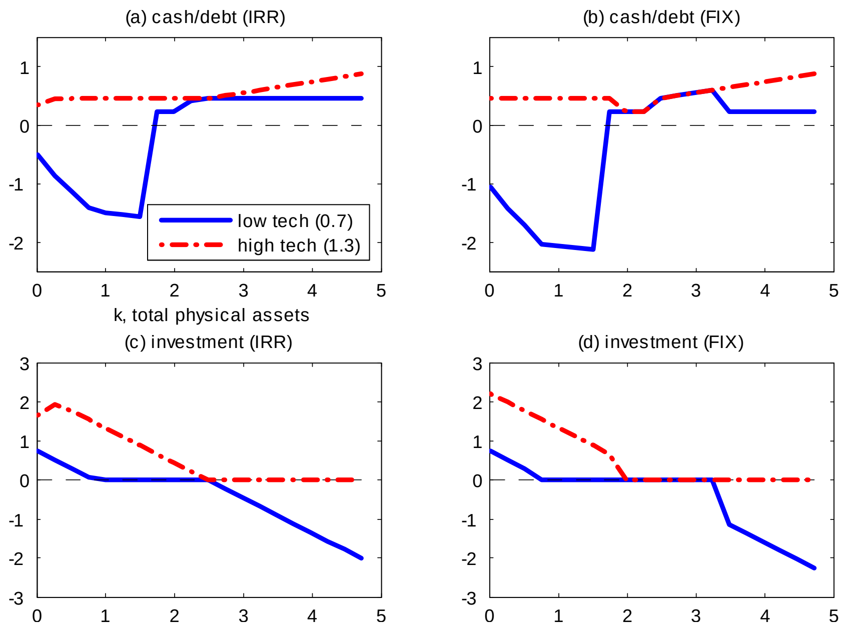

Figure 2: Growth option and demand for liquid assets

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 2 in panel (a), the growth option is so deep 'out of the money' that the firm assesses the probability of unexpected large cash needs to be close to zero. In panel (c), investment is indeed inactive in this region. Furthermore, the firm starts liquidating capital despite the heavy discount ($1 - p_K = 0.2$ in our calibration) once its capacity hits a boundary level of about 2.5. By contrast, when current capacity is very low, as, for instance, in the region below a capital accumulation level of 1, 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.

The firm's financial policy takes a very different form when the technology level is high, the case of red dotted lines in the figure. Since the growth option is deep 'in the money' in this case, the firm disburses all of its resources to finance a large scale expansion of productive capacity. Furthermore, it issues new debt and uses the proceeds for capacity expansion. In panel (c), one can see that investment expenditures increase linearly as we move from the current capacity level of 2.5 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 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. 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 2.5. The financial policy in this case is simply decrease cash holdings by paying out dividends and build up leverage to exploit tax benefits.

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 (d)). Second, investment also involves 'burst' episodes. For instance, investment (red dotted) at around $K = 2$ disproportionately jumps up, and disinvestment (blue solid) jumps down at around $K = 3$. These jumps up and down 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. This increase in cash holdings is due to the fact that fixed costs make one time large adjustments of capacity optimal, which in turn increases the precautionary demand for cash needed to finance such large-scale expansions.

In our previous discussion we have argued that when the value of growth option is close to zero, firm's financial policies take a dramatic turn from cash hoarding to leverage build-up. However, does that mean that the firm actually use up all of its financial slack? The answer to this question is sometimes, but not frequently. In our stochastic simulation, the proportion of observations with zero financial slack is about 5% for the pure irreversibility model, and a little less than 3% for the model that adds fixed costs. These results imply that firms in the model want to keep financial slack to insure themselves against unexpected deterioration of liquidity conditions even

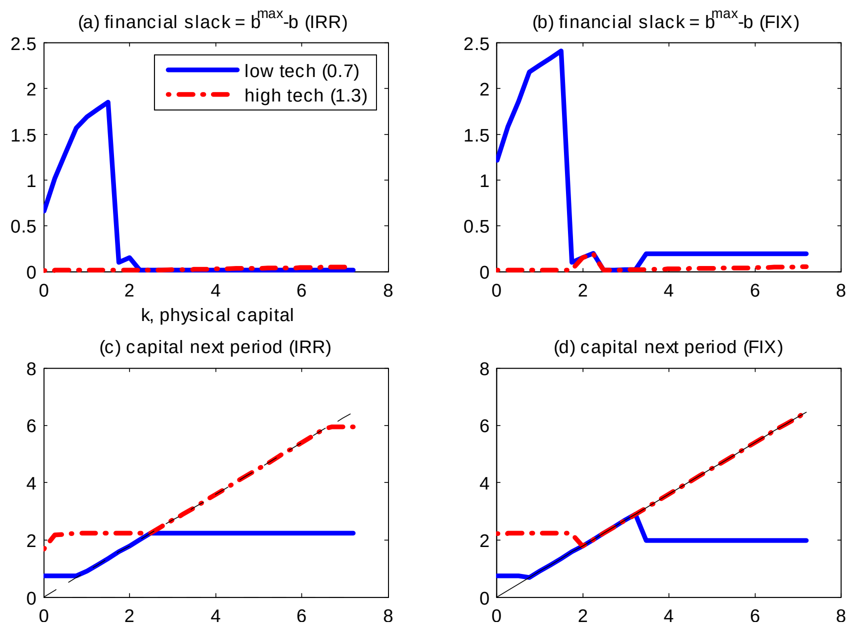

Figure 3: Financial slack and productive capacity

when they have substantial amount of overcapacity. This is because there is always a probability of large operating losses and/or arrival of new investment opportunities.[17]

Figure 3 shows the relation between firm financial slack and optimal capacity, where financial slack is defined as the sum of debt capacity and liquid asset holdings, $B^{\max}(K'; p_K, \theta) - B'$. Panels (a) and (b) again contrast the pure irreversibility with the irreversibility plus fixed cost of adjustment scenarios, respectively. The properties of debt capacity follow directly from those of optimal production capacity, which are shown in lower panels ((c) and (d)), since debt capacity is a constant fraction of tangible asset holdings. The thin black dotted lines in the lower panels plots the current capacity level, $(1-\delta)K$. Thus, the vertical difference between next period's optimal capacity choice (blue solid or red dotted lines) and this line represent investment expenditures shown in figure 2. When the two lines coincide, the firm is inactive in its investment, letting its capacity depreciate at a constant rate along the think black dotted line. When the firm is active, it tends to choose constant investment targets, one for expansion and the other for contraction.[18]

[17]We need to be careful in interpreting the flat part of the financial slack near zero level, for instance after capital accumulation level 2 in panel (a). In our stochastic simulation, the firms spend most of time in a region below $K = 3$. This means that the firms rarely have zero financial slack in actual simulation.

[18]However, optimal capacity choices sometime deviate from the standard (S,s) structure. As can be seen in the case of the high technology (red dotted line in panel (c)), there can be multiple expansion targets. When current capacity is very low, the expansion target increases with current capacity as if there were convex adjustment costs. This feature is an artifact of financial frictions: since the gap between the target and the current capacity is so large, the firm cannot

Firms with an unusually high technology almost completely deplete their financial slack (panel (a)). When the current capacity level is low, this is because the firm wants to spend large resources on capacity expansion. When the firm has overcapacity, this is because the firm views arrival of new investment opportunities as unlikely events. In fact, since technology shocks are mean reverting, the firm's expected TFP level is decreasing from the current level. Indeed, panel (c) displays a large investment inaction region. An analogous logic applies to the properties of financial slack when the adjustment of capital involves fixed costs (red dotted line, panel (b)). However, with fixed costs the firm still wants to hold small, but strictly positive amount of financial slack since fixed costs strengthen the precautionary motive for corporate saving.

By contrast, firms with unusually low technology hold large amounts of financial slack. At its peak, the firm sets aside almost as much financial slack as the book value of its current capacity. Mean reversion of the technological process plays an important role in the build up of financial slack: a low technology draw today implies that the firm's expected growth prospects are improving. Interestingly, when the adjustment of capacity involves fixed costs, the firm wants to carry over a substantial amount of financial slack despite a large capital overhang (blue line, panel (b)). This is because capital overhang makes downsizing more likely given the unusually low technology level, and downsizing is more costly due to the fixed costs of adjustment.

The upper panels of figure 4 compare the optimal financial policies, B', that correspond to four different levels of current net debt position, B. As before, partial irreversibility is shown on the left, while the combination of irreversibility and fixed costs is on the right. The blue solid lines correspond to the case with $B = \bar{B} \equiv 1/(TN)\Sigma_{it}B_{it}$ shown in fig 2. As mentioned earlier, $\bar{B}$ is negative since firms hold on average net financial assets when $\theta = 0.3$. We compare this case to the ones when current net-assets are cut by half of that level (blue dashed lines), when they are equal to zero (thin red solid lines), and, finally, when the firm has a small amount of net debt (thin red dashed lines). For each of these cases, we are holding all else equal. 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.

reach the target in one step, since that would imply a large amount of external financing, which is very costly.

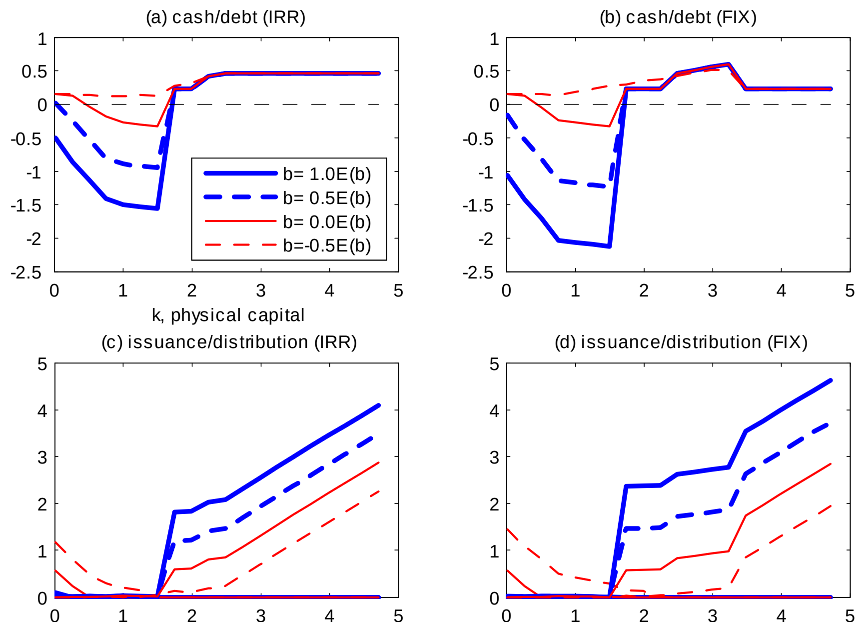

Figure 4: Inertial dynamics of financial policies

Equity frictions are responsible for making financial variables slow moving. Thus, the inertial dynamics of firms' balance sheet is an indicator of financial frictions.[19]

The lower panels of figure 4 show the payout/issuance policies in the same four financial conditions scenarios. Consider the thin red dashed line in panel (c), which is the case of the firm with positive net-debt obligation today. The initial downward sloping part shows that the firm is issuing new equity to finance its investment expenditures because small firms have higher marginal efficiency of capital, but the firm cannot generate enough internal funds to cover the investment costs due to the current net-debt position. The upward sloping part on the far right portion of the horizontal axis indicates that the firm is paying out dividends because the overcapacity problem and current technology level make its growth option almost useless. When the line is at the zero, it shows that the firm neither issues new shares nor pays out dividend. It is easy to see that the issuance/payout policies are affected by the current financial conditions in a linear way as firms

[19]This is also related with the phenomenon known as cash's sensitivity of 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 the frictional financial market, 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 cash-flow in their cash/debt policy, but it is also the firms with ample financial slacks that show sensitivity to current financial conditions. This is because the seemingly unconstrained firms have obtained such financial slacks to insure themselves against future financial constraints in a forward looking manner in our model. As will be shown later, these firms would have not obtained such cash positions without financial market friction to begin with.

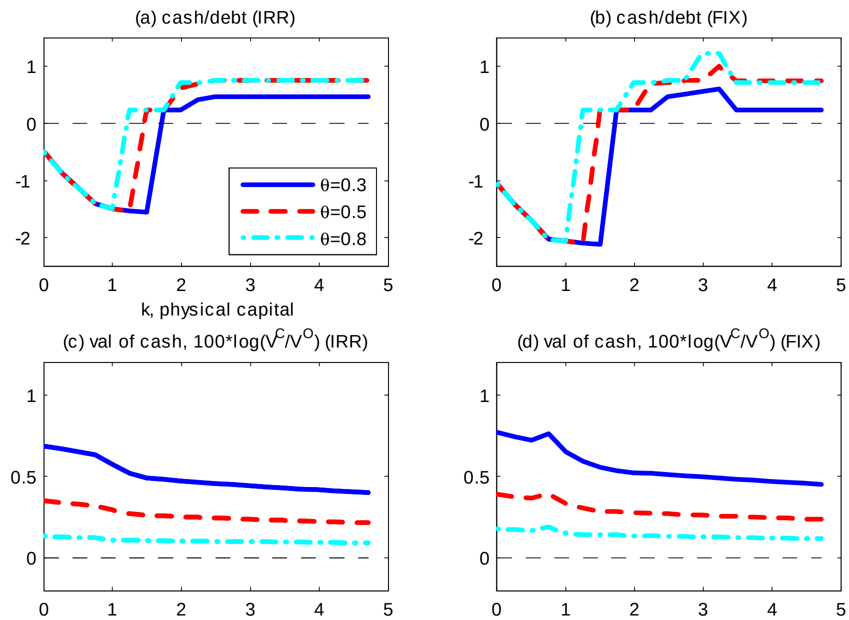

Figure 5: Pledgeability of capital assets, demand for cash and value of cash

follow a "pecking order" pattern in their financial strategy.

Our last exercise in this section analyzes the effect of technological change on the firm's optimal liquidity management strategy. Figure 5 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) and value of the option to invest in liquid financial assets (bottom panels). We also contrast the case of partial irreversibility (left) to the case of combined irreversibility and fixed costs (right). We hold all else equal.[20] 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! 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,

[20] All the state variables are set equal to their values for the blue solid line in panel (a) of figure 2

Table 2: The Effects of asset tangibility: Case with irreversibility only

Tangible Asset Ratio, θ	.8	.7	.6	.5	.4	.3
Moments:						
Cash-to-total assets (mean)	.08	.12	.12	.16	.18	.35
Agg cash-to-aggregate total assets	.07	.13	.14	.18	.21	.47
Net-debt-to-total assets (mean)	.20	.10	.08	-.00	-.07	-.29
Agg. net-debt-to-aggregate total assets	.24	.13	.09	-.00	-.08	-.41
Financial slack-to-total asset	.31	.32	.29	.29	.30	.42
Measure of zero financial slack	.03	.03	.06	.03	.07	.05
Corr (cash (B'), cash flow)	.91	.93	.93	.93	.94	.98
Corr (investment, cash flow)	.32	.28	.28	.27	.26	.19
Corr (Δcash ($\Delta B'$),investment)	-.37	.-47	-.46	-.52	-.52	-.33
Serial corr of investment	.28	.28	.28	.28	.27	.27
Measure of inv inaction	.10	.10	.10	.11	.10	.10

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. The figure shows the ratio of these two values, which measures the value of corporate liquidity in our model, that is the percentage change in firm's 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 cash increases firm value by 70 to 80 basis points. 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.

5.3 Stochastic Simulation Results

Our final set of model results uses stochastic simulations for the baseline formulation of our model to address the secular trend in corporate cash holdings. We ask the following quantitative question: how large a rise in corporate cash holdings does our model generate in response to a shift in the mode of production toward intangible capital? Tables 2 and 3 report the results for the case with partial irreversibility and the case with both irreversibility and fixed costs, respectively. We perform these simulations holding all else equal (identical random draws for Z) for the economies

Table 3: The Effects of asset tangibility: Case with irreversibility and fixed costs

Tangible Asset Ratio, θ	.8	.7	.6	.5	.4	.3
Moments:						
Cash-to-total assets (mean)	.15	.19	.32	.36	.40	.44
Agg cash-to-aggregate total assets	.16	.21	.43	.48	.52	.56
Net-debt-to-total assets (mean)	.08	-.01	-.20	-.27	-.33	-.39
Agg. net-debt-to-aggregate total assets	.10	.00	-.32	-.40	-.46	-.52
Financial slack-to-total asset	.39	39	.49	.49	.50	.56
Measure of zero financial slack	.02	.02	.02	.02	.04	.03
Corr (cash (B'), cash flow)	.93	.93	.98	.98	.98	.98
Corr (investment, cash flow)	.23	.23	.17	.19	.19	.19
Corr (Δcash ($\Delta B'$),investment)	-.35	.-41	-.33	-.41	-.41	-.43
Serial corr of investment	.21	.20	.21	.21	.21	.20
Measure of inv inaction	.23	.22	.22	.27	.23	.22

that differ only in their tangible capital ratios. We pick a range of these ratios between 0.8 and 0.3 to showcase the effect for a wide range of parameter values. The first two rows of each table report unweighted and weighted cash-to-total assets ratios.[21] A change in the economy from $\theta = 0.8$ to $\theta = 0.3$ leads to an increase in the unweighted (weighted) mean cash ratio of about 27 (40) percentage points in the model with irreversible capital, and to an even larger increase in the model that adds fixed costs of investment. This effect is quantitatively large, which suggests that the rise in intangible capital can explain a large share of the increase in corporate cash holdings over the last decades.[22]

The third and fourth columns show that in response to the increase in intangible capital (moving from $\theta = 0.8$ to $\theta = 0.3$) the corporate sector in both economies becomes a net creditor, which matches another stylized development of the US economy over the last decades. The dynamics

[21] Total assets are defined as the sum of total production assets including intangible capital and net financial outstanding.

[22] The seventh rows of tables 2 and 3 show how the cash's sensitivity to current cash flow (defined as $(1-\tau_c)[\Pi(K_T, K_N; \omega) - F_0 K] + \tau_c \delta K - (1 + r(B))B$) responds to the changes in asset tangibility. As expected, regardeless of the tangibility, cash is very sensitive to current cash flow. That said, one can also see that the sensitivity increases as the tangibility of firm's capital asset declines. This is because the loss of financial flexibility brought about by technological change puts firm's liquidity condition in a more vulnerable position, and the firm's risk management offsets this trend by holding more liquid assets. One interesting side effect of the growing importance of cash in the firm's risk management strategy is the tendency of declinining sensitivity of investment to cashflow. For instance, in the eighth row of table 2, the correlation between investment and cash flow is declining from 0.32 to 0.19 as θ declines from 0.8 to 0.3. The same tendency can be seen in table 3: the correlation declines from 0.23 to 0.19. This trend suggests that somehow, the firms in the model economy overreact to the financial inflexibility owing to the decline in asset pledgeability, and accumulate liquid assets to the point where the firm's investment is less sensitive to financial condition. It is an interesting study to see how much this result is model-specific.

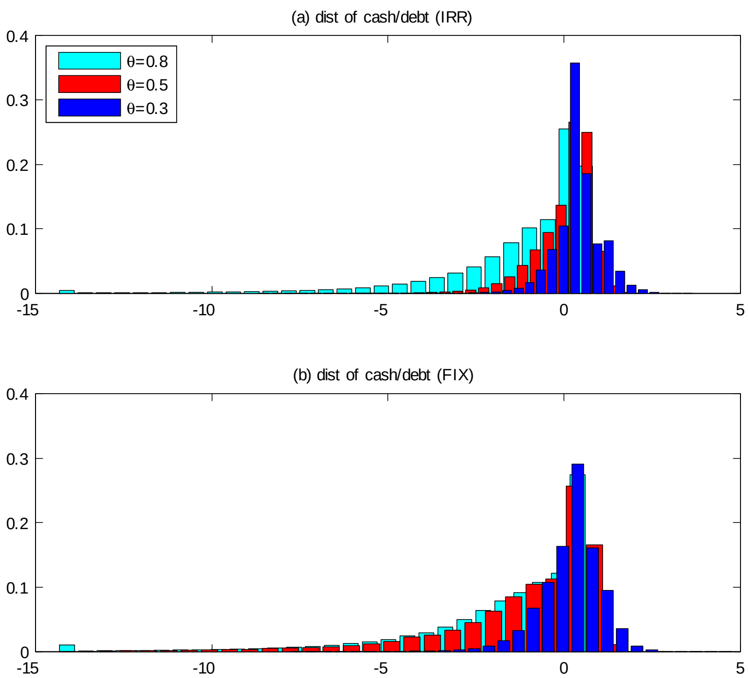

Figure 6: Intangible ratio and distribution of net debt (cash, when negative)

of the transformation of the U.S. corporate sector from net debtor to net creditor is also affected by investment frictions. Figure 6 shows changes in the distribution of net-debt position when asset tangibility declines from $\theta = 0.8$ to 0.5, and to 0.3 for two economies, one with partial irreversibility (top panel) and one with irreversibility and fixed costs of investment (bottom panel). The distribution in the economy with the irreversible investment friction responds to the decrease in asset tangibility rather linearly; by contrast, the distribution in the economy with fixed costs responds in a non-linear fashion. The distribution shifts a lot for a change from 0.8 to 0.5, but not as much for a change from 0.5 to 0.3.[23]

Our last set of simulation results consider other financial variables that can potentially impact firms' liquidity demand: the risk-free rate and the cost of outside equity. The results are shown in the top and bottom panels of table 4, respectively. The *ratio* of cash to total assets does not appear to be strongly affected by changes in the risk-free rate. This is the case since changes in cash levels are roughly offset by countervailing changes in real assets. As foe equity issuance costs, their

[23] This difference in the patterns of transitional dynamics has potentially important implications for structural estimation of real adjustment frictions. To the extent that the data supports a linear relation between the tangible capital ratio and cash-to-total assets or net-debt-to-total assets, allowing for lumpy investment frictions at the firm level may be at odds with the data. This suggests that having a realistic financial structure is also important for estimating non-financial parameters: one cannot simply omit financial structure just because s/he is estimating 'real' parameters.

Table 4: The Effects of interest rate and cost of equity

	Interest Rates/Cost of Equity ($\theta = 0.30$)				
	Risk-Free Rate				
	.06	05	. 04	.03	.02
Cash-to-total asset (IRR)	.35	-	.37	.40	.41
Cash-to-total asset (FIX)	.44	.53	.57	.48	-
	Cost of Equity				
	1.0	.75	.50	.25	.00
Cash-to-total asset (IRR)	.35	.32	.32	-	.00
Cash-to-total asset (FIX)	.44	.40	.39	.37	.00

effect is highly non-linear: while firms don't hold cash when equity issuance costs are set equal to zero (to take advantage of tax benefits), any positive issuance cost generates sizable cash holdings. However, increases in issuance costs along the intensive margins have only a small quantitative impact on average cash ratios.

6 Conclusions

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. Other factors, such as changes in interest rates and equity issuance costs, have a more muted quantitative effect on cash ratios at the margin. 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.

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Appendix A. Variable Definitions

The variables used in the analysis are defined as follows:

- Cash to book asset – our main dependent variaible – 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).
- 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.
- KZ-Index is based on Kaplan and Zingales (1997) and is as follows: KZ=-1.002*Cash flow +0.283*Q +3.139*Leverage -39.368*Dividends -1.315*Cash, where Q is the market-to-book ratio, Dividends is the ratio of total dividends to book assets, and the other variables are as defined above.
- WW-Index is based on Whited and Wu (2006) and is as follows: WW-Index=-0.091*CashFlow -0.062*Dividend +0.021*Leverage -0.044*Size +0.102*Industry Growth -0.035*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*Receivables(#2), 0.547*Inventory(#3), and 0.535*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 indeces 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 $|$Capex/book assets$|<.01$, $|$Capex/book assets$|\geq.01$, and $|$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 prodecure 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 prodecure 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 fim-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 good sold (#41). This measure gives a time-invariant cross-sectional ranking of 4-SIC industries.

Appendix B. Details on R&D Tax Credit

To construct firm-specific user cost of R&D capital, we follow Wilson (2009) and construct the (after-tax) user cost of R&D capital (per dollar of investment) as:

$$\rho_{it} = \frac{1 - sk_{it} - z_t \tau_{it}}{1 - \tau_{it}} [r_t + \delta]$$

where t indexes time. r_t is the real interest rate and δ is the economic depreciation rate of the R&D stock. τ_{it} denotes the effective corporate income tax rate; z_t denotes the PDV of tax depreciation allowances; k_{it} denotes the effective rate of the R&D tax credit (at the federal level); and s is the share of R&D that qualifies for preferential tax treatment. Data from IRS Statistics on Income indicate that roughly s = 0.5.

We follow Hall (1992) to compute R&E tax credit under federal rules. This has a firm-specific component, in part because the definition of what qualifies as allowable R&E for tax purposes depends on a firm-specific "base". There are three alternative ways to claim R&E credit that firms can elect.

The traditional R&E credit is 20 percent of the excess of qualified research expense ("QRE") for the current tax year over a base amount. The base amount is the product of the firm's fixed-base percentage and average annual gross receipts for the four tax years preceding the current year. In addition, the base amount cannot be less than 50 percent of qualified research expense for the credit year. The fixed-base percentage is the ratio of the aggregate qualified research expenses to the aggregate gross receipts for the 1984 through 1988 tax years and it may not exceed 16%. If the firm's first taxable year is after 1984 or if the firm has less than 3 taxable years between 1984 and 1988, it is considered a start-up. For start-ups, the fixed-base percentage is generally 3%.

Since the 1996 Small Business Jobs Protection Act, firms can elect to claim the alternative incremental research credit (AIRC) instead of the traditional R&E credit. The AIRC has three rates (2.65%, 3.20%, and 3.75%), which apply to the extent that QRE exceeds each of three tiers of base amount (1.0%, 1.5%, and 2.0% of average annual gross receipts for the preceding four tax years). In particular, tier one amount is equal to 2.65% of QRE in excess of 1% of the base amount but not more than 1.5% of the base amount. Tier two amount is equal to 3.2% of QRE in excess of 1.5% of the base amount but not in excess of 2% of the base amount. Tier three amount is equal to 3.75% of QRE in excess of 2% of the base amount.

In addition, if in a given year the firm has no tax liabilities, it cannot use R&E credit in that year. Instead, the credit can be carried back over the previous 3 or carried forward over the next 15 years.

Further, the IRS requires that firms substract the full amout of R&E credit amount from the deduction of R&E expenditures (recapture), which implies that all of the credit itself is considered taxable. This reduces the credit proportionally by $(1 - \tau_{it})$, where τ_{it} is the effective federal tax rate.

Finally, qualified research expenditures can be depreciated immediately which reduces user cost of R&D.

Table 1: Summary Statistics

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. After excluding Utilities (SIC codes 4900-4999), this yields a panel of 176,877 observations for 18,535 unique firms. The table reports summary statistics of the dependent variables and main explanatory variables. The main dependent variable is the ratio of cash holdings to book assets. Cash holdings are the sum of cash and short-term marketable securities. We also present baseline results for net leverage, which is the ratio of total debt net of cash holding to book assets, and robustness analysis for other definitions of cash holdings, including cash as a ratio to book assets net of cash and to market value of assets. Intangible capital 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 book assets net of cash. The summary statistics are reported for the entire sample as well as for the subsample of firms that report positive R&D. For both samples, the bottom panel shows summary statistics of cash as a ratio to book assets in fours bins based on quartiles of the distribution of intangible capital. Detailed variable definitions are provided in the Appendix.

		Whole Sample			R&D Firms Only		
Variable		Mean	Median	Std Dev	Mean	Median	Std Dev
Cash/Book Assets		0.15	0.07	0.19	0.19	0.10	0.21
Cash/Net Book Assets		0.25	0.07	0.44	0.35	0.11	0.54
Cash/Market Value of Assets		0.11	0.06	0.12	0.13	0.08	0.13
Dollar Cash ($M, 1990 real)		64.5	6.7	200.9	90.3	10.2	247.6
Net Leverage		0.14	0.16	0.35	0.02	0.07	0.36
Intangible Capital:							
Intangible Capital/Net Book Assets		0.65	0.34	0.84	0.90	0.53	0.95
R&D Stock/Net Book Assets		0.21	0.09	0.41	0.37	0.16	0.46
Business software/Net Book Assets		0.01	0.00	0.01	0.01	0.00	0.01
SG&A stock/Net Book Assets		0.39	0.25	0.42	0.47	0.32	0.44
Firm Controls:							
Industry Sigma		0.29	0.29	0.07	0.30	0.31	0.07
Market-to-Book		1.86	1.31	1.26	2.21	1.44	1.77
Size (log(Book Assets), 1990 real)		5.26	4.81	2.28	4.91	4.62	2.41
Cashflow/Book Assets		0.03	0.06	0.38	0.06	0.06	0.42
Capex/Book Assets		0.07	0.05	0.08	0.06	0.04	0.06
Dividend dummy		0.34	0	0.47	0.34	0	0.47
Acquisitions/Book Assets		0.02	0.07	0.06	0.02	0.07	0.05
Cash By Intangible Capital Quartiles:							
Cash/Book Assets	Q1	0.08	0.04	0.11	0.08	0.04	0.09
Cash/Book Assets	Q2	0.10	0.05	0.13	0.10	0.05	0.12
Cash/Book Assets	Q3	0.13	0.08	0.15	0.14	0.08	0.15
Cash/Book Assets	Q4	0.23	0.12	0.25	0.31	0.23	0.27

Table 2-A: Regression Analysis of Intangible Capital and Corporate Cash Holdings

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates, scaled by the standard deviation of the underlying variable, from panel regressions of cash holdings to book assets (Panel A) and net leverage (Panel B) on intangible capital for several different specifications. The interpretation of each reported coefficient is the change in the dependent variable associated with a one-standard deviation change in the determinant. For example, in the first column, a one-standard deviation change in intangible capital is associated with an 8.6% change in cash holdings. Intangible capital is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. Columns (1)-(6) report results for the entire sample, while Columns (7)-(11) report results for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions for the baseline specification that controls for standard determinants of cash (Columns (1) and (7)), median regressions (Columns (4) and (8)), OLS regressions using variables in changes rather than levels (Columns (5) and (9)), and OLS regressions with firm fixed effects (Columns (6) and (10)). Columns (2) and (3) are for OLS regressions that include a time trend instead of year dummies and control for net working capital, respectively. Columns (11) presents 2SLS estimates that treat intangible capital as endogenous and use R&D user cost as an instrument. Year dummies are included in all regressions except in Column (2). Detailed variable definitions are provided in the Appendix. p-values are in parentheses and are clustered at the firm level.

	Whole Sample						R&D Firms only				
	OLS Baseline	OLS Time Trend	OLS More Fin Controls	Median	Changes	FE	OLS Baseline	Median	Changes	FE	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intangible Capital	0.086	0.086	0.073	0.089	0.057	0.061	0.104	0.117	0.066	0.067	0.124
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry sigma	0.037	0.033	0.026	0.020	0.001	-0.007	0.041	0.023	-0.002	-0.001	-0.002
	(0.000)	(0.000)	(0.000)	(0.144)	(0.000)	(0.190)	(0.000)	(0.000)	(0.000)	(0.739)	(0.174)
Market-to-book	0.023	0.023	0.018	0.035	0.010	0.011	0.028	0.043	0.012	0.016	0.016
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	-0.024	-0.024	-0.022	-0.026	-0.037	-0.039	-0.022	-0.016	-0.015	-0.032	-0.020
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Cashflow	0.031	0.031	0.017	0.032	0.014	0.017	0.037	0.045	0.018	0.023	0.023
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Capex	-0.008	-0.008	-0.011	-0.002	-0.017	-0.012	-0.011	-0.003	-0.016	-0.011	-0.008
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dividend	-0.011	-0.010	-0.021	-0.006	-0.001	0.007	-0.023	-0.012	0.001	0.005	0.004
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.195)	(0.007)	(0.000)
Acquisitions	-0.010	-0.010	-0.007	-0.004	-0.016	-0.008	-0.012	-0.005	-0.018	-0.009	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.346)
Year fixed effects	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.299	0.194	0.329	0.237	0.217	0.665	0.340	0.287	0.268	0.689	0.276

Table 2-B: Regression Analysis of Intangible Capital and Net Leverage

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates, scaled by the standard deviation of the underlying variable, from panel regressions of cash holdings (Panel A) and net leverage (Panel B) on intangible capital for several different specifications. The interpretation of each reported coefficient is the change in the dependent variable associated with a one-standard deviation change in the determinant. For example, in the first column, a one-standard deviation change in intangible capital is associated with an 8.6% change in cash holdings to book assets. Intangible capital is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. Columns (1)-(6) report results for the entire sample, while Columns (7)-(11) report results for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions for the baseline specification that controls for standard determinants of cash (Columns (1) and (7)), median regressions (Columns (4) and (8)), OLS regressions using variables in changes rather than levels (Columns (5) and (9)), and OLS regressions with firm fixed effects (Columns (6) and (10)). Columns (2) and (3) are for OLS regressions that include a time trend instead of year dummies and control for net working capital, respectively. Column (11) presents 2SLS estimates that treat intangible capital as endogenous and use R&D user cost as an instrument. Year dummies are included in all regressions except in Column (2). Detailed variable definitions are provided in the Appendix. p-values are in parentheses and are clustered at the firm level.

	Whole Sample						R&D Firms only				
	OLS Baseline	OLS Time Trend	OLS More Fin Controls	Median	Changes	FE	OLS Baseline	Median	Changes	FE	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Intangible Capital	-0.111	-0.130	-0.133	-0.144	-0.050	-0.047	-0.125	-0.170	-0.068	-0.067	-0.175
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Industry sigma	-0.062	-0.071	-0.061	-0.049	0.002	0.022	-0.064	-0.048	0.003	0.037	0.003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.267)
Market-to-book	-0.032	-0.040	-0.047	-0.075	-0.009	-0.010	-0.037	-0.076	-0.004	-0.009	-0.028
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Firm size	0.025	0.023	0.024	0.029	0.036	0.011	0.005	0.007	0.061	0.067	0.006
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cashflow	-0.096	-0.114	-0.068	-0.098	-0.058	-0.091	-0.109	-0.103	-0.063	-0.108	-0.073
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Capex	0.017	0.013	0.007	0.012	0.019	0.005	0.018	0.015	0.016	0.002	0.013
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.038)	(0.000)
Dividend	-0.037	-0.038	-0.027	-0.029	-0.005	-0.036	-0.016	-0.013	-0.004	-0.033	-0.041
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Acquisitions	0.034	0.026	0.023	0.028	0.032	0.018	0.036	0.026	0.035	0.023	0.015
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year fixed effects	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.235	0.196	0.262	0.197	0.197	0.602	0.240	0.198	0.205	0.601	0.236

Table 3: Intangible Capital and the US Coporate Savings Glut

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. This table presents estimates of the contribution of each of the explanatory variables from Table 2 (Panel A) to the change in predicted cash to book assets. Change in predicted cash is measured as the difference between the average cash ratio in the 2000 to 2010 period and average cash in the 1970 to 1989 period. The determinants of cash are those in Column (3) of Table 2 (Panel A) with the addition of leverage and net debt and equity issuance. Predicted change in cash due to change in a determinant is obtained by taking the point estimates from an OLS regression estimated over the 1970-1989 period and multiplying them by the difference in average value of each determinant between the estimation (1970-1989) and the post-2000 period. Percent contribution with respect to overall change in cash is given in square brackets. Detailed variable definitions are provided in the Appendix. Column (1) reports results for the entire sample and Column (2) reports results for the subsample of firms that report positive R&D.

	Whole Sample	R&D Firms only
	(1)	(2)
Intangible Capital	0.030	0.052
	[42.5%]	[43.4%]
Industry sigma	0.010	0.014
	[14.5%]	[11.5%]
Market-to-book	0.001	-0.0002
	[1.8%]	[-0.2%]
Firm size	-0.004	-0.002
	[-5.2%]	[-1.5]
Cashflow	-0.008	-0.015
	[-10.6%]	[-12.8]
Capex	0.008	0.012
	[11.6%]	[9.9%]
Dividend	0.003	0.008
	[4.5%]	[6.3%]
Acquisitions	-0.002	-0.002
	[-2.8%]	[-1.9%]
NWC	0.028	0.045
	[39.8%]	[3.8%]
Leverage	0.003	0.011
	[4.9%]	[8.8%]
Net debt issuance	-0.0003	0.0001
	[-0.4%]	[0.1%]
Net equity issuance	0.004	0.007
	[5.6%]	[5.7%]
TOTAL Predicted Change	0.069	0.075

Table 4: Implications for the Empirical Literature on the Determinants of Corporate Cash Holdings and Other Robustness Analysis

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates, scaled by the standard deviation of the underlying variable, from panel regressions of cash holdings on intangible capital for several different specifications. The interpretation of each reported coefficient is the change in the dependent variable associated with a one-standard deviation change in the determinant. Intangible capital is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. Controls are as in Table 2 (Column 1). The estimates of these controls are omitted from the table for brevity and are available upon request. Columns (1)-(4) report results for the whole sample, while Columns (5)-(9) are for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions for the baseline specification that controls for standard determinants of cash (Columns (1) and (5)), median regressions (Columns (2) and (6)), OLS regressions using variables in changes rather than levels (Columns (3) and (7)), and OLS regressions with firm fixed effects (Columns (4) and (8)). Column (9) presents 2SLS estimates that treat intangible capital as endogenous and use R&D user cost as an instrument. Row [1] refers to a specification that replaces the intangible stock with R&D expenditures (flow), a standard determinant of cash in the literature; Rows [2] and [3] are for a specification that includes both R&D expenditures (flow) and Intangible Capital (stock); Row [4] replaces the intangible stock with a measure of asset tangibility (PPE to net book assets) which is commonly employed in the empirical capital structure literature; Rows [5] and [6] use alternative definitions of cash; Rows [7] and [8] are for sub-samples of firms that are present in all years in the sample and not in high-tech sectors, respectively. For detailed variable definitions, see the Appendix p-values clustered at the firm level are in parentheses.

		Whole Sample				R&D Firms only				
		OLS	Median	Changes	FE	OLS	Median	Changes	FE	IV
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Including R&D Expenditures (flows) instead of Intangible Capital									
[1]	R&D	0.019	0.029	0.000	0.010	0.027	0.038	0.004	0.008	•
		(0.000)	(0.000)	(0.458)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	•
	Including R&D Expenditures (flows) and Intangible Capital (IC)									
[2]	IC	0.071	0.064	0.044	0.059	0.085	0.074	0.054	0.065	0.144
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[3]	R&D	-0.006	-0.002	-0.001	-0.007	-0.008	-0.005	-0.000	-0.009	-0.019
		(0.000)	(0.000)	(0.443)	(0.000)	(0.000)	(0.000)	(0.818)	(0.000)	(0.000)
	Including Tangible Assets (PPE/Net Book Assets) instead of Intangible Capital									
[4]	PPE	-0.001	-0.002	0.007	0.001	-0.003	-0.003	0.009	0.002	•
		(0.460)	(0.099)	(0.000)	(0.610)	(0.100)	(0.099)	(0.000)	(0.163)	•
	Cash is Ratio to Net Book Assets									
[5]		0.173	0.134	0.114	0.142	0.224	0.209	0.143	0.172	0.232
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Cash is Ratio to Market Value of Assets									
[6]		0.059	0.047	0.039	0.062	0.069	0.056	0.044	0.071	0.135
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Constant Sample Composition									
[7]		0.058	0.051	0.016	0.049	0.072	0.066	0.024	0.060	0.115
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Excluding High-Tech Sectors									
[8]		0.074	0.069	0.025	0.068	0.105	0.086	0.034	0.078	0.127
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 5: Intangible Capital and Cash Holdings by Ex-Ante Proxies of Financial Frictions

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates, scaled by the standard deviation of the underlying variable, from panel regressions of cash holdings to book assets on intangible capital for several specifications and sub-sample splits of the data based on ex-ante proxies for the severity of financial frictions faced by firms. The interpretation of each reported coefficient is the change in the dependent variable associated with a one-standard deviation change in intangible capital. Intangible capital is the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. Controls are as in Table 2 (Column 1). The estimates of these controls are omitted from the table for brevity and are available upon request. Columns (1)-(4) report results for the whole sample, while Columns (5)-(9) are for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions for the baseline specification that controls for standard determinants of cash (Columns (1) and (5)), median regressions (Columns (2) and (6)), OLS regressions using variables in changes rather than levels (Columns (3) and (7)), and OLS regressions with firm fixed effects (Columns (4) and (8)). Column (9) presents 2SLS estimates that treat intangible capital as endogenous and use R&D user cost as an instrument. The sample is split between bottom and top quartiles of (year-prior) values of the following ex-ante proxies of financial frictions: firm size (Rows [1] to [2]), Kaplan and Zingales (1997) KZ-Index (Rows [5] to [6]), Whited and Wu (2006) WW-Index (Rows [7] to [8]), Berger et al. (1996) asset liquidation value (Rows [9] to [10]), and Balasubramanian and Sivadasan (2009) index of industry asset redeployability (Rows [11] to [12]), and by dividend payer status (Rows [3] to [4]). p-values clustered at the firm level are in parentheses. For detailed variable definitions, see the Appendix.

		Whole Sample				R&D Firms only				
		OLS	Median	Changes	FE	OLS	Median	Changes	FE	IV
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	By Firm Size									
[1]	Q1	0.102	0.105	0.093	0.112	0.120	0.123	0.097	0.120	0.162
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[2]	Q4	0.030	0.025	0.023	0.028	0.037	0.034	0.031	0.039	0.095
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Dividend Payer Status									
[3]	No	0.100	0.111	0.075	0.075	0.124	0.141	0.089	0.090	0.164
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[4]	Yes	0.028	0.026	0.027	0.034	0.033	0.032	0.031	0.035	0.099
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By KZ-Index									
[5]	Q4	0.079	0.109	0.072	0.092	0.101	0.119	0.092	0.094	0.159
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[6]	Q1	0.049	0.028	0.052	0.052	0.054	0.041	0.056	0.066	0.101
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By WW-Index									
[7]	Q4	0.104	0.113	0.087	0.090	0.126	0.136	0.099	0.107	0.155
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[8]	Q1	0.055	0.054	0.027	0.050	0.065	0.045	0.036	0.058	0.099
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Asset Liquidation Value									
[9]	Q1	0.145	0.102	0.089	0.109	0.152	0.186	0.089	0.115	0.180
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[10]	Q4	0.051	0.037	0.043	0.049	0.059	0.045	0.044	0.054	0.087
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Degree of Asset Redeployability									
[11]	Q1	0.199	0.244	0.075	0.126	0.207	0.254	0.079	0.132	0.203
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[12]	Q4	0.062	0.061	0.041	0.048	0.084	0.089	0.041	0.059	0.085
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 6: Intangible Capital and Cash Holdings by Ex-Ante Proxies of Investment Frictions

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports panel regressions of cash holdings to book assets on intangible capital for sub-sample splits of the data based on ex-ante proxies for the severity of investment frictions faced by firms. The interpretation of each reported coefficient is the change in the dependent variable associated with a one-standard deviation change in intangible capital. Intangible capital is the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. Controls are as in Table 2 (Column 1). The estimates of these controls are omitted from the table for brevity and are available upon request. Columns (1)-(4) report results for the whole sample, while Columns (5)-(9) are for the subsample of firms that report positive R&D. For each of the two samples, we report estimates of OLS regressions for the baseline specification that controls for standard determinants of cash (Columns (1) and (5)), median regressions (Columns (2) and (6)), OLS regressions using variables in changes rather than levels (Columns (3) and (7)), and OLS regressions with firm fixed effects (Columns (4) and (8)). Column (9) presents 2SLS estimates that treat intangible capital as endogenous and use R&D user cost as an instrument. The sample is split between bottom and top quartiles of the following ex-ante proxies of investment frictions: (4-SIC) industry frequency of investment inaction - $|\text{Capex/book assets}|<.01$ (Rows [1] to [2]), of small investments - $|\text{Capex/book assets}|\geq .01$ (Rows [5] to [6]), and whether in the industry there are investment spikes - $|\text{Capex/book assets}|>.2$ (Rows [3] to [4]), all based on Cooper and Haltiwanger (2006); time-series skewness (Rows [7] to [8]) and kurtosis (Rows [9] to [10]) of annual aggregate industry investment (Capex/book assets), based on Caballero (1999); and the time-series standard deviation of aggregate industry operating costs (Rows [11] to [12]). p-values clustered at the firm level are in parentheses. For detailed variable definitions, see the Appendix.

		Whole Sample				R&D Firms only				
		OLS	Median	Changes	FE	OLS	Median	Changes	FE	IV
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	By Industry Frequency of Investment Inaction									
[1]	Q1	0.024	0.020	0.032	0.031	0.030	0.027	0.041	0.036	0.026
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[2]	Q4	0.137	0.157	0.071	0.112	0.162	0.188	0.082	0.133	0.245
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Whether There Are Investment Spikes in the Industry									
[3]	No	0.049	0.050	0.038	0.048	0.061	0.065	0.049	0.049	0.094
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[4]	Yes	0.095	0.110	0.068	0.079	0.120	0.144	0.075	0.081	0.164
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Industry Frequency of Small Investments									
[5]	Q4	0.038	0.033	0.035	0.036	0.045	0.042	0.045	0.039	0.074
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[6]	Q1	0.106	0.129	0.067	0.100	0.174	0.203	0.075	0.146	0.215
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Time-Series Skewness of Aggreagte Industry Investment									
[7]	Q1	0.044	0.039	0.044	0.043	0.060	0.059	0.043	0.047	0.060
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[8]	Q4	0.100	0.109	0.065	0.079	0.145	0.162	0.078	0.104	0.144
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Time-Series Kurtosis of Aggregate Industry Investment									
[9]	Q1	0.048	0.044	0.041	0.046	0.065	0.061	0.047	0.051	0.081
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[10]	Q4	0.092	0.099	0.067	0.078	0.133	0.147	0.079	0.093	0.155
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	By Time-Series Variability of Operating Costs									
[11]	Q4	0.038	0.028	0.042	0.040	0.054	0.046	0.043	0.050	0.097
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
[12]	Q1	0.102	0.116	0.067	0.080	0.133	0.153	0.075	0.096	0.160
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Table 7: Intangible Capital and Corporate Cash Dynamics

The sample consists of all US nonfinancial firms in Compustat from 1970 to 2010. The table reports parameter estimates from different estimation procedures of the speed of adjustment (SOA) of cash for the overall sample (Row [1]) and for different sub-samples based on quartiles of the distribution of intangible capital (Rows [2] to [5]). Intangible capital is defined as the sum of stocks of past investments in firms' organizational capabilities, brand equity, and technological knowledge (R&D) normalized by book assets net of cash. The dynamic specification of this table adds a lagged dependent variable (first lag of cash) to the same set of explanatory variables as in Table 2 (Column 1): $\text{Cash}_{it} = \alpha_0 + (1-\alpha) * \text{Cash}_{it-1} + \beta * X_{it-1} + \epsilon_{it}$. Estimates of the explanatory variables, X, are omitted for brevity and are available upon request. Columns (1)-(3) report results for the whole sample, while Columns (4)-(7) are for the subsample of firms that report positive R&D. For each of the two samples, we report etimates of OLS regressions analogous to Fama and French (2002) (Columns (1) and (4)), OLS regressions with firm fixed effects analogous to Flannery and Rangan (2006) (Columns (2) and (5)), GMM estimates based on Blundell and Bond (1998) (Columns (3) and (6)), and IV-GMM estimates that add R&D user cost as an excluded instrument (Column (7)). Speed of adjustment is α. Cash half-life is the time (in years) that it takes a firm to adjust back to the target cash after a one-unit shock to ϵ, $\ln(0.5)/\ln(1 - \alpha)$. For detailed variable definitions, see the Appendix p-values clustered at the firm level are in parentheses.

			Whole Sample			R&D Firms only			
			OLS	FE	GMM	OLS	FE	GMM	IV-GMM
			(1)	(2)	(3)	(4)	(5)	(6)	(7)
[1]	All	SOA	0.281	0.538	0.425	0.268	0.523	0.401	0.360
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		Half-life	[2.1]	[0.9]	[1.3]	[2.2]	[0.9]	[1.4]	[1.6]
	By Intangible Capital Quartiles								
[2]	Q1	SOA	0.463	0.721	0.557	0.527	0.748	0.729	0.739
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		Half-life	[1.1]	[0.5]	[0.9]	[0.9]	[0.5]	[0.5]	[0.5]
[3]	Q2	SOA	0.350	0.631	0.512	0.381	0.643	0.550	0.553
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		Half-life	[1.6]	[0.7]	[1.0]	[1.4]	[0.7]	[0.9]	[0.9]
[4]	Q3	SOA	0.266	0.526	0.348	0.300	0.537	0.331	0.355
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		Half-life	[2.2]	[0.9]	[1.6]	[1.9]	[0.9]	[1.7]	[1.6]
[5]	Q4	SOA	0.210	0.424	0.294	0.225	0.431	0.319	0.290
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
		Half-life	[2.9]	[1.3]	[2.0]	[2.7]	[1.2]	[1.8]	[2.0]

Figure 1
Rising Intangible Capital and Rising Corporate Cash Holdings

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.

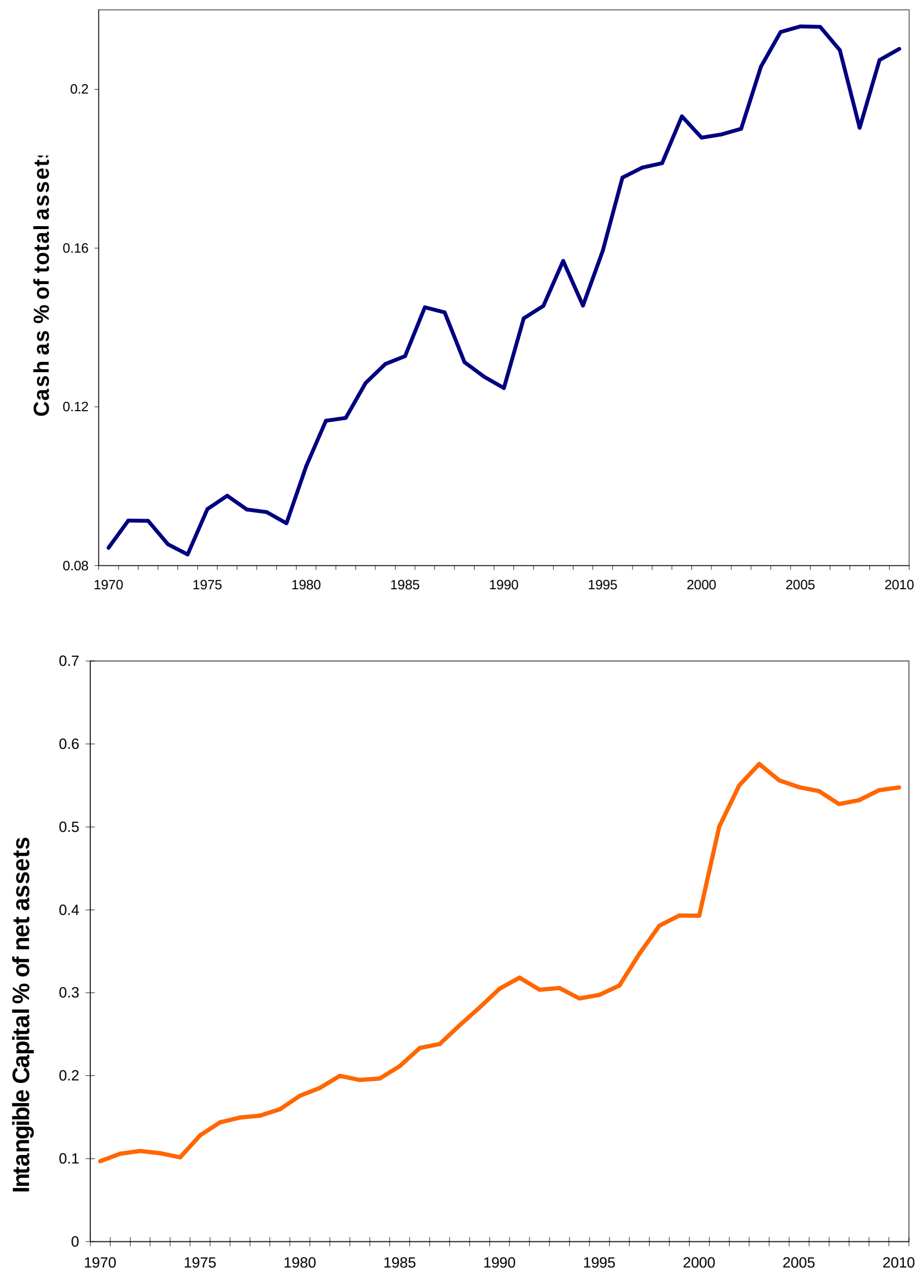
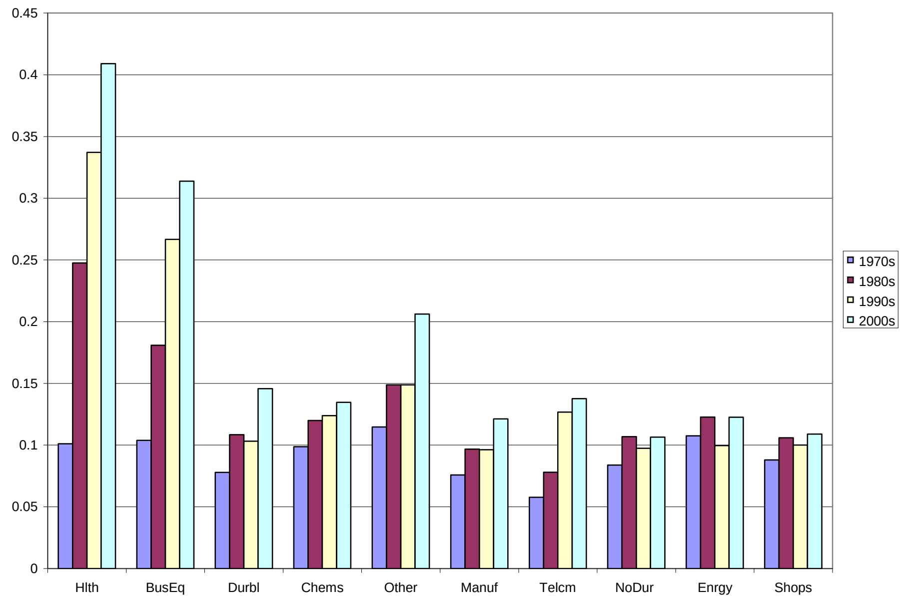


Figure 2
Rising Intangible Capital and Cash: Cross-Industry Variation

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.



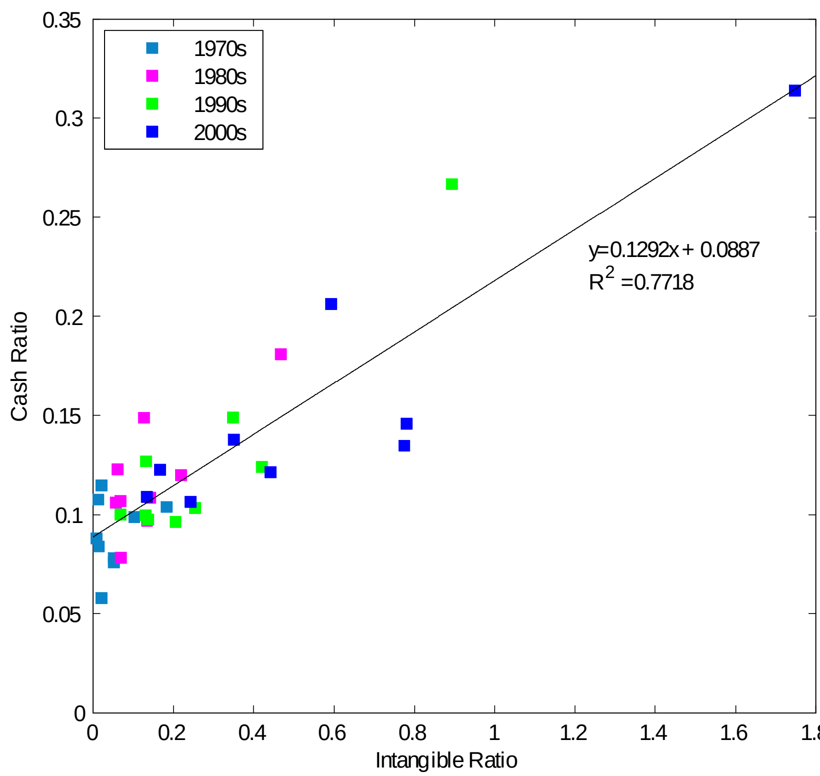


Figure 3
Rising Intangible Capital and Cash: Cross-Firm Variation

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.