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Rising Intangible Capital, Shrinking Debt Capacity, and the U.S. Corporate Savings Glut

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ABSTRACT

This paper explores the connection between rising intangible capital and the secular upward trend in U.S. corporate cash holdings. We calibrate a dynamic model with two productive assets—tangible and intangible capital—in which only tangible capital can serve as collateral. We highlight the following points: (i) a shift toward intangible capital shrinks firms' debt capacity and leads them to hold more cash, (ii) the effect accounts for three-quarters of the observed trend in average cash ratios, and (iii) it also accounts for the upward trend of cash ratios in the cross-section of small and large firms and in the aggregate.

PUBLIC CORPORATIONS IN THE UNITED STATES have undergone fundamental changes over the last decades. On the financial side, they have steadily increased cash holdings on their balance sheets, an issue that has attracted wide attention in the popular press, with commentators expressing the concern that the "corporate saving glut" might hamper growth of the U.S. economy and even suggesting that corporate savings be taxed. On the real side, their production technology increasingly relies on intangibles, with assets such

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[Correction added on 12 September 2022, after first online publication: Few textual corrections on pages 2–5 have been updated in this version.]

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as knowledge, brand, reputation, organizational, and information technology capital becoming in many respects defining features of the modern industrial corporation. Yet, despite recent progress in incorporating financing frictions into investment-based models in corporate finance (see, for example, Bolton, Chen, and Wang (2011)), these important trends have been studied mostly in isolation, and hence, the extent to which they may be connected remains relatively unexplored.

This paper explores the connection between the secular trends in intangible capital and the cash holdings of U.S. corporations. A critical feature of intangible capital is that it cannot be easily verified or liquidated, and thus, cannot be pledged as collateral to raise debt financing. Under frictional capital markets, where external funds command substantial premiums, the rising importance of intangible capital as an input of production increases firms' precautionary demand for cash to ensure that they have sufficient liquidity to exploit future investment opportunities. We build on Q-theoretic models of internal financing (e.g., Bolton, Chen, and Wang (2011)) and formalize this intuition within a dynamic model featuring two distinct productive assets, namely, physical and intangible capital. A motive for cash holdings arises in our model because of the interplay between real and financial frictions: when firms have growth options, they optimally hold cash since they anticipate having to make large (S,s)-type adjustments in capital and want to avoid raising costly external finance to fund investment. Since in the model, only tangible capital can be pledged as collateral, a shift toward intangible capital shrinks firms' debt capacity and leads them to hold more cash. Using a calibrated version of the model to quantify this mechanism, we show that the rise in intangible capital can account for about three-quarters of the increase in average cash ratios in the data. Other forces that have been proposed in the literature, such as, for example, the increase in cash flow volatility, also play a role but to less extent. The model can also account quantitatively for a broader set of cross-sectional and aggregate facts of the secular evolution of cash. Overall, our quantitative analysis strongly suggests that the rise in intangible capital is an important force behind the long-run increase in U.S. corporations' cash ratios.

Our focus on the rise in 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. In the aggregate, investment in intangible capital by U.S. firms has picked up substantially since the 1980s, especially investment in computerized information, private research and development (R&D), and organizational capital (Corrado, Hulten, and Sichel (2009), Corrado and Hulten (2010), 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 has 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.

We begin by detailing the stylized facts of the link between the rise in intangible capital and the secular trend in corporate cash holdings. The main measurement hurdle is that intangible assets are not reported on firms' balance sheet and investment in intangibles is generally treated as an expense. We overcome this problem by constructing a comprehensive firm-level measure of intangible capital as the sum of three components: knowledge capital, which is constructed as the stock of assets from investment in R&D; organizational capital, the stock of assets from investment in the value of brand names and employee training; and information technology capital.[1] Intangible capital rose almost fivefold relative to book assets (net of cash) from about 20% in 1970 to about 90% in 2010. Over the same period, average cash ratios displayed a pronounced upward secular trend, rising from about 9% in 1970 to more than 20% of book assets by 2010, which is in line with Bates, Kahle, and Stulz (2009). In the cross-section of firms, small firms experienced a more pronounced upward trend in cash ratios. Since the size distribution of cash is highly skewed, with the largest firms holding the bulk of aggregate cash, aggregate cash ratios also trended up, but less so than average cash ratios. Our battery of stylized facts indicates that there is a strong link between cash and intangible capital in the time series and that there are cross-sectional differences between large and small firms, all of which we use to confront the model in our quantitative analysis.

To better understand the economic mechanism behind the link, we develop a dynamic model of firms' capital structure, cash management, and real investment decisions that is rich enough to capture our proposed mechanism but at the same time parsimonious enough to allow for calibration to confront the mechanism with the data. The model is cast in a standard infinite-horizon, discrete-time stochastic environment, where managers make value-maximizing investment and financing decisions under costly external financing frictions. The key innovation is that firms make capital accumulation decisions over two types of real assets, tangible and intangible capital, and cannot pledge intangible capital as collateral for debt financing.

The model has two key ingredients. First, we allow for the interplay between real frictions, which arise because investment is subject to fixed costs of adjustment, and financial frictions, which arise because debt financing is subject to a collateral constraint while equity financing involves dilution costs. Second, intangible capital matters for financing and investment decisions because it cannot be pledged as collateral for borrowing. The financial-side frictions, other than for the addition of the debt collateral constraint and imperfect pledgeability of intangible capital, share features of dynamic corporate finance

[1] Our measure is highly correlated with other proxies that have been used in the literature, such as the firm-level intangible capital measure of Peters and Taylor (2017) and the industry-level measure based on Bureau of Economic Analysis Fixed Assets data used in DellAriccia et al. (2021), which support its validity.

models with costly external finance such as, for example, Bolton, Chen, and Wang (2011). The real-side frictions build on Abel and Eberly's (1994) unified theory of investment with nonconvex adjustment costs and partial irreversibility, which make adjustments of the capital stock infrequent and lumpy, generating large financing needs. By explicitly modeling real and financing frictions, we are able to highlight and evaluate the shrinking debt capacity mechanism behind the link between intangible capital and corporate financial policies.

Using a tightly calibrated version of the model with the parameters coming from previous studies or chosen to match empirical restrictions, we quantify the importance of intangible capital. In the first part of the analysis, we examine the ability of the model to account for the evolution over time of key financial ratios by comparing model-implied averages of these ratios to their empirical counterparts. We find the following main results. First, with a realistic combination of forces at work, the model can account for the full increase in average cash ratios of 8.3% that is observed in the data between the first and second halves of our sample period. We allow for four main forces to be at work, namely, changes in intangible capital, volatility, equity issuance costs, and interest rates, all chosen to match the changes in their empirical counterparts. The quantitative performance of the model stands in sharp contrast to the polar case in which firms use only tangible capital in their production technology. In this case, our model becomes similar to the traditional workhorse dynamic corporate finance benchmark and generates average cash ratios that are an order of magnitude smaller than their empirical counterparts. The intuition for this result is that intangible assets boost the precautionary demand for cash through a tightening of the collateral constraint, which leads firms with growth options to hold more cash in anticipation of (S, s)-type adjustments in capital to avoid raising costly external finance. The model provides a good fit not only for the magnitude of the increase in cash, but also for the levels of and changes in the other key financial ratios, such as leverage and equity issuance.

Second, what are the main drivers of the rise in cash, and how much of the increase in cash can be attributed to the rise in intangible capital? To isolate the quantitative importance of intangible capital, we "switch off" our proposed mechanism while allowing the other forces to still be at work. This quantitative counterfactual exercise gauges how much cash would have risen if firms had continued to rely on the same mix of tangible and intangible assets in the 1990s and 2000s as they did in the 1970s and 1980s. Notably, without our mechanism, the model fails to generate a meaningful increase in average cash ratios and predicts that the average cash ratio would have increased by only 2.1%, roughly one-quarter of the overall increase both in the data and in the full model response. As such, this counterfactual implies that about three-quarters of the overall increase can be attributed to the rise in intangible capital, which corresponds to an increase of 6.2% in the average cash ratio. Switching off the alternative mechanisms, while still allowing intangible capital to rise, has a more subdued impact on the predicted change. For example, without the increase in cash flow volatility, the model predicts that the average cash ratio would have increased by 6.9%, which is still a sizable increase. This counterfactual implies that less than one-fifth of the increase in cash ratios can be attributed to the increase in cash flow volatility. For equity issuance costs, despite their sizable impact on cash ratios, if anything they appear to have mitigated the upward trend because the data indicate that they have come down in recent years. Taken together, the results of the first part of our analysis indicate that intangible capital is a quantitatively important force behind the secular trend in corporate cash ratios, relative to both the data and the alternative forces that we consider.

In the second part of the analysis, we go beyond simple averages. We confront the model-implied size distribution of cash with its empirical counterpart to address two additional questions. First, we examine whether the model matches the heterogeneity in cash holdings between small and large firms that we observe in the data. In the data, small firms have higher cash ratios than large firms. The model matches closely the magnitude of the cross-sectional differences between the cash ratios of firms at the opposite ends of the size distribution (bottom versus top decile), which is 7.4% in the data and 7.1% in the model. It also fits the highly skewed concentration of cash levels, with the model-implied share of aggregate cash held by the largest firms (top size decile) closely matching its empirical counterpart at about 70%. The intuition is that, as we show using model-implied estimates of the opportunity cost of cash, even large firms hold cash to preserve financial flexibility because they want to save on the cost of external finance—that is, they prefer not to issue equity—when growth opportunities arise. Second, we examine how much of the cross-sectional differences in the evolution of cash ratios for firms at different points of the size distribution our model can explain. The model does a good job accounting quantitatively for the bulk of the upward trend in cash ratios of firms at each point of the size distribution. For example, it fully explains the doubling of the cross-sectional spread between the cash ratios of small and large firms, which went from 4.7% to 9.5% in the data and from 4% to 7.4% in the model. Moreover, the model generates a stronger upward trend in cash ratios for smaller firms and accounts for over two-thirds of the difference between the increase in cash ratios of small versus large firms, which is about 4.8% in the data. Finally, these results are achieved with the cross-sectional concentration of cash levels staying stable, as in the data. As a result, our proposed mechanism accounts for at least three-quarters of the increase in the aggregate cash ratio. This second set of results lends additional credibility to our proposed mechanism, by showing that it can account for the behavior not only of the average firm in the U.S. corporate sector, but also of a large swath of firms and of the sector as a whole.

We further probe the plausibility of the relation between cash and intangible capital using regression analysis. First, we confirm that the positive relation between cash and intangible capital continues to hold after controlling for a standard set of covariates that include cash flow volatility and firm size. The relation is robust to using the measure of intangibles by Peters and Taylor (2017) and a measure based on Bureau of Economic Analysis (BEA) data from

DellAriccia et al. (2021), as well as to a validity check that uses principal component analysis to extract a common latent intangible factor to aggregate the three subcomponents of our measure instead of taking their sum, among several specification checks. The reduced-form estimates confirm the quantitative importance of intangible capital, as they imply that more than 40% of the predicted increase in cash can be attributed to the rise in intangible capital.

Next, to address potential omitted variable concerns, we examine more saturated specifications that add controls for other covariates of cash that have been proposed in the recent literature, including industry competition (Morellec, Nikolov, and Zucchi (2014)), taxes (Faulkender, Hankins, and Petersen (2019)), interest rates (Azar, Kagy, and Schmalz (2016)), selection by young and newly listed R&D-intensive entrants (Begenau and Palazzo (2021)), employee equity compensation that may be used to substitute for debt by intangible capital-intensive firms (Sun and Xiaolan (2019)), and corporate profits (Chen, Karabarbounis, and Neiman (2017)). The estimates confirm that these alternatives are indeed significantly related to cash in the cross-section. However, the coefficient estimate on intangible capital remains stable even after adding these controls, suggesting that omitted variables are unlikely to be driving the result. Finally, while the reduced-form evidence does not rule out alternative mechanisms, additional evidence from the relation between cash and patent pledgeability following the work of Mann (2018) indicates that the collateral mechanism is economically significant, with the treatment effect of patent pledgeability on cash ratios estimated at about 2% to 3%.

We make two main contributions. First, we develop a calibratable model of liquidity management (see Froot, Scharfstein, and Stein (1993) for a seminal model of corporate liquidity) and use it to establish the quantitative importance of a new mechanism—rising intangible capital—for the secular trend in cash.[2] We contribute to the classical literature on collateral (Shleifer and Vishny (1992), Hart and Moore (1994), Rampini and Viswanathan (2010)) by examining the connection with cash in a setting that is parsimonious enough to bring this class of models closer to the data. As such, ours is the first attempt to quantify the importance of the collateral mechanism for secular changes in corporate liquidity.

A related contribution is that we also use the model to quantify the strength of other forces proposed in the literature, such as changes in cash flow volatility (see, for example, Bates, Kahle, and Stulz (2009)).[3] The contribution here is that we provide complementary model-based estimates of the quantitative

[2] Other models of liquidity management in this literature include Riddick and Whited (2009), Bolton, Chen, and Wang (2011), Nikolov and Whited (2014), Gamba and Triantis (2008), Hugonnier, Malamud, and Morellec (2013), Begenau and Palazzo (2021), Morellec, Nikolov, and Zucchi (2014), and Armenter and Hnatkovska (2017). Recent studies by Bolton, Chen, and Wang (2013), Eisfeldt and Muir (2016), and Warusawitharana and Whited (2015) focus on short-run fluctuations of cash associated with equity market timing.

[3] A large and established empirical literature, starting with Opler et al. (1999), has highlighted several other determinants of cash, including taxes (Foley et al. (2007), Faulkender, Hankins, and Petersen (2019)), industry competition (Morellec, Nikolov, and Zucchi (2014)), interest rates (Azar,

importance of these forces, which so far have been studied mainly in reduced form (see Graham and Leary (2018) for a comprehensive overview). As such, our calibrated model provides the first comprehensive quantitative assessment of key forces behind the secular evolution of corporate liquidity.

Second, we contribute to the small but growing literature on intangible assets in finance. Eisfeldt and Papanikolaou (2013) examine the link between one type of intangible asset—organization capital—and the cross-section of stock returns. Peters and Taylor (2017) show that intangible capital helps improve the performance of standard Q-theory, as investment is better explained by Tobin's Q and less sensitive to cash flow in firms and years with more intangible capital, as also confirmed by Andrei, Moyen, and Mann (2019). Our contribution to this literature is to examine the relation between intangible capital and corporate financial policies. Our results indicate that there is an important connection between intangible capital and the balance sheet and liquidity management decisions of U.S. corporations. Thus, our work suggests that departing from the default view that the typical U.S. corporation conforms to the model of a traditional "old-economy" firm, which relies mostly on tangible assets, is a promising direction to improve our understanding of the balance sheets of U.S. firms and their evolution.

The paper is organized as follows. In Section I, we detail the stylized facts of the relation between intangible capital and corporate cash holdings. In Section II, we present our dynamic model of corporate cash management. In Section III, we use a calibration approach to evaluate the quantitative importance of our proposed mechanism. In Section IV, we provide additional evidence in support of the relation between intangible capital and corporate cash holdings. Finally, in Section V, we conclude.

I. Intangible Capital and the Rise in Cash: Stylized Facts

The central message of our theory is that there is a link between the rise in intangible capital and the rise in corporate cash holdings. In this section, we construct a measure of intangible capital from micro data for a large sample of 18,535 U.S. corporations over the 1970 to 2010 period.[4] We use the measure to detail the stylized facts of the relation between intangible capital and corporate cash holdings. Specifically, we show that the relation holds in the time series and take a first step toward examining cross-sectional differences in the evolution of cash among firms, especially with respect to size.

Although investment in intangible assets is expensed in the year in which it is incurred, the capital that is created by such investment is not reported

Kagy, and Schmalz (2016)), and agency issues (Dittmar and Mahrt-Smith (2007)). See Graham and Leary (2018) for an overview.

[4] The sample includes 176,877 firm-year observations from Compustat. As is standard in the literature, we exclude financial firms (SIC codes 6000-6999), regulated utilities (SIC codes 4900-4999), and firms with missing or nonpositive book value of assets and sales in a given year.

on firm balance sheets.[5] We overcome this hurdle by constructing a measure that is defined for each firm-year as the sum (divided by net book assets) of the capital accumulated through three types of intangible investments 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 capital and informational capital.[6]

Knowledge capital is measured by capitalizing R&D expenditures using the perpetual inventory method with a depreciation rate of 15% (Hall, Jaffe, and Trajtenberg (2000)). This is consistent with the new approach adopted by the BEA in 2013 for the National Income and Product Accounts (NIPA). Organizational capital is defined as capitalized Selling, General, and Administrative (SG&A) expenses with a depreciation rate of 20% (Lev and Radhakrishnan (2005), Eisfeldt and Papanikolaou (2013)). These expenditures enhance the value of brand names and other knowledge embedded in firm-specific human capital and include employee training costs, payments to management and strategy consultants, and distribution systems. Since SG&A expenditures include other expenses unrelated to investments in organizational capabilities, we follow Corrado, Hulten, and Sichel (2009) and weigh the stock of organizational capital by 0.2.[7]

Finally, informational capital is constructed by capitalizing expenditures on computerized information and software with a depreciation rate of 31% following BEA. Since these expenses are not reported at the firm level, we use the annual (2-SIC) industry-level BEA Fixed Reproducible Tangible Wealth (FRTW) data. We then construct a multiple of this stock to tangible capital stock at the industry level and apply the multiple to each firm's tangible capital stock (PPE) to derive a firm-level stock.[8] On average, our resulting estimate for the ratio of intangible to tangible capital over the 2000s is close to one, which is

[5] The only exception is the (fair value of) intangible assets that are acquired via mergers and acquisitions (M&As), which can be booked as assets and are included in "intangibles" (item #33) in Compustat. Since this variable also includes goodwill and excess cost or premium of acquisition, which are unrelated to the economic definition of acquired intangible assets but rather measure overpayment in mergers, we opted for not including this variable in our baseline measure of intangible capital used in the main analysis. However, both our stylized facts and supporting evidence are robust to using an "augmented" version of the baseline measure that also includes the "intangibles" item 33 from Compustat. See Appendix C for additional details.

[6] Existing attempts to measure intangible capital empirically have been mostly in macroeconomics and thus involve constructing aggregate measures of intangible capital for the U.S. economy. For example, one approach is to construct a proxy using aggregate stock market or accounting data (Hall (2001), McGrattan and Prescott (2010)). While this approach measures 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)).

[7] We have explored alternative weights in a wide (+/−50%) range. Our results are qualitatively unchanged.

[8] Our results are little changed if we exclude informational capital.

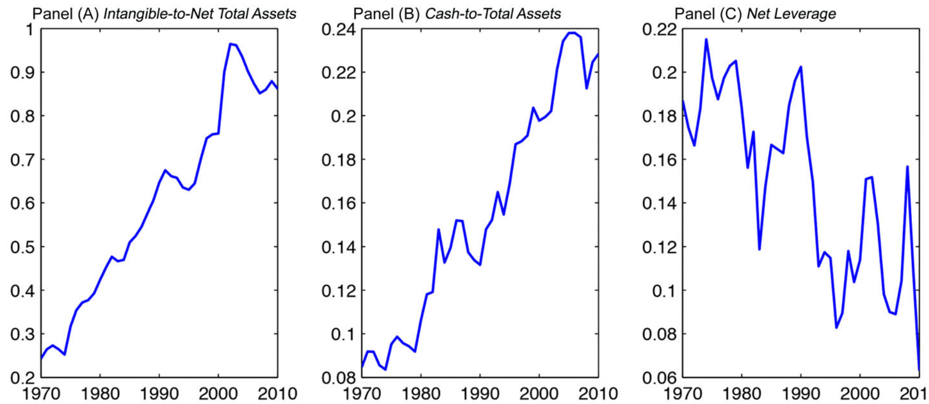

Figure 1. Intangible capital, cash holdings, and leverage. The figure depicts the long-run trend in the intangible capital ratio (relative to total assets net of cash) in Panel (A), the cash ratio (relative to total assets) in Panel (B), and the net debt ratio (relative to total assets) in Panel (C). The ratios are plotted as equal-weighted averages across all firms in the sample in each year. Total assets refer to the balance sheet book value of total assets. 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 Appendix B. (Color figure can be viewed at wileyonlinelibrary.com)

comparable to the estimate in Corrado, Hulten, and Sichel (2009) based on aggregate NIPA accounts.

To further cross-validate our measure, we examine its correlation with related proxies used in the literature. The correlation between our measure and other measures is high. For example, the firm-level intangible capital measure of Peters and Taylor (2017) has a correlation of 0.98 with our measure. An industry-level measure based on the BEA Fixed Assets data used in DellAriccia et al. (2021) (see their appendix for details) has a correlation of 0.51 with our overall measure and 0.60 with our measure of knowledge capital, which is reassuring since the BEA measure is narrower than ours and mainly includes R&D expenditures by both publicly traded firms and private firms in a given industry.

Figure 1 shows the time series of intangible capital and cash by plotting annual averages across firms of their respective ratios to book value of assets (left and middle panels, respectively) over the last four decades. For reference, we also plot average net debt ratios (right panel) to show the implications of the rise in cash for net indebtedness. The intangible ratio rose fivefold from about 20% of book assets (net of cash) in 1970 to about 90% in 2000s. The share of cash on the balance sheets of U.S. corporations also displayed a pronounced upward trend, with the cash ratio growing on average from 9% to 20% between the beginning and the end of our sample period. The secular trend in cash was steady and not concentrated in any particular decade. And it led to a

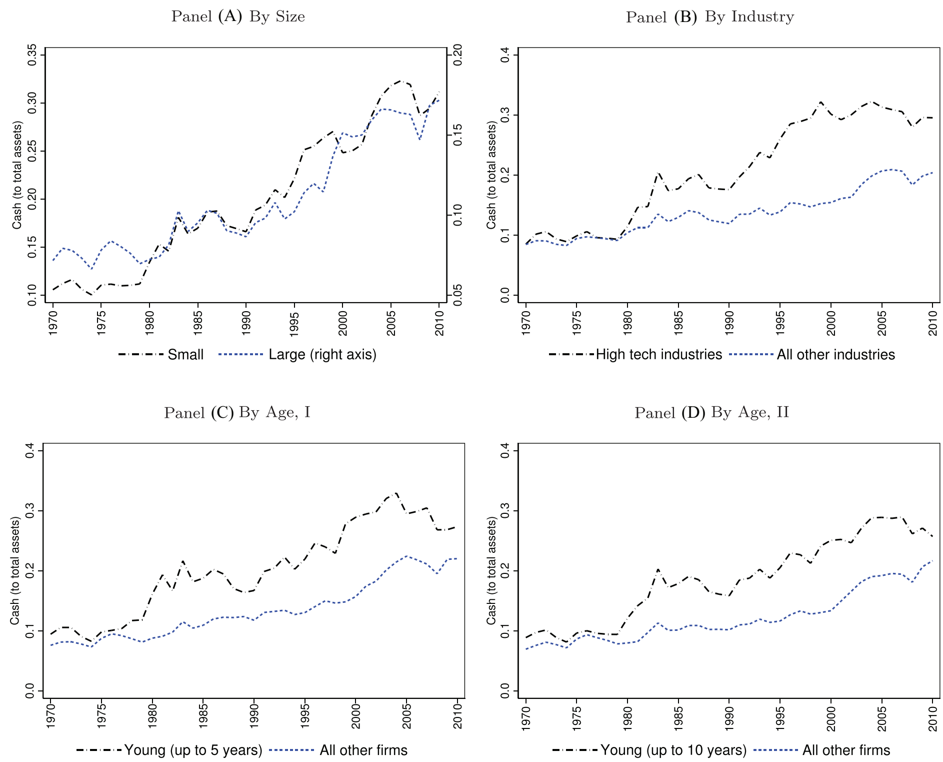

Figure 2. Cash holdings in subsamples by size, industry, and age. The figure depicts the long-run trend in the cash ratio in subsamples split by size (above and below median by total firm assets, Panel (A)), whether the firm is in a high-tech industry as defined by Loughran and Ritter (2004) (Panel (B)), and age (less than five years since IPO (Panel (C)) and less than 10 years since IPO (Panel (D)) versus all other firms). 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 Appendix B. (Color figure can be viewed at wileyonlinelibrary.com)

downward trend in net indebtedness of U.S. firms, with net leverage going down on average from 20% to 6%.

Figures 2 and 3 take a first step toward exploring cross-sectional differences in the trends by plotting annual averages of cash and intangible capital by subgroups of firms based on size (Panel A), industry (Panel B), and age (Panels C and D). Two clear patterns emerge. First, cash and intangible capital trend up robustly across all sub groups of firms. Second, the trends display systematic cross-sectional variation. In particular, they are relatively more pronounced for smaller firms and firms in high-tech sectors.[9]

[9] Internet Appendix Figures IA.1 to IA.4 further detail the trends and show that knowledge and organizational capital are behind the rise in intangible capital (Figure IA.1), which is not sensitive

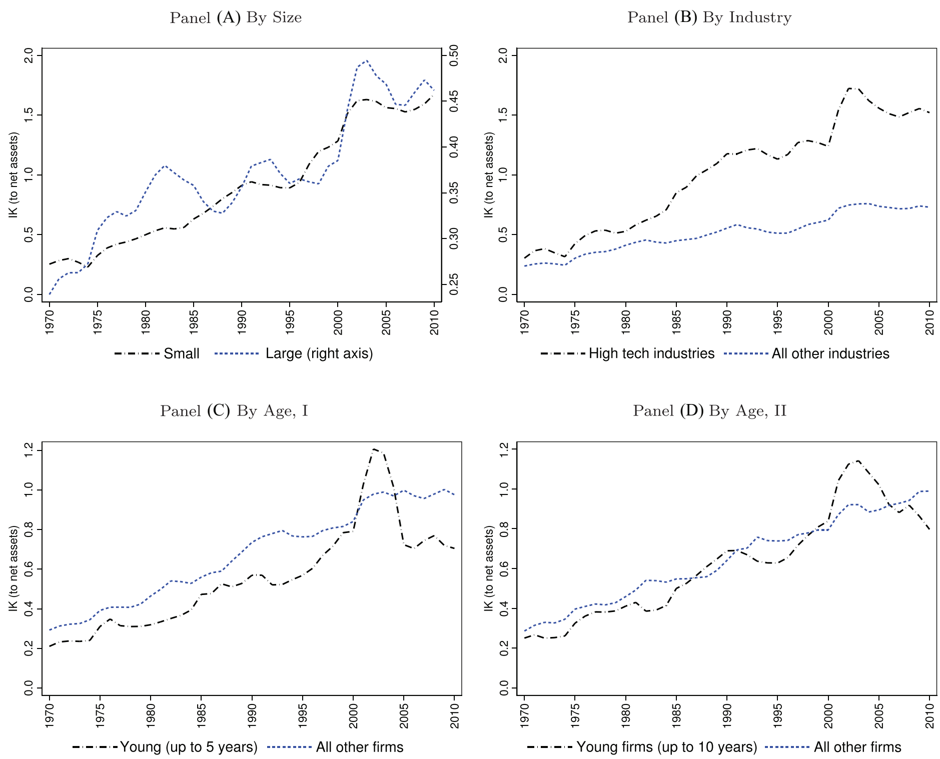

Figure 3. Intangible capital in subsamples by size, industry, and age. The figure depicts the long-run trend in the intangible capital ratio in subsamples split by size (above and below median by total firm assets, Panel (A)), whether the firm is in a high-tech industry as defined by Loughran and Ritter (2004) (Panel (B)), and age (less than five years since IPO (Panel (C)) and less than 10 years since IPO (Panel (D)) versus all other firms). 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 Appendix B. (Color figure can be viewed at wileyonlinelibrary.com)

Finally, turning to the aggregate facts, Figure 4 shows that there was also an upward trend in aggregate cash ratios, although the trend for aggregate cash ratios was weaker than the trend for average cash ratios. This evidence is consistent with the stronger upward trend in the cash ratio of small firms. As shown in the bottom panels, the size distribution of cash holdings in levels is highly skewed, with the largest firms (top size decile) holding the bulk of

to the parametric assumptions behind our measure (Figure IA.2). We also show that the rise in cash is not sensitive to the choice of denominator for the cash ratio (Figure IA.3) and that the relation between cash and intangible capital is not driven just by young firms, as cash also displays an upward-sloping relation with intangible capital for incumbent firms (Figure IA.4). The Internet Appendix is available in the online version of this article on *The Journal of Finance* website.

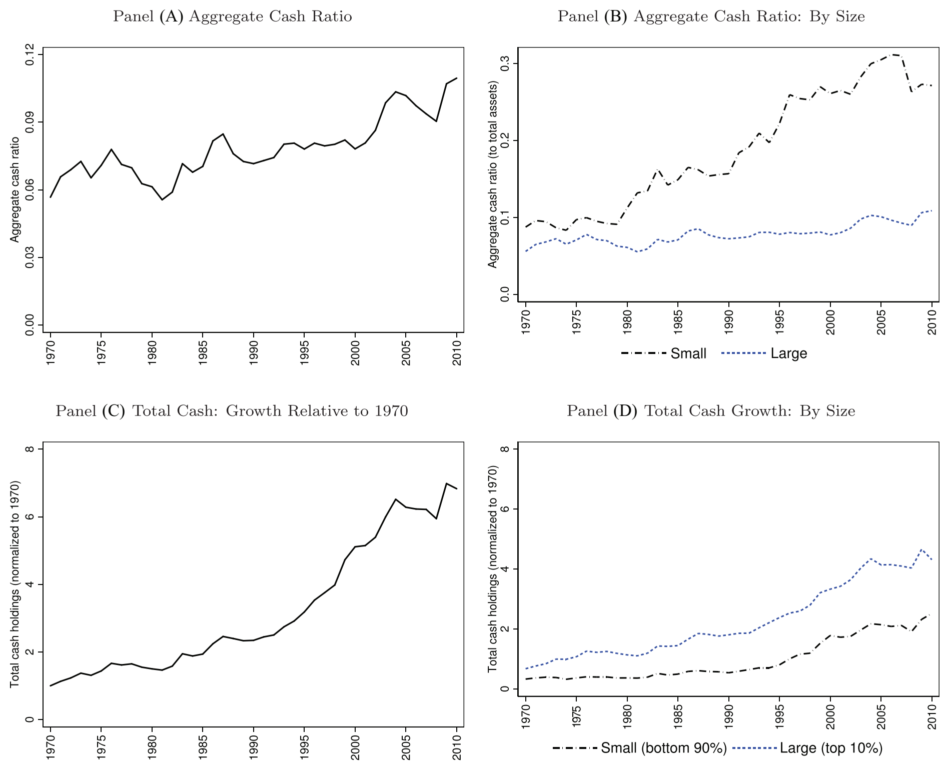

Figure 4. Cash, aggregate facts. The figure depicts the long-run trend in the aggregate cash ratio and aggregate cash holdings. Panel (A) plots the aggregate cash ratio, defined as the ratio of total cash holdings to total assets across all firms in each year. Panel (B) plots the long-run trend in the aggregate cash ratio in subsamples split by size (above and below median by total firm assets). Panel (C) plots the growth in annual aggregate cash holdings relative to 1970, defined as the sum of cash across all firms in the sample in each year normalized by the value of this sum in the beginning of sample (1970). Panel (D) plots the growth in annual aggregate cash holdings relative to 1970 for the largest decile of firms in each year versus the rest of the sample. 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 Appendix B. (Color figure can be viewed at wileyonlinelibrary.com)

aggregate cash. Even then, the fact that smaller firms experienced such a large increase in their cash ratios makes them an important factor behind the trend in aggregate cash. Thus, for our mechanism to successfully match the aggregate trends quantitatively, it must account not only for the average trends, but also for the cross-sectional differences between the cash trends of small versus large firms.[10]

[10] See Appendix D for additional cross-sectional stylized facts by industry and within-firm.

The stylized facts presented in this section indicate that there is a strong link between cash and intangible capital in the time series and that there are interesting cross-sectional differences, especially between large and small firms. We confront the model with both of these facts in our quantitative analysis.

II. A Structural Model of Corporate Cash Management

In this section, we develop a dynamic model of corporate cash management in which firms make optimal financing and liquidity decisions as well as decisions to invest in tangible and intangible capital in the presence of financial market frictions.

A. Technology

The firm combines two types of capital to produce output: tangible capital (K_T) and intangible capital (K_N). In particular, the operating income of the firm is given by

$$\Pi(Z, K_T, K_N) = Z^{1-\gamma}\Phi(K_T, K_N)^{\gamma} - ZF^O, \tag{1}$$

where Z is an idiosyncratic productivity shock that follows a geometric random walk,

$$\log Z' = \log Z + \log \eta',\ \log \eta \sim N(-0.5\sigma_Z^2, \sigma_Z^2),$$

γ is the curvature of the profit function, which reflects either the degree of decreasing returns to scale (DRS) or the market power of the firm,[11] $\Phi(K_T, K_N)$ is a capital aggregator that combines the services of the two types of capital, and ZF^O is the fixed cost of operation, which, to keep the firm's maximization problem stationary, is assumed to be proportional to the current technology level. The capital aggregator takes a general constant elasticity of substitution (CES) functional form

$$\Phi(K_T, K_N) = \left[\theta\left(\frac{K_T}{\theta}\right)^{-\rho} + (1-\theta)\left(\frac{K_N}{1-\theta}\right)^{-\rho}\right]^{-1/\rho}, \tag{2}$$

where the elasticity of substitution is given by $1/(1+\rho)$.

To assess the link between the illiquidity of capital assets and corporate liquidity demand, we follow Abel and Eberly (1994) and assume that the adjustment of both types of capital is costly and involves fixed costs (or so-called nonconvex adjustment costs), F_i^K per unit of capital stock for $i = T, N$. We can then express the total adjustment costs of the capital stock as

$$G(K_T', K_N', K_T, K_N) = \sum_{i=T,N} G_i(K_i', K_i). \tag{3}$$

[11] Throughout the paper, we denote future variables by primes.

where the type-specific adjustment cost function for tangible and intangible capital is given by

$$G_i(K_i', K_i) = [K_i' - (1 - \delta_i)K_i] + F_i^K K_i, \text{ for } i = T, N \tag{4}$$

and δ_i denotes the type-specific depreciation rate of capital.

B. Financing Frictions

Firms have access to three sources of financing: (i) internal funds, (ii) debt, and (iii) outside equity. The debt and equity market frictions laid out below make capital structure decisions deviate from the Modigliani-Miller theorem and introduce nontrivial trade-offs in firm financing choices.

B.1. Debt Market Friction

We denote the outstanding debt of the firm by B and new issuance by B'. Since in our setting, it is never optimal for the firm to issue debt and hold cash at the same time, we can use B to denote the firm's liquid asset position, with $B < 0$ denoting the firm's cash holdings. More generally, one can think of B as the net debt position of the firm. [12]

It is well established in the literature that tangible assets support more debt (see Hart and Moore (1994), Shleifer and Vishny (1992), and Rampini and Viswanathan (2010) for theoretical arguments, and Sibilkov (2009) for empirical evidence). This is because intangible capital is difficult to verify in terms of quality or quantity. Indeed, it often embodies the human capital of developers, which cannot be easily transferred to a third party either partially or entirely. 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.

As in Hart and Moore (1994), we also 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 these circumstances, as Kiyotaki and Moore (1997) show, 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 we introduce intangible capital in production and assume that only tangible capital assets constitute eligible collateral. The resulting contract for risk-free debt is subject to the borrowing constraint

$$B' \leq \bar{B}(K_T') \equiv \frac{(1 - \delta_T)K_T'}{1 + r(1 - \tau)}, \tag{5}$$

[12] To preserve tractability, we do not introduce additional frictions in the adjustment of the firm's financial accounts, such as issuance/refinancing costs for debt, which would make frequent refinancing of debt costly. These frictions would lead the firm to simultaneously hold debt and liquid assets, an issue that is beyond the scope of the paper, as our focus is to explain secular, low-frequency movements in cash.

where τ denotes the corporate tax rate and r is the risk-free rate. Note that the constraint is occasionally binding in our environment and that the collateral value does not depend on the realization of the shock at date $t+1$.[13]

The assumption that intangible assets cannot be used as collateral is broadly factual. Using a large sample of syndicated loans to U.S. corporations for which a detailed breakdown of collateral types used is available, we verify that contractual loan terms state that only assets that can be easily valued represent eligible collateral.[14] Consistent with the legal definition of eligible collateral, only a small minority of secured syndicated loans (about 3% of total loan value) have patents or brands used as collateral. For later reference, we define the financial slack of the firm as $\bar{B}(K_T') - B'$. The literature recognizes other instruments that firms can use to preserve debt capacity, such as financial derivatives (Rampini and Viswanathan (2013)), and has examined richer menu of borrowing instruments, such as leasing. Our contribution is to highlight the role of cash and explore the time-series implications for its secular trend within a calibratable setting with adjustment costs and equity issuance.

B.2. Equity Market Friction

If there were no equity market frictions, the firm could undo debt market frictions at no cost by issuing new equity whenever necessary. Therefore, to create scope for active liquidity management policies, we assume that equity issuance, denoted by E, is costly. In particular, we assume that equity issuance costs take the parametric form

$$\varphi(E) \equiv \varphi_0 \sum_{i=T,N} K_i + \varphi_1 E. \tag{6}$$

The firm incurs a fixed cost of issuing new equity, φ_0, that is proportional to its size as measured by the book value of capital assets, $\sum_{i=T,N} K_i$. It also faces a

[13] Another closely related paper is Rampini and Viswanathan (2013), who recently developed a model of investment, capital structure and risk management in a setting in which only tangible capital can be used as collateral. Our model differs from Rampini and Viswanathan (2013) in that it has a richer real side that allows for capital illiquidity. In addition, their financial side considers a state-contingent contract based on the realized cash flow, while in our setting, the debt contract cannot be contingent upon the realized cash flow. These features allow us to analyze how both real frictions and financial frictions contribute to precautionary savings in a quantitative setting.

[14] Using an additional data source, Capital IQ, which covers a smaller cross-section of firms (about 1,000 per year) and a shorter time series (2002 to 2010) but has detailed information on firm debt structure, we verify that the median ratio of secured to total debt value is about 80%. We find a similar pattern in the loan information from a 2011 extract of Loan Pricing Corporation's (LPC) Dealscan database, which consists of dollar-denominated private loans made by banks (e.g., commercial and investment) and nonbank lenders (e.g., insurance companies and pension funds) to U.S. corporations during the period 1981 to 2010 and includes about 90,000 loans. Most of the loans in this data set are senior secured claims, as it is common for commercial loans. However, a detailed breakdown of collateral types is available for only 20,000 loans. Finally, median leverage and net leverage for firms with very little tangible capital are 2% (0%) and −15% (−16%) for the bottom decile (quintile) of tangibility, respectively.

linear cost, φ_1, that is proportional to the amount issued. This functional form is standard in the literature and facilitates comparison with Bolton, Chen, and Wang (2011), who show that fixed costs of equity issuance significantly strengthen firms' precautionary demand for cash.[15]

C. Value Maximization Problem

To ease presentation of the value maximization problem of the firm, we introduce three indicator variables: $\nu_T^K \in \{0, 1\}$, $\nu_N^K \in \{0, 1\}$, and $\nu^E \in \{0, 1\}$. These indicators denote the action/inaction status of the firm regarding the adjustment of tangible capital stock, the adjustment of intangible capital stock, and equity issuance, respectively. The action/inaction margin is a consequence of the presence of fixed costs of investment and equity issuance. We collect the status of these three decisions in a single element of the Cartesian product, $\nu \in \{(0, 1) \times (0, 1) \times (0, 1)\} \equiv \mathbb{V}$. For instance, $\nu = (1, 1, 1)$ indicates a policy regime in which the firm makes nonzero adjustments for both tangible and intangible capital and its financial policy involves issuance of new shares. With this additional piece of notation in hand, we can define dividend payouts as

$$D(\nu) = (1-\tau)\Pi(Z, K_T, K_N) - \sum_{i=T,N} [\nu_i^K G_i(K_i', K_i) - \tau\delta_i K_i] - [1 + r(1-\tau)]B + B' + \nu^E E. \tag{7}$$

We assume that dividend payouts are subject to a nonnegativity constraint.[16]

The firm's problem can be defined in recursive form as the maximization of the value of equity,

$$W(K_T, K_N, B, Z) = \min_{\lambda,\mu} \max_{E, K_T', K_N', B', \nu} \Big\{(1+\lambda)D(\nu) - \nu^E[E + \varphi(E)] + \mu[\bar{B}(K_T') - B'] + \frac{1}{1+r}\int W(K_T', K_N', B', Z')Q(Z, dZ')\Big\}, \tag{8}$$

where $Q(Z, dZ')$ is the transition function of Z, and λ and μ are the Lagrange multipliers associated with the nonnegativity constraint for dividends and the collateral constraint for debt financing, respectively. The term $1 + \lambda$ can be interpreted as the shadow value of internal funds.

The objective function and the constraint correspondences of problem (8) are jointly homogeneous of degree one in (K_T, K_N, B, K_T', K_N', B', Z). We can exploit this property to reduce the dimensionality of the problem and the computational burden involved in solving it numerically. More specifically, we

[15] While (6) is exogenously imposed, such a cost can arise endogenously when outside investors face uncertainty about the value of capital in place and about the firm's investment opportunities as shown by Myers and Majluf (1984). As is standard in the literature, our equity issuance costs are aimed to capture in a parsimonious way the consequences of these underlying information frictions.

[16] For simplicity, we abstract from dividend taxation.

can normalize the firm's problem by the level of current technology such that $W(K_T, K_N, B, Z)/Z = W(K_T/Z, K_N/Z, B/Z, 1) \equiv w(k_T, k_N, b)$, where the normalized state variables are defined as $k_T \equiv K_T/Z$, $k_N \equiv K_N/Z$, and $b \equiv B/Z$. We also define a series of normalized policy variables: $e \equiv E/Z$, $\tilde{b}' \equiv B'/Z$, $\tilde{k}'_T \equiv K'_T/Z$, and $\tilde{k}'_N \equiv K'_N/Z$. It is straightforward to show that the problem given by (8) is equivalent to

$$w(k_T, k_N, b) = \min_{\lambda,\mu} \max_{e,\tilde{k}'_T,\tilde{k}'_N,\tilde{b}',\nu} \Bigg\{(1+\lambda)d(\nu) - \nu^E[e + \varphi(e)] + \mu[\bar{b}(\tilde{k}'_T) - \tilde{b}'] + \frac{1}{1+r}\int \eta' w\left(\frac{\tilde{k}'_T}{\eta'}, \frac{\tilde{k}'_N}{\eta'}, \frac{\tilde{b}'}{\eta'}\right) dH(\eta')\Bigg\}, \tag{9}$$

where $w(k_T, k_N, b)$ is the normalized conditional value function and

$$d(\nu) = (1-\tau)\Big[\Phi(k_T, k_N)^\gamma - F^O\Big] - \sum_{i=T,N}[\nu_i^K g_i(\tilde{k}'_i, k_i) - \tau\delta_i k_i] - [1 + r(1-\tau)]b + \tilde{b}' + \nu^E e. \tag{10}$$

The normalized adjustment costs, $g_i(\tilde{k}'_i, k_i)$, and debt capacity, $\bar{b}(\tilde{k}'_T)$, can be constructed in a straightforward manner because they are linear. Finally, $H(\cdot)$ denotes the lognormal cumulative distribution function of η.

D. Properties of Capital Accumulation and Financial Policies

We now discuss some key qualitative properties of the optimal firm investment and financing policies, which we denote by $\tilde{k}'_T(k_T, k_N, b)$, $\tilde{k}'_N(k_T, k_N, b)$, and $\tilde{b}'(k_T, k_N, b)$. A detailed characterization of these efficiency conditions is provided in Appendix A.

Panel A of Figure 5 plots the tangible and intangible investment policy functions of the model against the tangible capital stock k_T and the intangible capital stock k_N, respectively. For each policy, the two other state variables are fixed to their median values from our stochastic simulation. All parameters are set to the calibrated values for the full sample in Table I (see Section III.A for the discussion of calibration and model fit). The two graphs contrast two levels of asset tangibility θ, higher for the thick black line and lower for the thin blue line.

The red lines denote $(1-\delta_i)k_i$. If $\tilde{k}'_i$ coincides with the red line, the firm's capital stock k_i is in a region of inaction. The vertical black dotted lines delimit the inaction region for the case of high asset tangibility, while the vertical blue dashed-dotted lines delimit the inaction region for the case of low asset tangibility. If k_i is smaller than the lower bound of the inaction region or greater than its upper bound, the next period's capital stock jumps to its target. For example, the firm waits until its capital stock is sufficiently larger than its disinvestment target before making a downward capital adjustment. In both cases, the nonconvex adjustment friction leads the firm to avoid frequent adjustments of its capital stock.

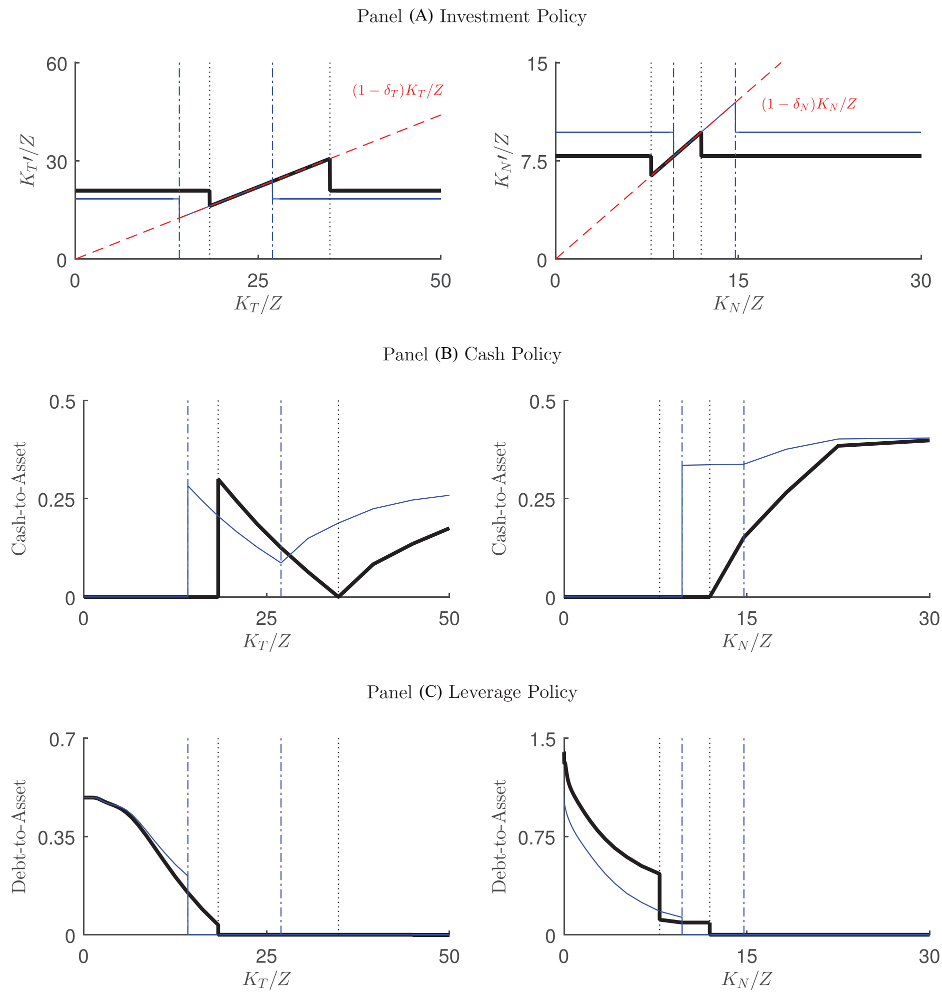

Figure 5. Optimal policies. The figure depicts the optimal investment (Panel A), liquidity (Panel B), and leverage policies (Panel C) as a function of tangible and intangible capital stocks, K_T/Z and K_N/Z. The other state variables are set to their steady-state values. The thick black lines refer to high asset tangibility ($\theta = 0.7$), while the thin blue lines refer to low asset tangibility ($\theta = 0.6$). The vertical black dotted lines delimit the inaction region for the case with high asset tangibility, while the vertical blue dashed-dotted lines delimit the inaction region for the case with low asset tangibility. All remaining parameters are set to their baseline values for the full sample as in Table I. (Color figure can be viewed at wileyonlinelibrary.com)

In both plots, the thin blue line shows that, as technology shifts toward increased reliance on intangible capital, the target for tangible capital shrinks while that for intangible capital rises. This is because, even though we allow for substitution between the two types of capital in the short run, a significant deviation from the long-run tangible capital ratio is costly in terms of firm profitability.

Table I

Baseline Calibration

The table reports the calibrated structural parameters. The frequency of the calibration is annual. F^O is reported as a proportion of average tangible capital in the economy.

Description	Calibration	Target/Restriction
Techonological Parameters		
Curvature of profit function	$\gamma = 0.600$	Hennessy and Whited (2005), Hennessy and Whited (2007)
Asset tangibility	$\theta = 0.660$	Average mix of tangible and intangible capital (data)
Depreciation of tangible capital	$\delta_T = 0.120$	Average depreciation of intangible capital (data)
Depreciation of intangible capital	$\delta_N = 0.190$	Average depreciation of intangible capital (data)
Elasticity of substitution between capital inputs	$\rho = 1.000$	High elasticity of substitution (=0.5)
Fixed cost of adjustment	$F_i^K = 0.005$	Bloom (2009)
Fixed cost of operation	$F^O = 0.085$	Average operating profits (data)
Volatility of technology shock	$\sigma_z = 0.350$	Idiosyncratic volatility of operating profits growth (data)
Financial Parameters		
Risk-free rate	$r = 0.011$	Average real interest (three-month Treasury) rate (data)
Fixed cost of issuance	$\varphi_0 = 0.011$	Bolton, Chen, and Wang (2011), Altinkilic and Hansen (2000)
Linear cost of issuance	$\varphi_1 = 0.015$	Average equity issuance (data)
Tax rate	$\tau = 0.200$	Nikolov and Whited (2014)

Panels B and C of Figure 5 illustrate the key properties of the firm's liquidity (cash) and financial (debt) policy. Again, all graphs contrast two different levels of asset tangibility θ, higher for the thick black line and lower for the thin blue line, and the vertical lines delimit the investment inaction regions. Because in the model firms never optimally hold cash and debt simultaneously, cash is zero when debt is positive and vice versa, as a comparison of Panels B and C highlights.

In Panel B, the thick black lines shows that, while some features of the policies depend on parameterizations, optimal cash-holding decisions are tightly linked to the arrival of investment opportunities. In the absence of financing frictions, corporate saving would be unnecessary as outside funding could be tapped costlessly. When firms face costly external financing because of equity flotation costs and collateral constraints, corporate savings become valuable in anticipation of investment spending. Firms accumulate cash to the right of the divestment action boundary, where they face lower external financing needs to cover investment spending. Panel C shows that firms heavily borrow to finance investment after the investment boundary to the left of the inaction region. Importantly, while the tangible capital stock limits the firm's debt capacity, firms allocate this debt capacity to financing intangible investment as well. As a consequence, for small values of intangible capital, the stock of debt can exceed the current intangible capital stock. In addition, firms use debt financing to cover income shortfalls that are due to the presence of fixed operating costs, F_0. This effect increases reliance on external debt toward the left of the inaction region.

Finally, the thin blue lines in Panel B indicate that corporate savings increase when the asset tangibility parameter, θ, decreases. As technological change increases the firm's reliance on intangible capital, its ability to pledge collateral for debt financing is limited, which strengthens the precautionary motive to hold cash. Conversely, the tighter collateral constraint leads to less reliance on debt financing.

III. Quantitative Results

How much of the increase in cash can be accounted for by the rise in intangible capital? In this section, we use a calibration approach to confront the model with data and evaluate the quantitative importance of our proposed mechanism. We start by detailing the calibration and model fit. We then present the main result on the importance of intangible capital using a quantitative counterfactual exercise. While the primary focus of the analysis is on sizing up how much of the secular trend in cash our proposed mechanism can account for, we also examine the ability of the model to account for a broader set of key corporate financing decisions, including leverage and equity issuance, as well as the contribution of other mechanisms that have been proposed in the literature, including changes in firm cash flow risk and interest rates. In the second part of the quantitative analysis, we turn to the model's implications for the cross-sectional size distribution of cash holdings and the evolution of aggregate cash holdings in the U.S. corporate sector.

A. Calibration and Model Fit

Our baseline calibration is summarized in Table I. The frequency of our calibration is annual. The model features 12 parameters, eight of which are on the technology side and four on the financing side. Starting with the technology-side parameters, we set the elasticity of the profit function with respect to capital, γ, to 0.6, following previous studies (see, for instance, Hennessy and Whited (2007)). The asset tangibility parameter, θ, which determines the mix between tangible and intangible capital, is new to the literature and we set it to match the average mix of these two types of capital—the ratio of tangible to total capital—in the data. The depreciation rates of each type of capital can also be directly measured in the data and we choose them to fit the average depreciation rates for tangible and intangible capital in our sample, which is the standard approach. The resulting values of 0.12 and 0.19 for tangible and intangible capital, respectively, are comparable to those in previous studies. For example, Gomes (2001) uses a depreciation rate of 0.145 and Riddick and Whited (2009) use 0.15 for tangible capital. Higher depreciation rates for intangible capital are supported by existing evidence (see, for example, table 5 in Hall (2005), who uses micro data to estimate a depreciation rate for R&D of 0.19). The elasticity of substitution between the two types of capital, ρ, is the only parameter for which we have limited guidance from either data or previous studies. We set it to one, which implies a relatively high elasticity of 0.5 ($= 1/(1+\rho)$), to show how far the baseline calibration can go toward accounting quantitatively for the increase in cash even when firms can substitute relatively easily away from intangible capital in their production needs. This is a conservative choice because firms will need less cash if they can use real hedging instead of financial hedging. That said, we ensure that the results are not driven by this particular parameter choice by performing an extensive set of sensitivity checks to varying the elasticity of substitution over a relatively wide range that includes even higher values than the baseline (see Internet Appendix Table IA.II).

For the fixed cost of investment, $F_N^K = F_T^K$, we choose a value on the low end of the range, 0.005 of installed capital, or, under our baseline calibration, 1.47% of sales. Using plant-level data for manufacturing, Cooper and Haltiwanger (2006) estimate a fixed adjustment cost of about 0.04 of installed capital (or about 20% of sales), which is at the high end of the range of existing estimates. Using the same plant-level data, Caballero and Engel (1999) estimate fixed adjustment costs of about 16% of sales. We use a lower value because investment is less lumpy at the firm level. For example, the annual frequency of large investment spikes (defined as investment rates in excess of 20%) is about 19% at the plant level (see table 1 in Cooper and Haltiwanger (2006)), but it is only about only 4% at the firm level for the median industry in our sample. We calibrate this parameter following Bloom (2009), who uses firm-level data and estimates fixed adjustment costs of 1.5% of sales, about a tenth of the plant-level estimates. We perform sensitivity checks on this parametric choice as well (see Table IA.II). The fixed cost of operation, F^O, is chosen to approximately match average profitability in our sample, which leads to a value of 0.069 of steady-state capital. For the idiosyncratic volatility of the technology shock, we set the annual standard deviation, σ_Z, to 0.35. This value is chosen to match its empirical counterpart. Specifically, we construct idiosyncratic profitability as the estimated residual from a regression of firm-level profitability on common factors, which we proxy for using average industry-level (4-SIC) profitability in any given year. The standard deviation of the change in the estimated residual in our sample is 0.35. This value is in line with previous studies: DeAngelo, DeAngelo, and Whited (2011) estimate a value of 0.2853, Li, Whited, and Wu (2016) report estimates ranging from 0.394 to 0.458, and Nikolov, Schmid, and Steri (2019) report a value of 0.283, which is similar to Riddick and Whited (2009).[17]

Turning to the four parameters on the financial side, the risk-free rate is calibrated to 0.011, the average one-year (real) Treasury rate over the sample period, which is a standard approach in the literature. We set the fixed cost of equity issuance to approximately 1% of the capital stock, following Bolton, Chen, and Wang (2011). We then set the proportional equity issuance costs to approximately match average equity issuance in the data. The value we use for proportional costs, 0.015, is also comparable to previous studies. For example, Gomes (2001) uses a value of 0.028. Using our calibrated values for the equity issuance costs and the asset tangibility moment, we can back out the implied average underwriting fees relative to the overall size of proceeds, which are equal to 5.78%.[18] This value is closely aligned with the estimate of 5.38% for average underwriting costs of common stock offerings relative to the overall size of proceeds in Altinkilic and Hansen (2000) and with the fee of 50,332 dollars for the first million dollars of gross equity proceeds in Hennessy and Whited (2007). Finally, following Nikolov and Whited (2014), we set the corporate tax rate to 0.20, as an approximation of the statutory corporate tax rate relative to personal tax rates.

Table II summarizes overall model fit for the baseline parameterization by comparing the model-implied moments, which are tabulated in the second column, with their empirical counterparts, tabulated in the first column.[19] Overall, despite being quite parsimonious, the model successfully matches

[17] We have examined the sensitivity of our estimate to using different specifications to construct idiosyncratic volatility, including using coarser industry groups at the 3-SIC or 2-SIC level or using the "market model" with the market factor proxied by average economy-wide profitability in any given year. These three alternatives lead to implied estimates for σ_Z of 0.35, 0.36, and 0.36, respectively.

[18] In the model, underwriting fees c (in USD) are implicitly defined as $c = \varphi_0(K_T + K_N) + \varphi_1(E - c)$. Rearranging the previous equation and using estimates of tangibility conditional on issuance, $tang$, and the size of equity issuance relative to tangible capital, $\frac{E}{K_T}$, one can back out $\frac{c}{E}$ as

$$\frac{c}{E} = \frac{1}{1+\varphi_1}\left(\frac{\varphi_0}{\frac{E}{K_T}\cdot tang} + \varphi_1\right).$$

[19] To compute the data moments, we trim all variables at 2.5%, which is a standard approach to ensure comparability with the model-implied moments (see, for example, Hennessy and Whited

Table II

Asset Tangibility and Cash Holdings: Baseline Quantitative Results

This table reports model-implied and data moments for the baseline calibration. The data moments in the first column are for a sample of nonfinancial, unregulated firms from the annual Compustat, which we complement with information on equity issuance from the Securities Data Company (SDC) database. The sample period is 1970 to 2010. The model-implied moments in the second column are calculated as averages of simulations of 1,000 firms and 100 time periods. To perform the simulation, we use 1,000 by 100 random draws from the lognormal distribution. The same set of random draws is applied to each economy. The expectation is approximated with 30-point Gauss-Hermite quadrature. The parameter values are as in Table I. The third column reports model-implied moments for the case in which firms use only tangible assets. All moments are self-explanatory, except for the Error Variance of Profits and Cash Autocorrelation, which are defined as the error variance and the slope coefficient from a first-order autoregression of idiosyncratic profit growth and the cash ratio, respectively. Details on model and data variable definitions are in Appendix B.

	Data (1970 to 2010)	Model (Baseline)	Model ($\theta = 1$)
Panel A: Main Moments			
Average Cash Ratio	0.140	0.151	0.020
Average Leverage Ratio	0.239	0.211	0.251
Average Equity Issuances	0.006	0.004	0.006
Frequency of Equity Issuances	0.035	0.043	0.031
Average Asset Tangibility	0.718	0.711	1.000
Average Operating Profitability	0.151	0.151	0.145
Panel B: Additional Moments			
Error Variance of Profits	0.003	0.002	0.002
Cash Autocorrelation	0.424	0.563	0.334
Skewness of Tangible Investment	1.572	2.124	1.974
Skewness of Intangible Investment	1.721	2.149	–

quantitatively the core financing policies of U.S. firms. As shown in Panel A, the model closely matches the magnitudes of our two main untargeted financial quantities of interest, the average cash- and debt-to-asset ratios, which are about 14% and more than 20% in the data, respectively. The model also well matches the average size and frequency of equity issues. This close fit is achieved for an empirically plausible parameterization, because the model also reproduces the empirical counterparts of the targeted real moments, namely, the average mix of tangible and intangible assets and profitability, on the real side. Panel B provides additional external validation of model fit by considering higher order nontargeted moments, such as the error variance of profits, the

(2007), who use trimming at 2%). We examined sensitivity to different cutoffs, including trimming at 2% and 1% and winsorizing at 2.5%, 2%, and 1%. These five alternatives lead to data moments for our main financial variables of interest that are close to the baseline. For example, the mean cash ratio is 0.142, 0.146, 0.152, 0.153, and 0.154, respectively.

Table III

Main Quantitative Counterfactual: Calibration

This table reports the calibrated structural parameters for the main quantitative counterfactual, which involves a comparison between model-implied and data moments for the 1975 to 1985 decade ("Early Period") and the 1995 to 2005 decade ("Late Period").

	Calibration	
Description	Early (1975 to 1985)	Late (1995 to 2005)
Techonological Parameters		
Asset tangibility (θ)	0.710	0.620
Fixed cost of operation (F^O)	0.056	0.119
Volatility of technology shock (σ_z)	0.340	0.360
Financial Parameters		
Risk-free rate (r)	0.014	0.013
Fixed cost of issuance (φ_0)	0.022	0.011
Linear cost of issuance (φ_1)	0.020	0.014
Tax rate (τ)	0.250	0.200

autocorrelation of cash, and the skewness of tangible and intangible investment. The model-implied magnitudes of these additional nontargeted moments are also close to the data. That said, the model slightly overestimates some of these higher order moments, especially the skewness of investment, suggesting that allowing for a richer adjustment cost function with asymmetric adjustment costs between investment and disinvestment, or costly irreversibility, could be a potentially useful extension to further improve model fit.

Finally, the third column offers another yardstick to evaluate model fit. We tabulate model-implied moments for the polar case in which all parameters are set as in the baseline calibration except for θ, which is now set equal to one. In this polar case, our model is similar to the traditional workhorse dynamic corporate finance benchmark in which firms use only tangible capital in their production technology. Strikingly, the average cash-to-assets ratio in this economy is an order of magnitude smaller than its empirical counterpart, at only about 2.1%. Intangible capital helps improve model fit on both the real and the financial sides. It helps account for the fact that U.S. firms are heavily reliant on intangible assets in their mode of production, but also turns out to be critical to account for why firms rely on internal financing so much. As such, the comparison to the traditional benchmark provides a first indication that intangible capital is a quantitatively important force behind cash holdings.

B. Baseline Quantification of the Impact of Asset Tangibility on the Rise in Cash

Tables III and IV report the parameterization and results of our main quantitative experiment. The experiment is designed to reproduce the magnitude

Table IV

Asset Tangibility and the Rise in Cash Holdings: Results of Main Quantitative Counterfactual

This table reports model-implied and data moments for the main quantitative counterfactual, which involves a comparison of data and model-implied moments between the "Early Period" (1975 to 1985) and the "Late Period" (1995 to 2005). The data moments in the first and third columns correspond to a sample of nonfinancial, unregulated firms from the annual Compustat, which we complement with information on equity issuance from SDC. The model-implied moments in the second and fourth columns are calculated as averages of simulations of 1,000 firms and 100 time periods. To perform the simulation, we use 1,000 by 100 random draws from the lognormal distribution. The same set of random draws is applied to each economy. The expectation is approximated with 30-point Gauss-Hermite quadrature. The parameter values are as in Table I. The fifth column reports model-implied moments for a counterfactual exercise in which the tangibility parameter (θ) is kept constant at its calibrated value for the early period (1975 to 1985). Details on model and data variable definitions are in Appendix B.

	Data (1975 to 1985)	Model (1975 to 1985)	Data (1995 to 2005)	Model (1995 to 2005)	Counterfactual (θ Fixed)
Average Cash Ratio	0.100	0.095	0.183	0.178	0.116
Average Leverage Ratio	0.256	0.204	0.221	0.191	0.210
Average Equity Issuances	0.004	0.003	0.007	0.005	0.004
Frequency of Equity Issuances	0.029	0.027	0.041	0.064	0.055
Average Asset Tangibility	0.754	0.754	0.677	0.672	0.751
Average Operating Profits	0.168	0.164	0.133	0.133	0.133

Change in Cash—Model (Late vs Early): 0.083
Change in Cash—Data (Late vs Early): 0.083
Change due to Intangible Cap. (Counterfactual): 0.062

Change in Leverage—Model (Late vs Early): −0.012
Change in Leverage—Data (Late vs Early): −0.035
Change due to Intangible Cap. (Counterfactual): −0.019

Change in Equity Issuance—Model (Late vs Early): 0.002
Change in Equity Issuance—Data (Late vs Early): 0.003
Change due to Intangible Cap. (Counterfactual): 0.001

of the technological transformation involving the shift of U.S. firms toward intangible capital in the data. Specifically, we choose the asset tangibility parameter, θ, so that the mix between the two types of capital matches its empirical counterpart in the first versus second half of the sample. To capture the time-series trend over the four decades that span our sample period, we divide the sample into two subsamples, one for the first half and the other for the second half of the overall 1970 to 2010 period. To focus on long-term variation behind the trend rather than short-term year-to-year changes, we take the midpoint decade for each of the two subperiods and compare model-implied moments to data moments averaged over the midpoint decade for each of the two subperiods, the 1975 to 1985 decade (the "Early Period") versus the 1995 to 2005 decade (the "Late Period"). Finally, to allow a broader set of forces beyond intangible capital to potentially be at work, we also vary the financing and other key real-side parameters, including volatility, to match their empirical counterparts in each of the two subperiods. Whenever possible, we calibrate the parameters for each subperiod following the same logic as in the baseline calibration. Since we do not have separate benchmark values for fixed equity issuance costs by subperiod, we make use of the fact that the equity issuance frequency in the late period is similar to that in the full sample. Thus, we keep the fixed equity issuance parameter approximately at its baseline values for the late period, and increase it in the early period to approximately match the lower average frequency of equity issues in the data.

Table IV reports the results of the main experiment. We address two main questions. First, how much of the increase in cash can our model explain? In the data, the average cash-to-assets ratio rose substantially, from 10% to 18.3%, which is an increase of 8.3%, that is, it almost doubled in the late period relative to the early period. In our quantitative experiment, the model generates an increase in the average cash-to-asset ratio that is strikingly close to the data, from 9.5% to 17.8%, which is also an increase of 8.3%. Thus, the model is able to fully account for the secular increase in corporate cash holdings. Importantly, the model can also account quantitatively for the evolution of other key financial and real policies of U.S. firms. For example, the model can account for roughly one-third of the relatively small average decrease in leverage and for roughly two-thirds of the increase in equity issuance proceeds. For the frequency of equity issues, the model if anything slightly overshoots the increase in the data. This result is due, at least in part, to the data moment understating the full frequency of equity issues in the recent period as a result of to the well-documented increase in private placements and shelf registrations, which may have substituted for traditional public placement via secondary equity offerings (see, for example, Gomes and Phillips (2012)). Finally, the model fits not only the magnitude of the change in cash-to-asset ratio, but also the level of the cash ratio as well as the other key financial ratios in each subperiod. As such, our quantitative exercise is relatively disciplined, as it involves three untargeted moments (two levels and one change) for each financial ratio - cash, leverage, and equity issuance proceeds.

Second, what are the main drivers of the rise in cash, and how much of the increase in cash can be attributed to the rise in intangible capital? To isolate the quantitative contribution of intangible capital to the rise in cash, we use a simple counterfactual experiment in which we keep the asset tangibility parameter, θ, fixed at its value for the early period while all other parameters are otherwise allowed to vary as per Table III. The idea behind this counterfactual exercise is that we can leverage our structural model by "switching off" the intangible capital mechanism to gauge the extent to which cash would have increased without the rise in intangible capital, that is, if firms had continued to rely on the same mix of tangible and intangible assets in the 1990s and 2000s as they did in the 1970s and 1980s. The results are shown in the last column of Table IV. Without the rise in intangible capital, the model predicts that the average cash-to-asset ratio would have increased by only 2.1%, which is roughly one-quarter of the overall increase both in the data and in the full model response. The difference between this counterfactual increase and the full model response, 6.2%, is the increase in cash that can be specifically attributed to intangible capital.[20] Thus, the results of the quantitative counterfactual indicate that about three-quarters of the increase in cash is due to the increase in intangible capital. Interestingly, the counterfactual also shows that our mechanism helps account for the secular evolution of the other financial moments, because without the rise in intangible capital, the model would counterfactually predict an increase, albeit small, in leverage and less of an increase in equity issuance.

In summary, the results of our main experiment and quantitative counterfactual indicate that the shift toward intangible capital can account for the bulk of the secular increase in the cash ratios of U.S. firms. As such, intangible capital is a quantitatively important force behind the secular trend in corporate cash holdings.

C. Sizing Up Alternative Mechanisms

In this section, we dig dipper into quantifying the relative importance of other forces. We do so by conducting three additional quantitative counterfactual exercises in which we now "switch off" some of the alternative mechanisms that have been proposed in the literature by fixing their respective parameters at their values for the early period. Table V reports the model-implied moments for each of the three counterfactuals. In the first column, we examine the quantitative importance of cash flow volatility (see, for example, Bates, Kahle, and Stulz (2009) and Bates, Chang, and Chi (2018)). Similar to what we do for the main counterfactual in Table IV, we now fix the profitability shock volatility parameter σ_Z at its value for the early period, while all other parameters are

[20] Note that our counterfactual is conservative because it evaluates the quantitative effect of tangibility while allowing for realistic changes in the other forces that mitigate the effect (see the next section for details). In fact, evaluating the counterfactual using the baseline values in Table I (instead of their values by subperiod in Table III) gives an even larger effect of 0.129.

Table V

Alternative Explanations for the Rise in Cash Holdings: Results of Additional Quantitative Counterfactuals

This table reports model-implied and data moments for additional quantitative counterfactuals. We consider three alternative explanations: risk, financing costs, and interest rates. The data moments correspond to a sample of nonfinancial, unregulated firms from the annual Compustat, which we complement with information on equity issuance from SDC. The data moments for the late period are reported in the third column of Table II. The model-implied moments in each column are calculated as averages of simulations of 1,000 firms and 100 time periods. To perform the simulation, we use 1,000 by 100 random draws from the lognormal distribution. The same set of random draws is applied to each economy. The expectation is approximated with 30-point Gauss-Hermite quadrature. Each column reports model-implied moments for a counterfactual exercise in which, respectively, the profitability shock volatility (σ_z), the equity issuance costs (φ_0 and φ_1), and the risk-free rate (r) are kept constant at their calibrated value in the early period (1975 to 1985). All other parameter values are otherwise set as in Table I. Details on model and data variable definitions are in Appendix Table B.

	Counterfactual Volatility (σ_z Fixed)	Counterfactual Issuance Costs (φ_0, φ_1 Fixed)	Counterfactual Interest Rate (r Fixed)
Average Cash Ratio	0.164	0.297	0.191
Average Leverage Ratio	0.196	0.162	0.191
Average Equity Issuances	0.004	0.022	0.008
Frequency of Equity Issuances	0.057	0.035	0.065
Average Asset Tangibility	0.669	0.671	0.674
Average Operating Profits	0.132	0.133	0.133
Change in Cash—Data (Late vs Early):	0.070	0.203	0.096
Change due to Alternatives (Counterfactual):	0.014	−0.119	−0.013
Change in Leverage—Data (Late vs Early):	−0.007	−0.041	−0.012
Change due to Alternatives (Counterfactual):	−0.005	0.029	−0.000
Change in Equity Issuance—Data (Late vs Early):	0.002	0.019	0.006
Change due to Alternatives (Counterfactual):	0.000	−0.017	−0.004

otherwise allowed to vary as per Table III. Without the increase in cash flow volatility, the model predicts that the average cash-to-asset ratio would have increased by 6.9%, which is still a sizable secular increase in cash holdings. Thus, the results of this counterfactual imply that an increase in cash of 1.4% can be attributed to the increase in cash flow volatility, which is less than a fifth of the overall increase in cash. Our model-based estimate corroborates the reduced-form estimate in Bates, Kahle, and Stulz (2009), who attribute roughly a quarter of the increase in cash to volatility.

The second column reports model-implied moments of a counterfactual with respect to equity financing costs. Bolton, Chen, and Wang (2011) and Eisfeldt and Muir (2016), among others, propose that higher costs of external finance heighten the precautionary motive and lead firms to hold more cash. Notably, our calibrated parameters for both equity issuance costs, φ_0 and φ_1, decrease in the later period (Table III). As evident from the table, without the reduction in issuance costs, the model generates an even larger increase in the average cash-to-asset ratio. This counterfactual indicates that the reduction in equity issuance costs contributed to a reduction in the average cash ratio of 11.9%. In addition, without the reduction in issuance costs, the model overshoots by an order of magnitude the size of equity issuances in the late period, because higher fixed costs of issuance lead to larger offerings. In sum, the results support the existing literature by showing that equity issuance costs are a quantitatively powerful driver of cash holdings. However, this force is unlikely to be an important driver of the secular trend in cash because the data indicate that equity issuance costs have come down since the 1970s.

Finally, the last column considers the cost of carry, which is driven by the interest rate r in our model. Previous papers including Azar, Kagy, and Schmalz (2016) and Chen, Karabarbounis, and Neiman (2017) suggest that interest rates are a determinant of cash holdings because they affect firms' opportunity costs of holding cash. Gao, Whited, and Zhang (2021) point to a nonmonotonic relationship between interest rates and corporate cash. In the data, real interest rates decreased a bit from 1.35% to 1.3%, as reported in Table III. The results of our counterfactual indicate that without the small decline in interest rates, the model predicts an increase in cash of 9.6%, which is slightly higher but little changed relative to the full response of 8.3%. Thus, the results indicate that a decrease in cash of 1.3% can be attributed to interest rates, suggesting that this force, while nonnegligible quantitatively as a determinant of cash, is unlikely to be one of the main drivers of its secular trend.

In summary, the additional counterfactuals suggest that some of the determinants that have been previously considered in the literature, such as volatility and interest rates, are relatively weak, while others, such as equity issuance costs, do not help account for the upward trend in cash because in the data they move in such a way as to decrease, rather than increase, cash.

D. The Cross-Sectional Size Distribution of Cash and Aggregate Implications

So far, our analysis focuses on cross-sectional averages of cash ratios and how they evolved over time. In the second part of the quantitative analysis, we go beyond the standard metrics and confront the model with the empirical cross-sectional size distribution of cash ratios as well as aggregate cash levels. This part of the analysis addresses two additional questions. First, does the model match the heterogeneity in cash holdings between small and large firms that we observe in the data? Second, how much of the cross-sectional heterogeneity in the increase in cash for firms at different points of the size distribution can our model explain?

Table VI examines the cross-sectional model fit for the baseline calibration by comparing model-implied and data moments conditional on each decile of the firm size distribution. Specifically, we sort firms into size deciles both in the model and in the data and report two key distributional moments averaged within each size bin, namely, the cash-to-asset ratio and the share of

Table VI

Asset Tangibility and Cash Holdings: Quantitative Analysis of the Cross-sectional Implications

This table reports model-implied and data moments for the baseline quantitative analysis of the cross-sectional implications, which are calculated by sorting firms based on deciles of the firm size distribution. The data moments in the first and third columns correspond to a sample of nonfinancial, unregulated firms from the annual Compustat between 1970 and 2010, which we complement with information on equity issuance from SDC. The model-implied moments in the second and fourth columns are calculated as averages of simulations of 1,000 firms and 100 time periods. To perform the simulation, we use 1,000 by 100 random draws from the lognormal distribution. The same set of random draws is applied to each economy. The expectation is approximated with 30-point Gauss-Hermite quadrature. The parameter values are as in Table I. The fifth column reports model-implied moments for the value of cash, which are calculated similar to Bolton, Chen, and Wang (2011) and Gamba and Triantis (2008) as the percentage gain in firm value from having the option to hold cash, that is, as the percentage difference between firm value in the baseline and constrained value when not allowed to hold cash. Details on model and data variable definitions are in Appendix Table B.

Size	Average Cash Ratio		Aggreg. Cash Shares		Value of Cash
Decile	Data (1970 to 2010)	Model Baseline	Data (1970 to 2010)	Model Baseline	Model Baseline
Small	0.154	0.173	0.002	0.000	14.868
2	0.147	0.165	0.004	0.000	14.239
3	0.144	0.162	0.007	0.001	14.006
4	0.134	0.159	0.011	0.003	13.791
5	0.132	0.157	0.016	0.007	13.743
6	0.124	0.157	0.026	0.017	13.618
7	0.117	0.156	0.039	0.035	13.549
8	0.105	0.152	0.062	0.071	13.176
9	0.094	0.131	0.127	0.127	11.300
Large	0.080	0.102	0.707	0.738	9.590

Cross-Sectional Cash Spread (Small vs. Large)—Data: 0.074
Cross-Sectional Cash Spread (Small vs. Large)—Model: 0.071

aggregate cash held by firms in each size bin. The first column shows that in the data, small firms have higher average cash-to-asset ratios than large firms, which is in line with previous findings in the literature (e.g., Almeida, Campello, and Weisbach (2004), Denis and Sibilkov (2009), Bates, Kahle, and Stulz (2009)). In addition, the third column shows that the size distribution of cash levels is highly skewed, with the bulk of the aggregate dollar amount of cash holdings highly concentrated among large firms. The model provides a highly accurate quantitative match to both facts. Specifically, the model matches closely the magnitude of the cross-sectional difference between the cash-to-asset ratios of small versus large firms, which is 7.4% in the data and 7.1% in the model for the difference between firms in the bottom versus top size decile. Even for the intermediate points of the size distribution, the magnitude of the cross-sectional spread predicted by the model closely matches its empirical counterpart. For example, the difference between the cash-to-asset ratio of small (bottom decile) versus mid-sized (median) firms is 2.2% in the data and 1.6% in the model, and that between mid-sized (median) versus large (top decile) firms is 5.2% in the data and 5.5% in the model. Finally, the model also generates an accurate quantitative fit for the concentration of cash levels. The model-implied shares of aggregate cash held by firms in each size decile closely match their empirical counterparts. For example, the largest firms (top decile) hold about 71% of aggregate cash in the data and about 70% in the model.

To help interpret the cross-sectional results, the last column reports an estimate of the model-implied average "value of cash" for firms in each size decile. The estimate is defined similar to Bolton, Chen, and Wang (2011) and Gamba and Triantis (2008) as the percentage gain in firm value from having the option to hold cash or, equivalently, the firm's willingness to pay for the option to hold cash. In the model, it is constructed using the baseline calibration and taking for any given firm the percentage difference between their value and the constrained value for the case in which they are not allowed to hold cash, which we operationalize by adding a nonnegativity constraint on net debt to the firm optimization problem. The results show that cash increases firm value by about 5.3% more for small (bottom decile) relative to large (top decile) firms. That said, cash remains valuable even for the largest firms, at over 9.5%, which is why the size distribution of cash is nondegenerate in the model and even large firms have sizable cash ratios. This result is in line with the standard intuition of costly external finance models, where the financial constraint status is not only a function of firm size but also of growth opportunities, that is, the realization of the technology shock. In our model, even large firms may find themselves in the financially constrained region when faced with a good realization of the technology shock (see, for example, figure 5 in Gomes (2001)). Given that the primary motive to hold cash is to preserve financial flexibility, even very large firms hold cash in our model because they prefer to save on costly external finance when growth opportunities arise, though they hold less cash than small firms because DRS reduces the value of growth opportunities for larger firms.

Next, we examine the evolution of the cross-sectional size distribution of cash and of aggregate cash ratios. To that end, we compute data and model-implied cross-sectional moments under the same parameterization that we use for the main quantitative experiment in Section III.B. We again consider two sets of cross-sectional moments, cash-to-asset and the share of aggregate cash held by firms in each size decile. The results are reported in Table VII. Overall, the model explains a large fraction of several key changes in the size distribution of the cash ratio. First, the cash-to-asset ratio in the data roughly doubled for the median firm, going from 9.1% to 18.3%, which corresponds to a change of 9.2%. The model provides a close match to this trend, generating an increase of 8.7% for the median firm. Second, the cross-sectional difference between the cash ratios of small and large firms almost doubled both in the data and in the model, going from 4.7% to 9.5% and from 4% to 7.4%, respectively.

Table VII

Asset Tangibility and the Increase in Cash Holdings: Quantitative Analysis of the Cross-Sectional and Aggregate Implications

This table reports model-implied and data moments for the quantitative analysis of the increase in cash holding for firms in each decile of the firm size distribution. The data moments in the first and third columns correspond to a sample of nonfinancial, unregulated firms from the annual Compustat, which we complement with information on equity issuance from SDC. The model-implied moments in the second and fourth columns are calculated as averages of simulations of 1,000 firms and 100 time periods. To perform the simulation, we use 1,000 by 100 random draws from the lognormal distribution. The same set of random draws is applied to each economy. The expectation is approximated with 30-point Gauss-Hermite quadrature. The parameter values are as in Table I. Details on model and data variable definitions are in Appendix Table B.

	Average Cash Ratio				Aggreg. Cash Shares			
Size Decile	Data (1975 to 1985)	Model (1975 to 1985)	Data (1995 to 2005)	Model (1995 to 2005)	Data (1975 to 1985)	Model (1975 to 1985)	Data (1995 to 2005)	Model (1995 to 2005)
Small	0.116	0.106	0.181	0.201	0.002	0.000	0.001	0.000
2	0.108	0.103	0.188	0.191	0.004	0.001	0.003	0.000
3	0.103	0.099	0.199	0.183	0.006	0.002	0.007	0.001
4	0.092	0.100	0.199	0.189	0.009	0.005	0.013	0.003
5	0.091	0.099	0.183	0.186	0.013	0.011	0.021	0.008
6	0.088	0.097	0.168	0.184	0.020	0.023	0.031	0.018
7	0.082	0.099	0.150	0.184	0.032	0.049	0.047	0.040
8	0.087	0.093	0.118	0.177	0.056	0.091	0.067	0.083
9	0.075	0.082	0.105	0.156	0.112	0.164	0.139	0.155
Large	0.069	0.066	0.086	0.127	0.746	0.656	0.670	0.691

Change in Cash (Data - Median Firm): 0.092
Change in Cash (Model - Median Firm): 0.087

Change in Cross-Sectional Cash Spread (Data - Small vs. Large): 0.048
Change in Cross-Sectional Cash Spread (Model - Small vs. Large): 0.034

Change in Aggregate Cash Ratio (Data): 0.042
Change in Aggregate Cash Ratio Due Intangible Capital & Top 5% Largest Firms (Counterfactual): 0.033
Change in Aggregate Cash Ratio Due Intangible Capital & Top 10% Largest Firms (Counterfactual): 0.039

Third, the upward trend in the cash ratio was stronger for small firms, with a difference of about 4.8% between the increase in the cash-to-asset ratio of small (bottom decile) versus large (top decile) firms in the data. The model accounts for a large fraction of the cross-sectional difference in the trend, generating a difference of about 3.4% between the trend of firms in the bottom versus top size deciles.

Finally, these results are achieved with the cross-sectional concentration of cash levels staying relatively stable, which is also the case in the data. As a result, our proposed mechanism is strong enough to account for the bulk of the increase in the aggregate, not just average, cash ratio. Specifically, as shown in the last three rows of Table VII, the aggregate cash ratio increased by 4.2% in the data. The increase in the aggregate cash ratio is smaller than the increase in the average ratio because it is driven disproportionately by large firms, which experienced a smaller increase in their cash ratios in the data. To take this important cross-sectional feature of the data into account, we repeat the main quantitative counterfactual with one modification: as in the analysis of the average cash ratio (Table IV), we keep the asset tangibility parameter fixed at its value for the early period, while all other parameters are otherwise allowed to vary as per Table III. The modification is that we now calculate the model-implied increase in the aggregate cash ratio counting in the numerator only the model-implied change in dollar cash of the largest firms, that is, excluding the effect on smaller firms. If the effect in the model were due just to small firms, this counterfactual would predict no increase in the aggregate ratio. Thus, the modified counterfactual provides a lower bound on the aggregate effect by quantifying whether the model-implied increase in cash ratios for large firms is strong enough to account for the overall increase in the aggregate cash ratio. The results show that our mechanism is indeed strong also in the aggregate, with the counterfactual implying an increase in the aggregate cash ratio of at least 3.3% for the case in which only the model-implied increase for the top 5% tail of the firm size distribution is included.

Overall, the second part of the analysis helps buttress our main conclusion that the rise in intangible capital is a quantitatively powerful mechanism by showing that it leads to a realistic size distribution of cash ratios and concentration of cash levels, and it can account for the magnitude of several key changes in the size distribution of cash ratios. In addition, the mechanism can account for a large fraction of the upward trend not only of average, but also of aggregate, cash ratios.

IV. Supporting Evidence

This section offers additional evidence in support of the relation between cash and intangible capital. We start by showing that the positive relation between cash and intangible capital that we describe in the stylized facts also holds in a regression setting, where we can control for other covariates of cash. To that end, we regress cash holdings on our firm-level measure of intangible capital while controlling for a set of standard covariates of cash (e.g., Opler et al. (1999) and Bates, Kahle, and Stulz (2009)). We consider two main specifications, with and without firm fixed effects.[21] The specification that controls for firm fixed effects ascertains whether intangible capital has incremental explanatory power over and above firm fixed effects, which are a well-established covariate of cash and other financial policies (e.g., Lemmon, Roberts, and Zender (2008)). We also examine more saturated specifications that add controls for other covariates of cash that have been proposed more recently in the literature. Finally, while the reduced-form evidence in this section does not rule out alternative interpretations, we explore the relation between cash and patent pledgeability following Mann (2018) to provide corroborating evidence for the collateral mechanism at the core of our model.

The baseline estimates are reported in the top panel of Table VIII for the overall sample (columns (1) and (2)) and for the subset of firms that report positive R&D (columns (3) and (4)).[22] The coefficient on intangible capital is robustly positive and significant across the two samples and both specifications with and without firm fixed effects.[23] In the baseline specification in column (1), one-standard-deviation increase in intangible capital is associated with an 8.5% increase in the cash ratio, which is equal to about half the sample mean cash ratio of 15%. Further supporting the quantitative importance of the relation, the coefficient estimates imply that more than 40% of the predicted increase in cash can be attributed to the rise in intangible capital.[24] Estimates are similar in magnitude for the specification that controls for firm fixed effects, suggesting that intangible capital has explanatory power over and above this previously established covariate of cash, and are larger for firms with R&D, suggesting that the baseline result is not spuriously driven by differential shocks to innovative firms. The lower panels examine external validity of the results by rerunning the baseline specification using either different

[21] All specifications include standard firm-level controls such as industry cash flow volatility, market-to-book ratio, firm size, cash flow, capital expenditures, (cash) acquisition expenditures, a dummy for whether the firm pays dividends in any given year, as well as year effects to control for aggregate factors. The sample for the panel regressions requires nonmissing observations for all controls and includes 150,574 firm-year observations. We evaluate statistical significance using robust clustered standard errors adjusted for nonindependence of observations within firms. See Appendix B for detailed variable definitions.

[22] Columns (3) and (4) address the concern that the main estimates for the overall sample may pick up spurious differential responses to aggregate shocks by innovative versus noninnovative firms.

[23] Table IA.III reports the coefficient estimates for the control variables. Signs and statistical significance of the controls are generally in line with the findings of the previous literature, which include firms with higher and more volatile cash flows and those with higher market-to-book holding more cash. The coefficients on capital expenditures and acquisitions are negative and significant, consistent with firms using their cash holdings to pursue investment opportunities. The coefficient estimates on firm size and dividend payer status are sensitive to the inclusion of firm effects.

[24] This calculation is implemented similar to Bates, Kahle, and Stulz (2009) by taking the point estimates from the regression estimated over the 1970 to 1989 period and multiplying them by the difference in the average value of intangible capital between the estimation (1970 to 1989) and the postestimation (1990 to 2010) period.

Table VIII

Panel Evidence on Intangible Capital and Firm Financing

This table reports estimates from panel regressions of the cash ratio on different measures of intangible capital for panel specifications with industry and firm fixed effects. In Panel A, intangible capital is the baseline IK measure defined as the sum of the stocks of past investments in firms' organizational capabilities and brand equity (organizational capital), technological knowledge (knowledge capital), and software and database development (IT capital) (see Section I for details). Panel B reports results from using only technological knowledge to measure intangibles. Panel C reports results from using only organizational capital to measure intangibles. Panel D reports results from using the Peters and Taylor (2017) measure of intangible capital. Reported coefficients in all panels are the change in the dependent variable associated with a one-standard-deviation change in the corresponding measure of intangible capital. Columns (1) and (2) correspond to the entire sample, while columns (3) and (4) correspond to the subsample of firms with positive R&D. Year dummies as well as firm-level controls for standard determinants of financial policies are included in all regressions (see Table IA.III for the full set of coefficient estimates on firm-level controls with the baseline measure). Firm fixed-effect regressions exclude firms with less than five years of data. p-Values are in parentheses and are clustered at the firm level. Predicted change in cash due to change in intangible capital is obtained by taking the point estimates from the regression estimated over the 1970 to 1989 period and multiplying them by the difference in average value of intangible capital between the estimation (1970 to 1989) and the postestimation 1990 to 2010 period. Detailed variable definitions are in Appendix B.

	Full Sample		R&D>0 Firms	
	(1)	(2)	(3)	(4)
	Baseline IK measure			
Intangible Capital	0.084***	0.083***	0.099***	0.098***
	(0.002)	(0.003)	(0.002)	(0.003)
% Pred rise	42.50%		43.30%	
Pred rise	0.069		0.075	
Observations	150,574	96,136	77,052	53,858
Adjusted R^2	0.333	0.732	0.367	0.754
	Only R&D Capital			
Intangible Capital	0.083***	0.066***	0.103***	0.087***
	(0.002)	(0.003)	(0.002)	(0.003)
Observations	150,574	96,136	77,052	53,858
Adjusted R^2	0.336	0.716	0.388	0.742
	Only Organizational Capital			
Intangible Capital	0.052***	0.077***	0.056***	0.090***
	(0.002)	(0.002)	(0.002)	(0.003)
Observations	150,574	96,136	77,052	53,858
Adjusted R^2	0.265	0.732	0.286	0.753
	Peters and Taylor (2017) measure			
Intangible Capital	0.087***	0.077***	0.107***	0.091***
	(0.002)	(0.003)	(0.002)	(0.003)
Observations	150,574	96,136	77,052	53,858
Adjusted R^2	0.329	0.727	0.372	0.748
Firm Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No
Firm FE	No	Yes	No	Yes

subcomponents of our intangible capital measure or alternative measures that have been used in the literature, in turn. Either set of validity checks leaves our baseline estimates little changed. In addition, the estimates are stable to excluding IT capital or using principal component analysis to extract a common latent intangible factor, which aggregates the three subcomponents, as an alternative to taking their sum (see Table IA.IV). They also remain strongly statistically and economically significant when we use alternative measures of intangible capital, including the measure of Peters and Taylor (2017) (Panel D of Table VIII) and an industry-level measure based on the BEA data of DellAriccia et al. (2021) (Table IA.IV). This reduced-form empirical evidence indicates that intangible capital is an important attribute of cash-holding firms, thus reinforcing the main conclusion from the quantitative analysis.[25]

Next, we offer further reassurance that the relation between cash and intangible capital is not due to the omission of covariates that have been previously established in the literature. The concern is that our baseline controls do not include other important covariates of cash that have been proposed in the recent literature (see Graham and Leary (2018) for a comprehensive overview). If these covariates of cash are also correlated with intangible capital, their exclusion may lead us to find a spurious correlation in the baseline. To that end, Table IX examines a more saturated specification that adds controls for the following covariates of cash in turn: industry competition (Morellec, Nikolov, and Zucchi (2014)), corporate taxes that may lead multinationals to hold on to their profits abroad by holding cash (Faulkender, Hankins, and Petersen (2019)), the risk-free interest rate that determines the opportunity cost of money and, hence, of holding cash (Azar, Kagy, and Schmalz (2016)), selection due to young R&D-intensive entrants (Begenau and Palazzo (2021)), employee equity compensation that may be used to substitute for debt by intangible capital-intensive firms (Sun and Xiaolan (2019)), and the rise in corporate profits (Chen, Karabarbounis, and Neiman (2017)). The coefficient estimates on each of the additional controls are generally significant and the signs are in line with the previous literature, confirming that these alternative forces do indeed matter for cash. For example, as shown in columns (3) and (4), firms that face a higher repatriation tax penalty hold more cash, and the same holds for firms with higher corporate profits relative to value-added (columns (9) and (10)). However, the coefficient estimate on intangible capital remains

[25] The relation between cash and intangible capital is also robust to three additional batteries of specification tests, which comprise alternative parametric assumptions to construct the intangible capital stock variable (Table IA.IV), alternative definitions of the cash ratio, weighting observations by firm size (Table IA.V), an alternative definition of the market-to-book control to address potential measurement error issues with Tobin's Q (Table IA.V), alternative samples, and inclusion of additional controls to address potential omitted variables concerns related to changes in the industrial composition of the United States (Table IA.VI and row 4 of Table IA.V). In Table IA.IX, we also explore empirically the relation between intangible capital and equity issuance. See Appendix D for a detailed summary of these additional results, as well as of additional empirical analyses of the mechanism.

Table IX
Panel Evidence on Alternative Channels

The table reports parameter estimates from panel regressions of the cash ratio on intangible capital and a set of determinants (X) that have been previously shown to impact the cash ratio. Columns (1) and (2) show results from controlling for industry competition as proxied by the Herfindahl-Hirschman index of firm sales within three-digit Standard Industrial Classification (SIC) industries. Columns (3) and (4) show results from controlling for the implied repatriation tax penalty as constructed in Foley et al. (2007). Columns (5) and (6) show results from controlling for deferred employee pay, measured as the ratio of broad-based option compensation plans to total assets. Columns (7) and (8) show results from controlling for the cost of carry as in Azar, Kagy, and Schmalz (2016). Columns (9) and (10) show results from controlling for higher profit share of the corporate sector in the aggregate economy, as proxied by the inverse of the corporate labor share. Columns (11) and (12) show results from adding a control for firm age. Reported coefficients are the change in the dependent variable associated with a one-standard-deviation change in the explanatory variable. Other firm-level controls are as in Table IA.III. In addition, regressions in columns (3) and (4) control for the foreign income ratio as in Foley et al. (2007). Regressions in columns (1) to (6), (11), and (12) include year fixed effects, while those in columns (7) to (10) include controls for the time trend up to third order, as in Azar, Kagy, and Schmalz (2016). Firm fixed-effect regressions exclude firms with less than five years of data. p-Values are in parentheses and are clustered at the firm level. The predicted change in cash due to change in each determinant X is obtained by taking the point estimates from the regression estimated over the 1970 to 1989 period and multiplying them by the difference in average value of the variable between the estimation (1970 to 1989) and the postestimation 1990 to 2010 period. Variable definitions are in Appendix B.

	X Controls for											
	Industry Competition		Multinationals		Broad-Based Equity Comp		Cost of Carry		Decline in Labor Share		Firm Age	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Intangible Capital	0.088***	0.089***	0.094***	0.096***	0.066***	0.083***	0.088***	0.089***	0.088***	0.089***	0.092***	0.089***
	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)	(0.004)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)

(*Continued*)

Table IX—*Continued*

	X Controls for											
	Industry Competition		Multinationals		Broad-Based Equity Comp		Cost of Carry		Decline in Labor Share		Firm Age	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
X=HHI	−0.008***	0.001										
	(0.001)	(0.001)										
X=Foreign taxes			0.004***	0.001								
			(0.001)	(0.001)								
X=Stock Options					−0.001	−0.002**						
					(0.001)	(0.001)						
X=Cost of Carry							−0.003***	−0.006***				
							(0.001)	(0.001)				
X=Labor Share									−0.006***	−0.005***		
									(0.001)	(0.001)		
X=Firm Age											−0.027***	−0.009***
											(0.001)	(0.003)
% Pred rise due to X	1.2%		0.5%		−0.7%		11.2%		2.1%		−1.4%	
Observations	150,574	95,741	67,628	49,218	72,514	47,076	150,574	95,741	144,108	92,306	131,102	95,741
Adjusted R^2	0.334	0.733	0.353	0.777	0.226	0.700	0.331	0.731	0.329	0.733	0.364	0.733
Firm Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Firm FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

remarkably stable across specifications with these controls, suggesting that omitted variables are unlikely to be driving the result.

In Appendix Table IA.VI, we further address potential confounds from selection by young entrants by showing that the cross-sectional relation between cash and intangible capital is robust to adding controls for IPO cohorts and excluding young entrants from the sample (see Appendix D for details). A recent literature (Begenau and Palazzo (2021) and Graham and Leary (2018)) examines whether the increase in cash is due to the extensive margin (i.e., changes in the composition of public firms) versus the intensive margin (i.e., changes in the cash holdings of existing firms). Our model is agnostic about this question because the main implication that the rise in intangible capital should be accompanied by an increase in cash holds regardless of whether the rise in intangible capital is due to a change in the composition of public firms toward more intangible capital-intensive firms or an increase in the reliance on intangible capital by existing firms. That said, selection raises two interesting empirical questions. First, is the relation robust to controlling for other characteristics of initial public offering (IPO) firms that may also be associated with higher cash? Second, what is the relative contribution of the extensive versus intensive margins to the relation between cash and intangible capital? While beyond the scope of this paper, in Table IA.VII, we offer some perspective on these questions based on the reduced-form cross-sectional approach of this section. Specifically, we rerun the baseline cross-sectional regression with additional controls for cash at IPO and intangible capital at IPO, in turn, an approach that is similar to Lemmon, Roberts, and Zender (2008).[26] The estimates in columns (2) and (6) indicate that there is a positive relation between cash and cash at IPO, in line with the findings of previous literature. However, even after controlling for cash at IPO, the relation between cash and intangible capital remains strongly statistically and economically significant, suggesting that the relation between cash and intangible capital is unlikely to be due to other factors associated with selection. Finally, the estimates from the specification that adds intangible capital at IPO show that there is a positive relation between this variable and cash (columns (4) and (6) of Table IA.VII), suggesting that both the extensive and intensive margins contribute to the cross-sectional relation between intangible capital and cash.

Finally, we provide supporting evidence for the collateral mechanism at the core of our model by exploring the relation between cash and patent usage as collateral. Mann (2018) shows that pledging patents as collateral to raise debt financing has become more common among patenting firms since the 2000s and that firms raise more debt after court decisions that strengthen creditor rights to patents in bankruptcy. We build on this work to examine two questions. First, does the use of patents as collateral reduce cash holdings? Second, do state laws that increase the collateral value of patents also lead to a reduction in cash holdings? As predicted by our model, both effects would be in

[26] To mitigate multicollinearity issues, in this specification, we exclude the IPO year from the intangible capital variable and include only post-IPO year values.

Table X

Additional Panel Evidence on Patent Pledgeability

The table reports parameter estimates from panel regressions of the cash ratio on intangible capital and controls for the ability of a firm to pledge patents as collateral. Panel A shows results from including a firm's number of pledged patents as control. Panel B shows results from a difference-in-differences specification around the 2002 passage of the ABSFA law in Delaware as in Mann (2018), where we allow the effect of the law to vary by firms' intangible capital ratio. Reported coefficients are the change in the cash ratio associated with a one-standard-deviation change in the explanatory variable. Firm fixed-effect regressions in Panel A exclude firms with less than five years of data. The sample in Panel A spans the entire sample period (1970 to 2010), while that in Panel B is limited to eight years before and after the year of ABSFA passage. Columns (1) and (2) correspond to the entire sample, while columns (3) and (4) correspond to the subsample of firms with positive R&D. Year dummies as well as firm-level controls for standard determinants of financial policies are included in all regressions and are omitted for brevity. p-Values are in parentheses and are clustered at the firm level. Variable definitions are in Appendix B.

	Full Sample		R&D Firms Only	
	(1)	(2)	(3)	(4)
Panel A: Controlling for Pledged Patents				
Intangible Capital	0.089***	0.089***	0.092***	0.094***
	(0.002)	(0.003)	(0.002)	(0.003)
Pledged patents	−0.061***	−0.016***	−0.079***	−0.022***
	(0.004)	(0.003)	(0.005)	(0.004)
Observations	150,574	95,741	77,052	53,645
Adjusted R^2	0.334	0.733	0.369	0.754
Firm Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	No
Firm FE	No	Yes	No	Yes
Panel B: Difference-in-Differences Analysis				
Intangible Capital	0.085***	0.087***	0.093***	0.094***
	(0.003)	(0.003)	(0.003)	(0.003)
Treated	−0.007	−0.001	−0.017***	−0.013*
	(0.005)	(0.005)	(0.006)	(0.007)
Intangible Capital*Treated		−0.006**		−0.003
		(0.003)		(0.003)
Observations	62,217	62,217	35,778	35,778
Adjusted R^2	0.771	0.771	0.780	0.780
Firm Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

response to an increase in debt capacity, stemming from an increase in the pledgeability of patents. The results are summarized in Table X. In Panel A, we replicate the cross-sectional analysis of Mann (2018) for cash by adding his main measure of a firm's reliance on patents as collateral—the number of pledged patents—to our baseline specification. The coefficient estimate on pledged patents is negative and significant, which is in line with our prediction. In Panel B, we replicate his difference-in-differences (DD) analysis by adding a dummy that equals one for firms incorporated in Delaware after the 2002 passage of the Asset-Backed Securities Facilitation Act (ABSFA) that strengthened creditor rights with respect to patents in bankruptcy, thus increasing their collateral value.[27] The coefficient estimate on the treatment dummy is also negative and statistically significant for R&D firms, further supporting the link between cash and collateral at the core of our model. The coefficient estimate on our intangible capital measure remains stable relative to the baseline across these tests, indicating that the recent opening up of the market for collateralizing patents has not reduced the importance of the "core" intangible assets that are included in our measure, such as knowledge from R&D and organizational capital from SGA, which remain mostly uncollateralizable.

While we caution that the reduced-form empirical analysis in this section does not rule out alternative mechanisms, the magnitude of the estimates in Table X indicates that the collateral mechanism is economically significant. For example, the estimates in column (1) of Panel A imply that one-standard-deviation increase in pledged patents is associated with a decrease in the cash ratio of about 6%, which is equal to approximately 40% of the sample mean cash ratio of 15% and about two-thirds of the estimate on intangible capital. As for the DD estimates, they imply that the treatment effect leads to a decrease in the cash ratio of about 2% to 3%, depending on the intensity of the treatment (columns (1) and (3) of Panel B and columns (2) and (5) of Table IA.8, respectively),[28] which corresponds to about 10% to 20% of the sample mean of the cash ratio and about 20% to one-third of the estimate on intangible capital. In sum, these results indicate that the collateral mechanism is economically significant.

Overall, the cross-sectional evidence indicates that intangible capital is an economically important covariate of cash holdings, thus helping build confidence in the main takeaway of our model analysis.

V. Conclusion

There is a strong link between the rise in intangible capital and the increase in cash holdings of U.S. corporations over the last four decades. We use a model with two productive assets, tangible and intangible capital, to highlight this point. The economic mechanism at the heart of our results is shrinking debt capacity that arises from the imperfect pledgeability of intangible capital.

[27] Internet Appendix Figure IA.7 shows diagnostics for the DD analysis and indicates that there are no significant differential preevent trends between Delaware and non-Delaware firms. Note that the DD estimates correspond to the later part of the sample period.

[28] Note that the intensity of the treatment depends on whether firms have patents, because the Delaware law increased the pledgeability of patents. In line with this reasoning, the intensity of the treatment is higher for R&D-active firms (columns (3) and (4) of Table X and for firms with active patent applications pretreatment (Table IA.VIII).

Using a calibration approach to quantify the strength of the mechanism, we estimate that the rise in intangible capital can account for about three-quarters of the upward trend in average cash ratios as well as for a variety of important quantitative features of the evolution of cash ratios in the cross-section and in the aggregate. We conclude that intangible capital helps make progress on providing a satisfactory analytic account of the evolution of the cash holdings of U.S. corporations, which has proved challenging to date.

There are several caveats and avenues along which our approach can be extended. On the empirical side, we take a step in the direction of constructing a firm-level measure of intangible capital, but clearly more can be done to measure assets that anecdotally are well known to matter for the modern public corporation but are not routinely reported by firms on their balance sheets, including brand, customer loyalty, and other reputational assets. In addition, the inputs that go into the construction of our intangible capital measure are readily available at the firm level for a wide cross-section of countries. Extending the analysis to an international setting could help shed light on whether differences in the pace of technological progress across countries can account for differences in the secular evolution of their corporate balance sheets, which would be interesting given the growing evidence that cross-country differences in financial policies are large and do not seem to be easily explained by standard country characteristics. Finally, the reduced-form nature of our empirics helps corroborate the relation between cash and intangible capital but does not rule out alternative mechanisms. While beyond the scope of this paper, providing more direct causal evidence would help better size up the importance of the collateral mechanism and constitutes a fruitful venue for future research. Relatedly, more work is needed to gauge the relative contribution of the extensive versus intensive margins to the rise in intangible capital, which would be a valuable contribution to the recent literature on selection in corporate finance (Graham and Leary (2018), Begenau and Palazzo (2021)).

A second set of extensions pertains to the model. While we keep the setup simple by design to allow for a disciplined calibration, it would be interesting to enrich our framework to allow for more heterogeneity across firms due, say, to different types of corporate taxes, including subsidies to investment and R&D, or to a richer structure of adjustment costs, which would likely further enhance the model's cross-sectional fit and shed light on additional dimensions of heterogeneity in the evolution of cash, either across sectors or across firm characteristics beyond size. Relatedly, another interesting dimension along which our framework could be extended is to incorporate rents and make contact with the recent literature on increasing firm heterogeneity (see Van Reenen (2018) for an overview). Our results on the increase in the cross-sectional differences between the cash ratios of small and large firms are broadly in line with this literature, which generally finds evidence of increasing differences among firms in terms of their sales, productivity, and wages. Another recent literature explores the interaction between intangible capital and rents on firm value (Crouzet and Eberly (2019)), which raises the intriguing possibility that there may be interaction effects between intangible capital and rents on firm financing.

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Appendix A: Efficiency Conditions of the Model

A. Payout / Issuance Policy

The necessary condition for equity issuance is given by the first-order condition

$$1 + \lambda = 1 + \varphi'(e) = 1 + \varphi_1 > 1. \tag{A1}$$

This condition states that the firm issues new shares to finance its expenditures *only if* its value of internal funds exceeds one. It also implies that the firm's shadow value of internal funds is bounded above by $1 + \varphi_1$ as it faces unlimited supply of external funds at the marginal price φ_1. However, a direct consequence of the presence of fixed costs of equity finance is that the converse of this proposition is not true: $1 + \lambda > 1$ does not establish the optimality of $\nu^E = 1$. In other words, even when the firm's shadow value of internal funds exceeds one, it may still be optimal to delay issuance if the marginal improvement of the value of $w(k_T, k_N, b|\nu^E = 1)$ is not enough to justify it. The sufficient condition for equity finance is given by $w(k_T, k_N, b|\nu^E = 1) - w(k_T, k_N, b|\nu^E = 0) \geq 0$. In other words, the equity value must be improved sufficiently enough to compensate for the forgone fixed cost of issuance.

B. Cash / Debt Policy

To state the efficiency for net debt position ($b' = B'/Z$), we define *financial Q* as

$$q^F(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}') \equiv -\frac{1}{1+r} \int w_b \left(\frac{\tilde{k}'_T}{\eta'}, \frac{\tilde{k}'_N}{\eta'}, \frac{\tilde{b}'}{\eta'} \right) dH(\eta'). \tag{A2}$$

Financial Q measures the cost of issuing one more unit of debt (or equivalently, reducing one more unit of liquid assets). The efficiency condition for $\tilde{b}'$ requires the cost to be equated with the marginal benefit of additional cash inflow from debt issuance, which should be measured by the shadow value of internal funds, $1 + \lambda$. However, this marginal benefit should be adjusted by the shadow cost of reducing the financial slack, μ, and hence, the efficiency condition is given by

$$1 + \lambda - \mu = q^F(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}'). \tag{A3}$$

When the firm does not issue debt and holds a strictly positive amount of cash, in which case the borrowing constraint becomes a slack ($\mu = 0$), this condition becomes identical to that of Bolton, Chen, and Wang (2011). In fact, $q^F(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}')$ is what they call the marginal value of cash. Our framework generalizes their notion of the value of liquidity by allowing for debt issuance. Note that when the firm accumulates cash, the left and right sides of (A3) interchange their roles: the left side measures the marginal cost of setting aside extra liquidity today for tomorrow's use and the right side measures the future benefit of a marginal unit of liquid asset tomorrow.

The Benveniste-Scheinkman formula implies $w_B(k_T, k_N, b|\nu) = -(1+\lambda)[1 + r(1-\tau)]$ regardless of ν. Hence, $w_B(k_T, k_N, b) = -(1+\lambda)[1 + r(1-\tau)]$. We can then express the first-order condition as

$$1 + \lambda - \mu = \frac{1 + r(1-\tau)}{1+r} \int (1+\lambda') dH(\eta') \quad \text{if } \tilde{b}' \geq 0 \tag{A4}$$

and

$$1 + \lambda = \frac{1 + r(1-\tau) - \kappa}{1+r} \int (1+\lambda') dH(\eta') \quad \text{if } \tilde{b}' < 0, \tag{A5}$$

where we use the fact that the collateral constraint is slack, that is, $\mu = 0$ when $\tilde{b}' < 0$.

Consider (A4) first. Suppose that the firm issues new shares today. In this case, $1 + \lambda = 1 + \varphi_1$. Since $1 + \lambda' \leq 1 + \varphi_1$, $1 + \lambda > \int (1+\lambda') dH(\eta')$. Furthermore, $[1 + r(1-\tau)]/[1+r] < 1$. Hence, it must be the case that the collateral constraint binds, $\mu > 0$, to satisfy (A4). This means that the firm never issues shares before using up its borrowing capacity.[29]

Now consider (A5). Again suppose that the firm issues new shares today. Since $1 + \lambda = 1 + \varphi_1 > \int (1+\lambda') dH(\eta')$ under this assumption and $[1 + r(1-\tau)]/[1+r] < 1$, condition (A5) cannot be satisfied. This means that the firm never simultaneously issues shares and accumulates liquid assets.

Finally, suppose that the firm does not issue new shares. Due to the presence of fixed costs of equity issuance, this case does not necessarily imply that $\lambda = 0$. Suppose, however, that the firm's liquidity conditions are indeed good enough that $\lambda = 0$, and thus, the left-hand side of (A5) is equal to one. This means that the firm pays out a strictly positive amount of dividends to shareholders.

C. Investment Policy

To derive the efficiency conditions for tangible and intangible capital accumulation, we follow the approach of Abel and Eberly (1994), who characterize these conditions in a neoclassical setting with one type of real asset, namely, tangible capital, and without financial frictions. We extend their analysis by incorporating the choice between two capital inputs that are different

[29] This argument does not depend on the differential tax treatment of debt.

in their ability to back financial claims under frictional capital market conditions.[30]

We first derive the efficiency condition for tangible investment, we then follow an analogous approach to derive its counterpart for intangible investment. As in Abel and Eberly (1994), we proceed as if $\nu_T^K = 1$ were optimal and derive the efficiency condition that would be optimal under this assumption. To that end, we first define the marginal value of capital i as[31]

$$q^{K_i}(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}') \equiv \frac{1}{1+r} \int w_{K_i}\left(\frac{\tilde{k}'_T}{\eta'}, \frac{\tilde{k}'_N}{\eta'}, \frac{\tilde{b}'}{\eta'}\right) dH(\eta',) \quad \text{for } i = N, T, \tag{A6}$$

where w_{K_i} denotes the first derivative of w with respect to $\tilde{k}'_i/\eta'$. Without nonconvex adjustment frictions, the efficiency condition would simply require the marginal benefit of investment given by (A6) to be equal to the marginal cost of investment.

The marginal cost is given by the derivative of the adjustment cost (4) with respect to $\tilde{k}'_i$ evaluated at the internal pricing term, that is, at the shadow value of internal funds $1 + \lambda$. Hence, the marginal cost can be expressed as $g_{i,1}(\tilde{k}'_i, k_i)(1 + \lambda)$. The marginal benefits consist of two elements: the shadow value of capital measured by the marginal Tobin's $q^{K_i}(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}')$, and the marginal effect of the increase in capital stock i on the debt capacity $\bar{b}(\tilde{k}'_T)$. This additional benefit has to be evaluated at the shadow value of the collateral constraint and subtracted from the marginal cost. Thus,

$$q^{K_i}(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}') = (1 + \lambda) g_{i,1}(\tilde{k}'_i, k_i) - \mu \bar{b}(\tilde{k}'_T),$$

and the optimality condition requires that $\tilde{k}'_T$ satisfy

$$q^{K_i}(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}') = (1 + \lambda) - \mu \frac{1 - \delta_i}{1 + r}. \tag{A7}$$

A limiting case of (A7) is as follows. In the case with no financial frictions, that is, when $\lambda = \mu = 0$ for all time, (A7) is simplified to

$$q^{K_i}(\tilde{k}'_T, \tilde{k}'_N, \tilde{b}') = 1, \tag{A8}$$

which implies that the firm should increase its investment until the marginal value of tangible capital falls to the level of its purchase price, which is normalized to one.

If there were no nonconvex adjustment costs, this would be the necessary and sufficient condition for optimality. However, in the presence of nonconvex

[30] See also Gilchrist, Sim, and Zakrajsek (2014) for a setting with both real and financial frictions, but without intangible capital and with unsecured rather than secured debt. More importantly, Gilchrist, Sim, and Zakrajsek (2014) do not allow for corporate cash holdings.

[31] While $W_{k_T}(\boldsymbol{K}', B', Z')$ is discontinuous due to the nonconvex adjustment costs, its integrated value $Q_T^K(\boldsymbol{K}', B', Z)$ is nonetheless well defined since the discontinuity occurs finite times.

adjustment costs, (A7) is only a necessary condition for optimality. In other words, *given that the action is optimal*, investment has to satisfy (A7). However, the converse is not necessarily true. The sufficient condition for the optimality of action requires

$$w(k_T, k_N, b|\nu_i^K = 1, \nu_j^K, \nu^E) - w(k_T, k_N, b|\nu_i^K = 0, \nu_j^K, \nu^E) \geq 0. \qquad \text{(A9)}$$

This last condition creates an inaction region since it requires a large enough gain from (dis)investment to warrant action.

The comparison of (A7) and (A8) shows how financial frictions affect real investment decisions. First, and most importantly, (A7) differs from the neoclassical efficiency condition in that the equity market friction elevates the marginal cost of investment by a factor $1 + \lambda$. In this sense, today's liquidity problem, which is manifested by the shadow value of internal funds being strictly greater than one, raises the required return on equity. Second, because of the occasionally binding collateral constraint, investing in tangible capital benefits the firm not only by increasing future profits, but also by expanding its debt capacity, a benefit that is measured by the effective shadow value term μ. This implies that tangible capital commands a liquidity premium. Conversely, more reliance on intangible technology implies that the firm has to compensate for the loss of liquidity service by holding more liquid financial assets.

Appendix B: Detailed Variable Definitions

The variables used in the analysis are defined as follows:

- Cash ratio is the ratio of cash and marketable securities (data item #1) to 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 PP&E is cash and marketable securities (#1) divided by property, plant, and equipment (#8).
- 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. The standard deviation of cash flow to book assets is computed for each firm-year using data over the previous 10 years. We then average these cash flow standard deviations over 2-SIC 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 the Consumer Price Index [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 leverage is the ratio of long-term debt (#9) plus debt in current liabilities (#34) less cash (#1) to book assets (#6).
- R&D (flow) is the ratio of R&D expenditures (#46) to book assets (#6).
- 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.
- Net equity issuance is sale of common and preferred stock (#108) minus purchase of common and preferred stock (#115) divided by book assets (#6). To exclude equity issuances, we set a cutoff equal 1% and 5% of assets for equity issuance.
- Industry competition is defined as the Herfindhahl-Hirshmann index of sales of all firms in a given (3-SIC) industry-year. Firm sales are obtained using sales from Compustat (#12).
- Implied repatriation tax penalty follows Foley et al. (2007) and is defined as the maximum between zero and foreign pretax income (#273) times the marginal tax rate minus foreign taxes paid (#64).
- Foreign income is defined as the ratio of foreign pretax income (#273) to book assets (#6).
- Broad-based equity compensation is defined as the ratio of reserved shares to market value of equity (#199*#25), where reserved shares are defined as follows: for pre-1983 years, we use common shares reserved for conversion total (#100) less preferred stocks and convertible debt (#39); for the 1984 to 1995 period, we use common shares reserved for stock options conversion (#215).
- Cost of carry is based on Azar, Kagy, and Schmalz (2016) and is defined as three-month Treasuries times the share of interest bearing to noninterest-bearing (currency and checking account) assets in liquid asset portfolios of the nonfinancial corporate sector. Data on Treasuries are downloaded from St Louis FRED and data on the nonfinancial corporate sector's composition of assets are from the Flow of Funds.
- Labor share is defined as corporate labor share from NIPA (downloaded from the country level data set of Karabarbounis and Neiman (2013)).
- Firm age is defined as the number of years since the firm went public (first entry on CRSP).
- WW-Index is based on Whited and Wu (2006) and is defined 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 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, Ofek, and Swary (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 the 4-SIC level, and constructed using hand-collected U.S. Census Bureau data. Since these data are available only once every five years and not for more recent years, we compute a time-invariant index by averaging the available quinquennial indices at the 4-SIC level. This measure is available only for a restricted sample of manufacturing firms.
- Investment inaction, small investments, and investment spikes are defined at the firm level based on Cooper and Haltiwanger (2006) as those firm-year observations corresponding to $|\text{Capex/book assets}| < 0.1$, $|\text{Capex/book assets}| \geq 0.01$, and $|\text{Capex/book assets}| > 0.2$, respectively. Industry is 4-SIC. In each industry-year, we compute the frequency as number of observations involving investment inaction (small investment) to the total number of observations in the industry. This procedure results in a time-invariant cross-sectional ranking of 4-SIC industries.
- Time-series skewness and kurtosis of annual aggregate industry investment are based on Caballero (1999) and calculated as the skewness and kurtosis of average annual Capex (#128) to book assets (#6) in each (4-SIC) industry. For each year, we calculate annual averages in each industry as the industry-year mean of individual firm-year Capex to book assets. This procedure results in a time-invariant cross-sectional ranking of 4-SIC industries.
- Time-series standard deviation of aggregate industry operating costs is calculated after aggregating firm-level operating costs by taking annual means at the 4-SIC industry level. For each industry, the measure is the standard deviation of these annual industry means of operating costs. Operating costs are costs of goods sold (#41). This measure gives a time-invariant cross-sectional ranking of 4-SIC industries.

Appendix C: Issues with Measuring Intangible Capital

Under current accounting rules (worldwide), intangibles done in house are expensed (hence reported R&D expenditures, advertising expenditures, SG&A, etc.), not booked as assets. For this reason, intangible assets are generally absent from firms' balance sheet, with the exception of the (fair value of) intangible assets that are acquired via mergers and acquisitions (M&As), which can be booked as assets and are included in the "Intangibles" (item #33) in Compustat. This variable also includes goodwill and the excess cost or premium of acquisition, items that have been extensively shown in the literature to be largely unrelated to the economic definition of acquired intangible assets but rather are closely related to overpayment in mergers. Due to these issues, we choose not to include this variable in our measure of intangible capital. In this appendix, we offer additional details on these measurement issues.

The main measurement concern with the “Intangibles” variable in Compustat is that it includes items that are unrelated to the economic definition of intangible capital. In particular, Compustat’s “Intangibles” (item #33) includes the following:

- excess of cost or premium of acquisitions,
- goodwill (the difference between the actual price paid in a merger transaction and the accounting fair value of the total assets of the target company), and
- (fair value of) intangible assets acquired in a merger (such as the patents, copyrights, etc.) of the target company.

Due to the inclusion of goodwill, the item picks up overpayment in M&As. In fact, extensive evidence in the accounting literature shows that goodwill does not really capture assets, but rather liabilities for mergers involving overpayment. Ideally, one would address this issue by subtracting goodwill and any other merger overpayment-related items from the intangibles variable. Unfortunately, it is not possible to correct for the issue prior to 2000, since accounting rules did not require firms to disclose goodwill and other M&A-related intangibles separately prior to that year (for the specific M&A accounting rules, see Financial Accounting Standards Board (FASB)’s promulgation of Statements of Financial Accounting Standards (SFAS) #141 (Business Combinations, 2001) and #142 (Goodwill and Other Intangible Assets, 2001)). Around the tech merger wave, controversy ensued about goodwill accounting in M&As. As a result, there was a change in the accounting rules in 2000. In particular, starting in 2000 there is an “Intangibles - Other” variable in Compustat (item #352) that is net of goodwill, but it still includes “excess of cost or premium of acquisitions,” so it is still subject to the issue of overpayment in M&A transactions.

Based on these considerations, since item #33 from Compustat also includes goodwill and excess cost or premium of acquisitions, items that are unrelated to the economic definition of acquired intangible assets but rather capture overpayment in mergers, we do not include this variable in our baseline measure of intangible capital used in the main analysis.

Appendix D: Additional Stylized Facts, Robustness Checks, and Analysis of the Mechanism

Stylized Facts: Internet Appendix Figure IA.5 shows that sectors in which intangible capital rose the most are also those in which cash increased the most. Panel (A) plots the distribution of average industry cash by decade for broad Fama-French 12-industry categories sorted based on their respective sector-average intangible capital ratio in the 2000s. Clearly, the increase in cash was more dramatic in industries that became heavily reliant on intangible capital by the 2000s (e.g., by a factor of almost 40, from 0.13 to 5.07, in Healthcare), relative to those that did not shift to intangible capital as much, such as retail (Shops). Even more directly, Panel (B) shows that the top-six

Fama-French 48-sectors in which intangible capital rose the most over the last two decades were exactly the same top-six sectors in which cash rose the most. Panel (C) shows that the finding that cash ratios also rise in nonhigh-tech sectors is not an artifact of classifying the "Business Services" sector as nonhigh-tech: when we separate out "Business Services" from the nonhigh-tech sectors, the remaining nonhigh-tech sectors show almost a doubling of the cash ratios over our sample period. Finally, Appendix Figure IA.6 shows that there also is a strong positive relation between cash and intangible capital within-firm over time. We sort firms on the horizontal axis based on deciles of the distribution of annual changes in intangible capital and, for each decile bin, plot the corresponding average annual change in cash on the vertical axis. Firms that experienced a decline in intangible capital also saw their cash ratios decline, while those for which intangible capital rose the most were those that experienced the largest increase in cash. In line with the evidence from the regressions showing that the relation between cash and intangible capital is robust to controlling for firm fixed effects, the slope of the relation between cash and intangible capital is roughly comparable between Figures IA.4 and IA.6, at about 0.24 (=ΔCash(10-1)/ΔIK(10-1)=0.12/0.5) in Figure IA.6 versus 0.17 (=ΔCash(10-1)/ΔIK(10-1)=0.5/3) in Figure IA.4.

Additional Robustness Checks: The relation between cash and intangible capital is robust to three batteries of tests, in which we use alternative parametric assumptions to construct the intangible capital stock variable (Table IA.IV), alternative definitions of the cash ratio and the market-to-book control to address potential measurement error issues with Tobin's Q (Table IA.V), alternative samples and additional controls to address potential omitted variables concerns related to changes in the industrial composition of the United States (Table IA.VI and row (4) of Table IA.V).[32] The estimates are little changed when we vary the depreciation rate parameters for knowledge and organizational capital or the weight that is applied to SG&A expenditures to construct the stock of organizational capital (rows (1) to (3) and (4) to (5) of Table IA.IV, respectively), and remain large and significant for different definitions of the cash ratio and Tobin's Q adjusted for measurement error as per the approach of Erickson and Whited (2012) (rows (1) to (2) and (3) of Table IA.V, respectively). The estimates also remain quite stable in subsamples that exclude newly IPO'ed firms ("entrants" —Table IA.VI, rows (4) and (5)) or high-tech sectors (Table IA.V, row (4)), or in specifications that add controls for firm profitability (Table IA.V, row (5)), as well as firm age and IPO cohort (Table IA.VI, rows (1) to (3)), suggesting that entrants or high-tech firms are not driving our result. In line with recent evidence in Begenau and Palazzo (2021), age and IPO cohort controls are also significant. This evidence indicates that while entrants or high-tech firms may have also contributed to the rise in cash, they are not driving our result. As such, selection and rising intangible

[32] In all of the tests, we take the two full specifications, with and without firm fixed effects, as our starting point and report results for both the full sample (columns (1) and (2)) and the subset of firms that report positive R&D (columns (3) and (4)).

capital are distinct and complementary mechanisms. Table IA.IX reports results on the relation between intangible capital and equity issuance. The evidence indicates that, consistent with our model and with what had been previously conjectured in the literature, there is a positive relation that is stronger among R&D firms.

Additional Analysis of Mechanism: We use sample-split analysis to further examine whether the data support the main mechanism of the model. If firms with more intangible capital hold more cash because of financing frictions, the relation between intangible and cash should be stronger among firms for which external financing frictions are more severe. Table IA.X reports evidence supporting this unique prediction of the model. We follow the standard approach in the literature (e.g., Hennessy and Whited (2007)) and in each year over the sample period, we rank firms based on five ex-ante indicators of their financial constraint status: firm size, dividend payer status, the WW-Index of Whited and Wu (2006), a measure of asset liquidity that comes from Berger, Ofek, and Swary (1996), and an index of industry asset redeployability proposed by Balasubramanian and Sivadasan (2009). We assign to the financially constrained (unconstrained) groups those firms in the bottom (top) quartile of the annual distribution of each of these measures in turn, except for the financial constraints index, for which the ordering is reversed. Consistently across specifications and irrespective of which indicator of ex-ante financing status we employ, we find that the economic significance of the coefficient on intangible capital is stronger in the subsamples of firms that are more likely to face financial frictions. For example, the coefficient in column (1) more than triples when we go from the top to the bottom quartile of the size distribution (rows (1) and (2)). Further supporting our debt capacity mechanism, Appendix Table IA.IX shows that there is a positive relation between intangible capital and equity issuance, which is in line with the premise of our model that intangible capital leads firms to move away from debt to finance their growth opportunities.

Table IA.XI repeats the analysis for investment frictions. The basic insight of the vast literature on real options (e.g., Abel and Eberly (1994), Bertola and Caballero (1994)) is that fixed adjustment costs lead firms to make large, lumpy investments. Thus, if intangible capital makes it more difficult to raise external finance, real frictions may lead firms with more intangible capital to accumulate even more cash to finance large investments. We split the sample between bottom and top quartiles of five proxies for investment frictions: 4-SIC industry frequency of investment inaction and an indicator for whether there are investment spikes in the industry, both defined following Cooper and Haltiwanger (2006); the skewness and kurtosis of annual aggregate industry investment, both based on Caballero (1999); and the standard deviation of aggregate industry operating costs. The intuition underling these proxies is that, due to technological differences, the extent to which firms face fixed costs varies across industries. Thus, industries in which fixed costs are higher are those in which 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. We assign to the high (low) investment-friction groups those firms in the top (bottom) quartile of the distribution of each of these measures in turn, except for the variability of operating costs, for which the ordering is reversed. For all specifications and indicators chosen, the coefficient on intangible capital is larger in the subsamples of firms that are more likely to face investment frictions. Overall, the data support the unique economic mechanism at the heart of our model.

REFERENCES

Abel, Andrew B., and Janice C. Eberly, 1994, A unified model of investment under uncertainty, *American Economic Review* 84, 1369–1384.

Almeida, Heitor, Murillo Campello, and Michael S. Weisbach, 2004, The cash flow sensitivity of cash, *Journal of Finance* 59, 1777–1804.

Altinkilic, Oya, and Robert Hansen, 2000, Are there economies of scale in underwriting fees?, Evidence of rising external financing costs, *Review of Financial Studies* 13, 191–218.

Andrei, Daniel, Nathalie Moyen, and William Mann, 2019, Why did the Q theory of investment start working?, *Journal of Financial Economics* 133, 251–272.

Armenter, Roc, and Viktoria Hnatkovska, 2017, Taxes and capital structure: Understanding firms' savings, *Journal of Monetary Economics* 87, 13–33.

Azar, José A., Jean-Francois Kagy, and Martin C. Schmalz, 2016, Can changes in the cost of carry explain the dynamics of corporate "cash" holdings?, *Review of Financial Studies* 29, 2194–2240.

Balasubramanian, Natarajan, and Jagadeesh Sivadasan, 2009, Capital resalability, productivity dispersion, and market structure, *Review of Economics and Statistics* 91, 547–557.

Bates, Thomas W., Ching-Hung Chang, and Jianxin Daniel Chi, 2018, Why has the value of cash increased over time?, *Journal of Financial and Quantitative Analysis* 53, 749–787.

Bates, Thomas W., Kathleen M. Kahle, and René Stulz, 2009, Why do U.S. firms hold so much more cash than they used to?, *Journal of Finance* 64, 1985–2021.

Begenau, Juliane, and Berardino Palazzo, 2021, Firm selection and corporate cash holdings, *Journal of Financial Economics* 139, 697–718.

Berger, Philip G., Eli Ofek, and Itzhak Swary, 1996, Investor valuation of the abandonment option, *Journal of Financial Economics* 42, 257–287.

Bertola, Guiseppe, and Ricardo J. Caballero, 1994, Irreversibility and aggregate investment, *Review of Economic Studies* 61, 223–246.

Bloom, Nicholas, 2009, The impact of uncertainty shocks, *Econometrica* 77, 623–685.

Bolton, Patrick, Hui Chen, and Neng Wang, 2011, A unified theory of Tobin's Q, corporate investment, financing, and risk management, *Journal of Finance* 66, 1545–1578.

Bolton, Patrick, Hui Chen, and Neng Wang, 2013, Market timing, investment, and risk management, *Journal of Financial Economics* 109, 40–62.

Caballero, Ricardo J., 1999, Aggregate investment, in J. B. Taylor, and M. Woodford, eds., Handbook of Macroeconomics, volume 1 (Elsevier, Amsterdam).

Caballero, Ricardo J., and Eduardo M. R. A. Engel, 1999, Explaining investment dynamics in U.S. manufacturing: A generalized (S,s) approach, *Econometrica* 67, 783–826.

Chen, Peter, Loukas Karabarbounis, and Brent Neiman, 2017, The global rise of corporate saving, *Journal of Monetary Economics* 89, 1–19.

Cooper, Russell W., and John C. Haltiwanger, 2006, On the nature of capital adjustment costs, *Review of Economic Studies* 73, 611–633.

Corrado, Carol, Charles Hulten, and Daniel Sichel, 2009, Intangible capital and U.S. economic growth, *Review of Income and Wealth* 55, 661–685.

Corrado, Carol A., and Charles R. Hulten, 2010, How do you measure a "technological revolution"?, *American Economic Review* 100, 99–104.

Crouzet, Nicolas, and Janice C. Eberly, 2019, Understanding weak capital investment: The role of market concentration and intangibles, NBER Working paper 25869, National Bureau of Economic Research.

DeAngelo, Harry, Linda DeAngelo, and Toni M. Whited, 2011, Capital structure dynamics and transitory debt, *Journal of Financial Economics* 99, 235–261.

DellAriccia, Giovanni, Dalida Kadyrzhanova, Lev Ratnovski, and Camelia Minoiu, 2021, Bank lending in the knowledge economy, *Review of Financial Studies* 34, 5036–5076.

Denis, David J., and Valeriy Sibilkov, 2009, Financial constraints, investment, and the value of cash holdings, *Review of Financial Studies* 23, 247–269.

Dittmar, Amy, and Jan Mahrt-Smith, 2007, Corporate governance and the value of cash holdings, *Journal of Financial Economics* 83, 599–634.

Eisfeldt, Andrea L., and Tyler Muir, 2016, Aggregate external financing and savings waves, *Journal of Monetary Economics* 84, 116–133.

Eisfeldt, Andrea L., and Dimitris Papanikolaou, 2013, Organization capital and the cross-section of expected returns, *Journal of Finance* 68, 1365–1406.

Erickson, Timothy, and Toni M. Whited, 2012, Treating measurement error in Tobin's Q, *Review of Financial Studies* 25, 1286–1329.

Faulkender, Michael W., Kristine W. Hankins, and Mitchell A. Petersen, 2019, Understanding the rise in corporate cash: Precautionary savings or foreign taxes, *Review of Financial Studies* 32, 3299–3334.

Fritz Foley, C., Jay C. Hartzell, Sheridan Titman, and Garry Twite, 2007, Why do firms hold so much cash? A tax-based explanation, *Journal of Financial Economics* 86, 579–607.

Froot, Kenneth A., David S. Scharfstein, and Jeremy C. Stein, 1993, Risk management: Coordinating corporate investment and financing policies, *Journal of Finance* 48, 1629–1658.

Gamba, Andrea, and Alexander Triantis, 2008, The value of financial flexibility, *Journal of Finance* 63, 2263–2296.

Gao, Xiaodan, Toni M. Whited, and Na Zhang, 2021, Corporate money demand, *Review of Financial Studies* 34, 1834–1866.

Gilchrist, Simon, Jae Sim, and Egon Zakrajsek, 2014, Uncertainty, financial frictions, and investment dynamics, NBER Working paper 20038, National Bureau of Economic Research.

Gomes, Armando, and Gordon Phillips, 2012, Why do public firms issue private and public securities?, *Journal of Financial Intermediation* 21, 619–658.

Gomes, Joao F., 2001, Financing investment, *American Economic Review* 91, 1263–1285.

Graham, John R., and Mark T. Leary, 2018, The evolution of corporate cash, *Review of Financial Studies* 31, 4288–4344.

Hall, Bronwyn H., 2005, Measuring the returns to R&D: The depreciation problem, *Annals of Economics and Statistics* 79–80, 341–381.

Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg, 2000, Market value and patent citations: A first look, NBER Working paper 7741, National Bureau of Economic Research.

Hall, Robert E., 2001, The stock market and capital accumulation, *American Economic Review* 91, 1185–1202.

Hart, Oliver, and John Moore, 1994, A theory of debt based on the inalienability of human capital, *Quarterly Journal of Economics* 109, 841–879.

Hennessy, Christopher A., and Toni M. Whited, 2005, Debt dynamics, *Journal of Finance* 60, 1129–1165.

Hennessy, Christopher A., and Toni M. Whited, 2007, How costly is external financing? Evidence from a structural estimation, *Journal of Finance* 62, 1705–1745.

Hugonnier, Julien, Semyon Malamud, and Erwan Morellec, 2013, Capital supply uncertainty, cash holdings, and investment, Swiss Finance Institute Research Paper Series 11-44.

Jovanovic, Boyan, and Peter L. Rousseau, 2005, General purpose technologies, in Philippe Aghion and Steven Durlauf, eds., Handbook of Economic Growth, volume 1 (Elsevier, Amsterdam).

Karabarbounis, Loukas, and Brent Neiman, 2013, The global decline of the labor share, *Quarterly Journal of Economics* 129, 61–103.

Kiyotaki, Nobuhiro, and John Moore, 1997, Credit cycles, *Journal of Political Economy* 105, 211–248.

Lemmon, Michael L., Michael R. Roberts, and Jaime F. Zender, 2008, Back to the beginning: Persistence and the cross-section of corporate capital structure, *Journal of Finance* 63, 1575–1608.
Lev, Baruch, 2001, Intangibles: Management, Measurement, and Reporting (Brookings Institution Press, Washington, DC).
Lev, Baruch, and Suresh Radhakrishnan, 2005, The valuation of organization capital, in Carol Corrado, John Haltiwanger, and Dan Sichel, eds., Measuring Capital in the New Economy (University of Chicago Press, Chicago).
Li, Shaojin, Toni M. Whited, and Yufeng Wu, 2016, Collateral, taxes, and leverage, *Review of Financial Studies* 29, 1453–1500.
Loughran, Tim, and Jay Ritter, 2004, Why has IPO underpricing changed over time?, *Financial Management* 33, 5–37.
Mann, William, 2018, Creditor rights and innovation: Evidence from patent collateral, *Journal of Financial Economics* 130, 25–47.
McGrattan, Ellen R., and Edward C. Prescott, 2010, Technology capital and the U.S. current account, Technical Report 4.
Morellec, Erwan, Boris Nikolov, and Francesca Zucchi, 2014, Competition, cash holdings, and financing decisions, Swiss Finance Institute Research Paper Series 13-72.
Myers, Stewart C., and Nicholas S. Majluf, 1984, Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics* 13, 187–221.
Nikolov, Boris, Lukas Schmid, and Roberto Steri, 2019, Dynamic corporate liquidity, *Journal of Financial Economics* 132, 76–102.
Nikolov, Boris, and Toni M. Whited, 2014, Agency conflicts and cash: Estimates from a dynamic model, *Journal of Finance* 69, 1883–1921.
Opler, Tim, Lee Pinkowitz, Rene Stulz, and Rohan Williamson, 1999, The determinants and implications of corporate cash holdings, *Journal of Financial Economics* 52, 3–46.
Peters, Ryan H., and Lucian A. Taylor, 2017, Intangible capital and the investment-Q relation, *Journal of Financial Economics* 123, 251–272.
Rampini, Adriano A., and S. Viswanathan, 2010, Collateral, risk management, and the distribution of debt capacity, *Journal of Finance* 65, 2293–2322.
Rampini, Adriano A., and S. Viswanathan, 2013, Collateral and capital structure, *Journal of Financial Economics* 109, 466–492.
Riddick, Leigh A., and Toni M. Whited, 2009, The corporate propensity to save, *Journal of Finance* 64, 1729–1766.
Shleifer, Andrei, and Robert W. Vishny, 1992, Liquidation values and debt capacity: A market equilibrium approach, *Journal of Finance* 47, 1343–1366.
Sibilkov, Valeriy, 2009, Asset liquidity and capital structure, *Journal of Financial and Quantitative Analysis* 44, 1173–1196.
Sun, Qi, and Mindy Z. Xiaolan, 2019, Financing intangible capital, *Journal of Financial Economics* 133, 564–588.
Van Reenen, John, 2018, Increasing differences between firms: Market power and the macroeconomy, Discussion paper, Centre for Economic Performance, LSE.
Warusawitharana, Missaka, and Toni M. Whited, 2015, Equity market misvaluation, financing, and investment, *Review of Financial Studies* 29, 603–654.
Whited, Toni M., and Guojun Wu, 2006, Financial constraints risk, *Review of Financial Studies* 19, 531–559.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.
Replication code.