Fragile New Economy: Intangible Capital, Corporate Savings Glut, and Financial Instability

By Ye Li*

The transition towards an intangible-intensive economy reshapes financial system by creating a self-perpetuating savings glut in the production sector. As intangibles become increasingly important, firms hoard liquidity to finance investment in intangibles of limited pledgeability. Firms' savings feed cheap leverage to financial intermediaries and allow intermediaries to bid up asset prices, which in turn encourages firms to save more for asset creation. This paper develops a macro-finance model that offers a coherent account of the rising corporate savings, debt-fueled growth of intermediaries, declining interest rates, and rising asset valuation. Along these secular trends, endogenous financial risk accumulates.
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I. Introduction

The development of financial markets and institutions has profound impact on industrial structure (Rajan and Zingales, 1998). Is the reverse true? Can the evolution of industrial structure shape the financial system? In this paper, I examine the transition towards an intangible-intensive economy. In the U.S., investment in intangibles has overtaken physical investment as the largest source of economic growth (Corrado and Hulten, 2010). By incorporating a defining feature of intangibles—limited pledgeability—in a dynamic model of macroeconomy with financial markets and intermediaries, I show that the rise of intangibles contributes to several secular trends in the U.S. economy, such as the accumulation of corporate savings, the downward trend in interest rates, the growth of financial intermediation sector, and the rising valuation in asset markets. Importantly, by

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connecting these secular trends through the rise of intangibles, my model reveals a mechanism of endogenous risk that makes the new economy financially fragile.

U.S. nonfinancial corporations have accumulated a substantial amount of cash (Bates, Kahle, and Stulz, 2009; Chen, Karabarbounis, and Neiman, 2017; Gao, Whited, and Zhang, 2020) and turned from a net borrower to a net saver (Quadrini, 2017). The connection between intangibles and corporate savings is intuitive: To finance investment in intangibles of limited pledgeability, firms cannot rely on external financing and must hold internal funds (Pinkowitz, Stulz, and Williamson, 2015; Falato, Kadyrzhanovaz, Sim, and Steri, 2018; Begenau and Palazzo, 2021).

The first innovation of this paper is to connect firms' intangible-driven demand for liquid assets to the secular decline in interest rates. Some have suggested a link between the demand for liquid assets and low interest rates (Del Negro, Giannone, Giannoni, and Tambalotti, 2017). The focus has been on foreign savings (Caballero, Farhi, and Gourinchas, 2008; Caballero and Krishnamurthy, 2009; Gourinchas and Rey, 2016). Domestic corporate savings, which are comparable in magnitude, received little attention in the literature on low interest rates.[1]

The second innovation and a distinguishing feature of my model is a general equilibrium analysis of liquid assets. What firms hold as cash are mainly deposits and other debt instruments issued by financial intermediaries. In the decades leading up to the Great Recession, debt issuance fueled growth of the intermediation sector (Adrian and Shin, 2010; Greenwood and Scharfstein, 2013; Pozsar, 2014). Taking advantage of the low interest rate, intermediaries are able to lever up cheaply and drive up the prices of collateral assets that can back debt issuance.

In the model, these trends arise in response to an exogenous increase in intangible investment needs. To finance intangibles, firms hold savings in the form of intermediaries' debts. Intermediaries' debts are in turn backed by claims on firms' tangible capital. As firms' savings push down the interest rate, intermediaries can borrow cheaply and bid up the value of tangible capital. Tangible capital can be pledged for external financing, so a higher value of tangible capital allows firms to lever up savings for larger and more profitable investments. As a result, firms are more eager to save and the interest rate declines more, encouraging intermediaries to borrow more and to further bid up the value of tangible capital. A self-perpetuating savings glut pushes down the interest rate and pushes up the asset (tangible capital) price, allowing intermediaries to grow in the process.

This feedback mechanism also generates endogenous risk. Unlike intermediaries that play the roles as suppliers of liquid assets and hold tangible capital to back their debts, households have higher funding costs and are only willing to pay a lower price for tangible capital. As tangible capital value increases and firms accumulate savings in booms, the interest rate on liquid assets goes down, giving intermediaries an increasingly large advantage in funding cost. The longer booms

[1] The ratio of nonfinancial firms' liquidity holdings to foreigners' holdings has been stable since the 1990s, around 75%. Liquid assets include currency and deposits, open market papers, and repurchase agreements held directly or indirectly via mutual funds (source: Financial Accounts of the U.S.).

last, the wider the funding-cost wedge is between intermediaries and households. When negative shocks hit and intermediaries deleverage, the reallocation of tangible capital from intermediaries to households causes a collapse of the market value of tangible capital, which discourages firms from saving for investment and exacerbates intermediaries' deleveraging. This channel, based on investment-driven demand for liquid assets, differs from the standard balance sheet channel. It offers a new explanation on why severe crises follow prolonged booms.[2]

In the model, firms' investment is financially constrained and internal funds are necessary due to the intangible component that has limited pledgeability. The tangible component makes available external financing and a leverage on internal funds, but its endogenous market value triggers feedback effects. Importantly, when the value of tangible capital increases, firms increase savings. I provide evidence on this feature of corporate savings. In contrast, households' holdings of liquid assets decline when asset prices rise. This paper highlights the importance of firms' liquidity demand for understanding asset prices, interest rates, and financial stability. The macro-finance literature focused on households' demand for liquid assets (Kiyotaki and Moore, 2000; Stein, 2012; Moreira and Savov, 2017; Krishnamurthy and Vissing-Jørgensen, 2015; Piazzesi and Schneider, 2016; Van den Heuvel, 2018; Begenau, 2019; Begenau and Landvoigt, 2018).

Next, I provide an overview of the model and more details on the mechanism and results. The continuous-time economy has entrepreneurs, bankers, and households. Their roles are discussed sequentially. A unit mass of infinitely-lived entrepreneurs manage tangible and intangible capital to produce non-durable generic goods. Capital represents efficiency units and its output is normalized to one unit of goods per unit of time. Capital depreciates stochastically, loading on an aggregate Brownian shock. A negative shock reduces capital stocks that represent the production capacity in the economy. In spite of these common features, tangible and intangible capital differ in liquidity.

As in Holmström and Tirole (1998), entrepreneurs face liquidity shocks. Idiosyncratic Poisson shocks entail a restart of business – a firm's existing capital is destroyed, but it may create new capital. The entrepreneur chooses the amount of goods to invest (scale) and the intangible share of investment (composition). To finance the investment, the entrepreneur can sell the ownership of tangible capital at the market price and commit to dutifully managing the capital on behalf of buyers, delivering goods it produces. In other words, tangible capital is liquid (tradable and pledgeable). In contrast, intangible capital is not tradable or pledgeable, representing technological, human, and organizational capital that are inalienable or difficult for creditors to repossess.

The illiquidity of intangible capital tightens the funding constraint on investment. Investing in tangible capital relaxes the constraint, but intangible invest-

[2]Studies on endogenous risk accumulation focus on intermediaries as lenders rather than issuers of liquid assets (Jordà, Schularick, and Taylor, 2013; Gorton and Ordoñez, 2014; Krishnamurthy and Muir, 2016; Baron and Xiong, 2017; López-Salido, Stein, and Zakrajšek, 2017; Gorton and Ordoñez, 2020).

ment can be sufficiently productive such that entrepreneurs optimally choose a positive intangible share. Importantly, the productivity of intangible investment increases over time. This captures technological changes. And, as capital is essentially a stream of future consumption units, the fact that intangible investment creates increasingly more capital (production units) also captures the shift of consumers' preference towards output generated by intangibles. For example, the share of expenditure on services has been growing in the U.S., and intangibles are the key factor input in the sector (McGrattan, 2020).[3]

The funding constraint implies that entrepreneurs want to hold liquidity and finance investment with a combination of internal funds and external funds (raised against tangible capital). One solution of liquidity provision, in the spirit of Holmström and Tirole (1998), is to pool all entrepreneurs' tangible capital—the source of capitalizable output—into a mutual fund whose shares are distributed back to entrepreneurs. The fund diversifies away the idiosyncratic Poisson shocks, so when the shock hits an individual entrepreneur, her fund shares are still valuable and can be used to finance investment, even though her own capital is destroyed.

However, such diversification services require expertise. In reality, firms mainly hold money-market instruments issued by financial intermediaries in their portfolios of "cash and cash equivalents". A unit mass of infinitely-lived bankers are introduced to intermediate the supply of liquidity.

Bankers buy tangible capital with their own wealth (equity) and by issuing short-term safe debts ("deposits") that entrepreneurs hold as liquidity buffers. Bankers create value not as lenders (their typical roles in macro-finance models) but instead as the issuers of liquid assets. The model highlights bankers' role in addressing asset shortages (Caballero, 2006; Caballero, Farhi, and Gourinchas, 2017b). Entrepreneurs assign a liquidity premium to deposits, which is equal to the marginal value of liquidity due to the Poisson-arriving investment needs (Holmström and Tirole, 2001). This liquidity premium lowers the deposit rate, encouraging bankers to expand their balance sheets. However, acquiring tangible capital and issuing safe deposits involve risk-taking, so bankers' capacity to intermediate the liquidity supply depends on their wealth as the risk buffer.

Finally, households are introduced, competing with entrepreneurs to hold deposits. Following the literature, households' demand is from deposit-in-utility, motivated by the roles of deposits as means of payment. Households can also own tangible capital, but relative to bankers, they cannot earn the liquidity premium by issuing deposits so they face a higher funding cost and thereby require a higher expected return for holding tangible capital.

The exogenous process of intangible investment productivity and other param-

[3]Two channels have been proposed to explain the growing demand of services. First, income growth, under non-homothetic preferences, makes the services sector grow faster than the rest of the economy (Kongsamut, Rebelo, and Xie, 2001; Herrendorf, Rogerson, and Ákos Valentinyi, 2013). Second, productivity growth is biased. Labor-intensive sectors benefit less from technological progress, so the relative prices of their output increase over time relative to other products, forcing an increasingly large share of consumer expenditure (Baumol, 1967; Ngai and Pissarides, 2007).

eters of entrepreneurs' investment technology are calibrated to match the trends and cyclical fluctuations of intangible investment and tangible investment. The arrival rate of the Poisson shock is calibrated to generate a positive response of entrepreneurs' liquidity holdings to intangible investment needs that matches the empirical estimate. The model features both firms' and households' liquidity demand, and one of the main contributions is to evaluate their relative importance in driving interest rates, asset prices, and endogenous financial risk through counterfactual analysis. Therefore, it is important to generate realistic dynamics of both firms' (i.e., entrepreneurs') and households' liquidity holdings in the baseline model. For this purpose, an exogenous trend is introduced in households' deposit-in-utility, and it is calibrated so that the magnitude of households' liquidity holdings, especially relative to those of entrepreneurs', matches data. The calibration exercise targets the evolution of quantity variables, such as investment and liquidity holdings. For price variables, such as the interest (deposit) rate and tangible capital value, the calibration exercise only targets the values at the beginning of the sample period and leaves the trends to endogenous forces.

In response to the exogenous increase in intangible investment productivity, the model generates upward trends in the intangible share of investment, entrepreneurs' liquidity holdings (and bankers' debt issuances), and tangible capital value and a downward trend in the deposit rate. To address the rising needs for intangible investment, entrepreneurs hold more deposits and push down the deposit rate, feeding bankers with cheap funding and allowing them to bid up the market value of tangible capital. A higher value of tangible capital allows entrepreneurs to lever up their liquidity holdings to larger and more profitable investment. Therefore, entrepreneurs' incentive to save is strengthened, and the deposit rate declines further. The self-enforcing mechanism successfully replicates these secular trends except that for the interest rate, it delivers a stronger downward trend into the negative territory likely due to the lack of nominal frictions and zero lower bound. Note that the feedback effects can be so strong that equilibrium multiplicity arises, in which case, the equilibrium with intangible share of investment closest to data is selected. The multiplicity is interesting by itself as it offers a potential explanation for why the rise of intangibles and the associated secular trends are more prominent in the U.S. than the rest of the world.

The feedback mechanism also amplify economic fluctuations along the trends. Endogenous financial risk accumulates after positive shocks and materializes into a downward spiral when negative shocks hit. Consider a positive shock to capital stocks. Given bankers' levered positions in tangible capital, their wealth increases significantly. The liquidity premium on deposits makes bankers' marginal costs of financing (and discount rates) lower than households'. Therefore, when bankers—the natural buyers of tangible capital—become richer, their demand drives up the market value of tangible capital, which in turn leads to a higher leverage on entrepreneurs' deposits and higher investment profits. So, entrepreneurs save more, driving down the deposit rate and bankers' discount rate, further widening the discount-rate gap between bankers and households. This makes the value of tangible capital increasingly sensitive to negative shocks that trigger reallocation of tangible capital away from the natural buyers (bankers) to households and back to entrepreneurs. Asset price volatility affects the real economy. The value of tangible capital falls significantly after negative shocks, reducing entrepreneurs' leverage on deposit holdings and their investments. By reducing bankers' wealth, the decline of tangible capital value also causes bankers to shrink balance sheets, so entrepreneurs hold fewer deposits and their investments decline further.

I construct counterfactual scenarios to highlight the quantitative importance of the rise of intangibles. In the first scenario, the trend in intangible investment productivity is muted, so parameters governing entrepreneurs' liquidity demand are fixed in the 1980s while households' liquidity demand exhibited an upward trend. In the second scenario, the trend in households' liquidity demand is shut down while the upward trend in intangible investment productivity is preserved. For interest rate and asset price (i.e., tangible capital value), these two scenarios generate weaker trends than the main model with upward trends in both entrepreneurs and households' liquidity demand.

However, when it comes to endogenous risk, the scenario with an upward trend in intangible investment productivity but no trend in households' liquidity demand dominates the main model. The reason is that entrepreneurs' incentive to save comoves with asset price (tangible capital value) as a higher tangible capital value allows entrepreneurs to lever up their savings for larger and more profitable investments. I provide evidence on such dynamics. In contrast, households' liquidity demand exhibits countercyclicality in both the model and data. In the main model, households' liquidity demand counterbalances entrepreneurs' liquidity demand, moderating the fluctuations of aggregate demand for bank deposits. Without the upward trend in households' liquidity demand, the procyclicality of entrepreneurs' savings is fully unleashed, so the hypothetical scenario where only the rise of intangibles is present features the strongest shock amplification mechanism. Therefore, despite being less than 14% of households' liquidity holdings (both in the model and data), firms' liquidity holdings, driven by the rising needs for intangible investments, have a much stronger impact on financial stability.

As the economy becomes more intangible-intensive, the pledgeability of intangible assets improves (Mann, 2018) and new markets emerge for the exchange of intangibles (Akcigit, Celik, and Greenwood, 2016) I extend the model by allowing a fraction of intangibles to be pledgeable or sellable. Note that as long as intangibles are not fully pledgeable, investment still cannot fully rely on external financing and liquidity holdings are necessary. What improved pledgeability does is to increase the leverage on liquidity holdings, which leads to a higher marginal benefit of holding liquidity. Therefore, the feedback mechanism is amplified. The trend in intangible-investment productivity triggers an increasing and convex trend in the intangible share of investment, in contrast to the linear trend in the intangible share of investment in the baseline model. As a result, entrepreneurs' savings increase more over time, resulting in a much lower deposit rate, higher tangible capital value, and a higher level of endogenous financial risk.

Literature. This paper contributes to the broad literature on the macroeconomics of intangible capital.[4] The focus is on the limited pledgeability of intangible capital and firms' savings for intangible investment, motivated by evidence on the concentration of massive cash holdings in intangible-intensive firms.[5] The increase of intangible investment productivity is a driving force behind the accumulation of corporate savings that is distinct from what has been proposed in the literature on corporate savings in macroeconomic dynamics (Bacchetta and Benhima, 2015; Chen, Karabarbounis, and Neiman, 2017; Quadrini, 2017).

A unique feature of the model is that liquid assets are supplied endogenously by financial intermediaries.[6] Corporate savings have become a major cash pool that lends to financial intermediaries (Adrian and Shin, 2010; Pozsar, 2011; Carlson et al., 2016). However, the existing studies on corporate savings and the shortage of saving instruments have ignored the unique roles of financial intermediaries as issuers of liquid assets (Woodford, 1990; Holmström and Tirole, 1998, 2001; Giglio and Severo, 2012; Farhi and Tirole, 2011; Martin and Ventura, 2012; Hirano and Yanagawa, 2017; Miao and Wang, 2018). The broader literature on asset shortage also studies foreign savings as sources of demand for liquid assets, but when it comes to the supply of liquid assets, the active roles of financial intermediaries are absent (Bernanke, 2005; Caballero and Krishnamurthy, 2006; Caballero, Farhi, and Gourinchas, 2008; Caballero and Krishnamurthy, 2009; Gourinchas and Rey, 2016; Maggiori, 2017; Bolton, Santos, and Scheinkman, 2018).[7]

Connecting firms' demand for liquid assets and financial intermediaries' supply delivers several unique predictions. The downward trend in interest rates has drawn enormous attention and has been studied jointly with other secular trends (Caballero, Farhi, and Gourinchas, 2017a; Eggertsson, Robbins, and Wold, 2018; Farhi and Gourio, 2018; Marx, Mojon, and Velde, 2018; Corhay, Kung, and

[4]Previous studies has shown that the rise of intangible capital is important for explaining the secular trends in corporate profits and investment (McGrattan and Prescott, 2010b; Crouzet and Eberly, 2018; Gutiérrez and Philippon, 2017; Peters and Taylor, 2017). Dell'Ariccia, Kadyrzhanova, Minoiu, and Ratnovski (2018) and Döttling and Perotti (2017) emphasize the decline of firms' borrowings from banks as a result of less collateral assets. In contrast, this paper focuses on the liability side of banks' balance sheets, i.e., firms holding banks' liabilities as liquidity buffer. Previous studies also explores broad implications of intangible capital on productivity (Atkeson and Kehoe, 2005; McGrattan, 2020), current account (McGrattan and Prescott, 2010a), stock valuation (Hansen, Heaton, and Li, 2005; Ai, Croce, and Li, 2013; Eisfeldt and Papanikolaou, 2013), and investment (Daniel, Naveen, and Yu, 2018).

[5]See the related findings on corporate cash holdings (Pinkowitz, Stulz, and Williamson, 2015; Graham and Leary, 2018; Falato, Kadyrzhanovaz, Sim, and Steri, 2018; Begenau and Palazzo, 2021).

[6]The literature of firms' liquidity management problem takes a partial equilibrium approach and assume a perfectly elastic supply of storage technology, leaving out the question of who issues the securities called "cash and cash equivalents" (e.g., Froot, Scharfstein, and Stein, 1993; Riddick and Whited, 2009; Bolton, Chen, and Wang, 2011; Décamps, Mariotti, Rochet, and Villeneuve, 2011; He and Kondor, 2016).

[7]U.S. nonfinancial corporations' holdings of intermediary debts are comparable in magnitude to foreigners' holdings. The ratio of the former to the later is stable since the 1990s, around 75%. Liquid intermediary debts include currency and deposits, open market papers, and repurchase agreements held directly or indirectly via money-market or mutual funds (Financial Accounts of the United States, 2019).

Schmid, 2019). This paper proposes corporate savings as a driving force behind the declining interest rate and demonstrates the quantitative importance of this channel. The low interest rate allows financial intermediaries to borrow cheaply and creates a discount-rate wedge between financial intermediaries and the rest of the economy, which has a destabilizing effect on the financial system: When negative shocks trigger reallocation of assets from intermediaries to the rest of the economy, asset prices collapse. Moreover, the longer a boom lasts, the wider the discount-rate wedge is and thus sharper the asset prices fall when negative shocks hit.[8] The previous literature on financial accelerators focuses on firms' borrowing rather than firms' savings as a source of financial instability (Kiyotaki and Moore, 1997; Bernanke, Gertler, and Gilchrist, 1999).

Recent studies in the macro-finance literature highlight the value of bank liabilities in incomplete markets (Brunnermeier and Sannikov, 2016) and as liquid assets for households (Kiyotaki and Moore, 2000; Krishnamurthy and Vissing-Jørgensen, 2015; Piazzesi and Schneider, 2016; Moreira and Savov, 2017; Begenau and Landvoigt, 2018; Van den Heuvel, 2018; Begenau, 2019; Egan, Lewellen, and Sunderam, 2021).[9] This paper is the first to model both households' and firms' liquidity demand, and the model is calibrated so their relative contributions to intermediaries' funding match data. This allows for a counterfactual analysis to show the relative importance of firms' liquidity demand in affecting interest rates, asset prices, and financial instability.[10] Section 2 and 4 provide evidence on the distinct responses of households' and firms' liquidity demand to asset-price variations that are consistent with the model's predictions.[11]

II. Corporate Liquidity Demand

This section establishes a robust empirical link between intangible investment and firms' holdings of liquid assets. The intangible-liquidity link is stronger when the value of tangible capital (i.e., capitalizable or pledgeable value of future output) increases. The sample is Compustat firm-year observations from 1980 to 2019 (CRSP, 2019).[12] Firms' liquidity holdings are given by cash and cash equivalents. Intangible intensity is measured by the ratio of intangible investment to

[8]This procyclical discount-rate wedge is distinct from the constant cash-flow wedge between intermediaries and households in Brunnermeier and Sannikov (2014) due to differences in production skills.

[9]See also the banking literature (Diamond and Dybvig, 1983; Gorton and Pennacchi, 1990; Goldstein and Pauzner, 2005; Dang, Gorton, Holmström, and Ordoñez, 2017; Hart and Zingales, 2014).

[10]Related, Eisfeldt (2007) show that the liquidity premium of Treasury bills cannot be explained by the liquidity demand from consumption smoothing under standard preferences. Eisfeldt and Rampini (2009) document that corporate liquidity needs are correlated with measures of liquidity premium.

[11]Except Eisfeldt and Muir (2016), the empirical literature on firms' cash holdings focuses on trends not cycles. A new finding in this paper is the comovement between corporate savings and asset prices.

[12]This includes Compustat firm-year observations with non-missing data for total assets and sales. All firms incorporated in the United States are included except financials (SIC 6000-6999) and utilities (SIC 4900-4999). The sample starts from 1980 because, before the 1980s, Regulation Q imposed various restrictions on deposit rates. For example, it prohibited banks from paying interest on demand deposits. This practice is inconsistent with the model specification that the deposit rate, r_t, is the price variable that clears the deposit market. Appendix C provides summary statistics.

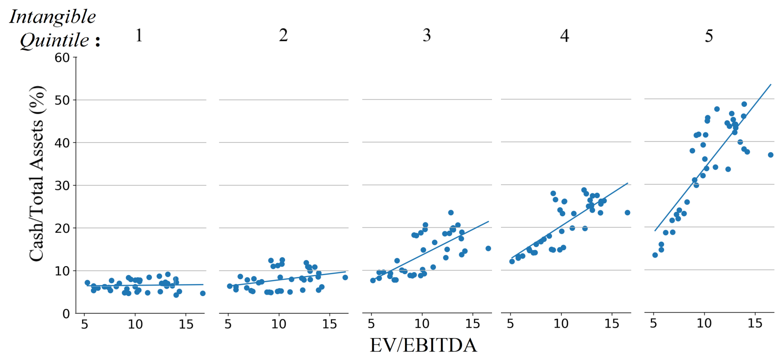

Figure 1. : Capital Valuation and Cash Holdings by Intangible Quintile

total assets averaged over time within firm. Firms are sorted into quintiles to form the ranking variable "Intan./Assets". Following the literature, intangible investment includes R&D and organizational-capital investment that is 30% of SG&A expenses.[13] Two aggregate measures of tangible capital valuations are constructed. Each year, I calculate the market capitalization-weighted average ratio of enterprise value (EV) to earnings before interest, tax, depreciation, and amortization (EBITDA). The data is from WRDS (2019). EV is the present value of a firm's *capitalizable* output, i.e., the value of tangible capital in the model.[14]

Figure 1 reports scatter charts of cash/assets against capital valuation (and regression lines) for Intan./Assets quintiles. A point is given by the quintile's market capitalization-weighted average cash/assets in a year and average EV/EBITDA in that year. More intangible firms hold more cash with a stronger correlation between cash and capital valuation. Appendix D reports similar patterns with tangible EV/EBITDA and Tobin's Q as measures of capital valuation. Tangible EV/EBITDA is the average EV/EBITDA in the lowest Intan./Assets quintile.[15]

Table 1 reports regression results that correspond to the patterns in Figure 1. The explanatory variables of interest, capital valuation and the quintile ranking variable Intan./Assets, are the same as in Figure 1. Different from Figure 1 that plots the time-series variation of within-quintile average cash/assets, the regression dependent variable, cash/assets, has both time-series and cross-section variation. I consider different specifications controlling for firm characteristics and/or time fixed effects.[16] Column (1) to (4) in Panel A shows that more

[13]This follows a large literature on measuring intangible investment (Corrado et al., 2009; Eisfeldt and Papanikolaou, 2013; Falato et al., 2018; Peters and Taylor, 2017; Belo et al., 2014).

[14]Appendix D uses more restrictive Tangible EV/EBITDA from the lowest quintile of Intan./Assets.

[15]Two versions of Tobin's Q are calculated, the total average Tobin's Q and tangible Tobin's Q that is the average Q of firms in the lowest Intan./Assets quintile. Averages are market capitalization-weighted.

[16]The control variables are selected and winsorzied following Opler et al. (1999) and Bates et al. (2009). They include (Compustat codes in parenthesis): acquisition activity (aqc/at), capex (capx/at), cash flow ([oibdp – xint – dvc – txt]/at), net working capital ([wcap – che]/at), payout dummy (equal to 1 if dvc is positive), leverage ([dlc – dltt]/at), market to book ratio ([at + prcc_f*csho – ceq]/at), R&D to sales

Table 1—: Intangible Investment, Capital Valuation, and Cash Holdings

***Panel A**: Intangibility & Corporate Cash Holdings*

$\frac{\text{Cash}}{\text{Assets}}$	Intangibility = Intan./Assets (quintile)				Intangibility = Intan./Investment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intangibility	6.600***	6.493***	5.277***	5.009***	0.207***	0.196***	0.186***	0.170***
	(0.440)	(0.455)	(0.320)	(0.335)	(0.015)	(0.016)	(0.010)	(0.010)
Controls	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	152,826	152,826	132,632	132,632	112,171	112,171	98,571	98,571
Adjusted R^2	0.1669	0.1903	0.2588	0.2757	0.0964	0.1185	0.2467	0.2585

***Panel B**: Capital Valuation & Intangible-Driven Corporate Cash Holdings*

$\frac{\text{Cash}}{\text{Assets}}$	Valuation = Ave. EV/EBITDA				Valuation = Tangible EV/EBITDA			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intan./Assets	-2.427**	-2.742**	-1.484	-1.846*	-1.039	-1.511	-0.277	-0.813
	(1.199)	(1.134)	(1.012)	(0.943)	(1.438)	(1.449)	(1.207)	(1.216)
Valuation	-0.731***		-0.590***		-0.789***		-0.738***	
	(0.097)		(0.066)		(0.131)		(0.082)	
Intan./Assets×	0.849***	0.881***	0.638***	0.661***	0.833***	0.884***	0.612***	0.649***
Valuation	(0.121)	(0.116)	(0.098)	(0.94)	(0.153)	(0.157)	(0.127)	(0.131)
Controls	No	No	Yes	Yes	No	No	Yes	Yes
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	152,826	152,826	132,632	132,632	152,826	152,826	132,632	132,632
Adjusted R^2	0.2008	0.2128	0.2763	0.2883	0.1863	0.2044	0.2674	0.2832

Firm-year clustered standard errors in parentheses
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

intangible-intensive firms hold more cash.[17] In Column (5) to (8), the ranking variable, Intan./Assets, is replaced by intangible investment-to-total investment ratio that maps more directly to the model setup in Section III. The estimates will guide model calibration. Column (1) to (4) in Panel B report a positive coefficient of the interaction between asset valuation and intangibility that is robust across specifications. As in Figure 1, more intangible firms' cash holdings are more sensitive to capital valuation. In Columns (5) to (8) of Panel B, I use a more restrictive measure of tangible capital valuation, tangible EV/EBITDA. Appendix C reports similar results with Tobin's Q as measure of capital valuation.[18]

Figure 2 examines the general equilibrium of liquid assets by shifting focus from demand to supply. Nonfinancial firms' liquid assets are mainly issued by financial intermediaries (Financial Accounts of the United States, 2019). Mutual fund and money market fund holdings are attributed to underlying assets based on sector level tables. Firms are among the major cash pools that feed leverage to

ratio (xrd/sale), size (log of at in 2005 dollars), Tobin's Q ([at + prcc_f*csho – ceq – txdb]/[0.1*(at + prcc_f*csho – ceq – txdb) + 0.9*at]), and industry sigma, which is the 10-year mean of the cross-sectional standard deviations of firms' cash flow/assets in a two-digit SIC industry.

[17]Investment need is a key determinant of cash holdings (Denis and Sibilkov, 2010; Duchin, 2010). Firms with less collateral hold more cash (Almeida and Campello, 2007; Li, Whited, and Wu, 2016).

[18]Table D.3 reports similar results under sorting by tangible assets (PPE). Less tangible firms exhibit stronger correlation between cash and capital valuation (measured by EV/EBITDA or Tobin's Q).

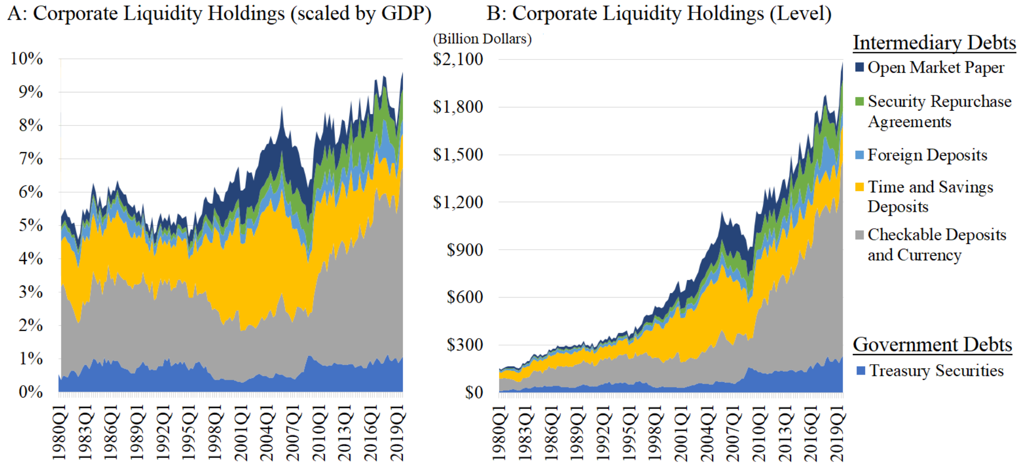

Figure 2. : Decomposing Nonfinancial Firms' Holdings of Liquid Securities

intermediaries (Carlson et al., 2016; Pozsar, 2014). Their liquid assets scaled by GDP almost doubled by 2019. The trend was interrupted by the financial crisis and firms flighted to Treasuries, but the trend resumed afterwards. However, the loss of firms' savings for intermediaries in the crisis was recognized by regulators. Retail deposits are assigned 90% to 95% stable funding factor while corporate deposits are assigned 50% (Basel Committee on Banking Supervision, 2014).

The rise of corporate savings in Figure 2 coincided with the secular increase in intangible investment especially relative to tangible investment in Panel A of Figure 3. Moreover, in Panel B of 3, capital valuation exhibits an upward trend, which, according to the evidence in Figure 1 and Table 1, reinforced the rise of intangibles in fueling the corporate savings glut. Along the secular trends, cyclical fluctuations emerge in both investment and capital valuation, feeding procyclicality to corporate savings. Panel C of Figure 3 plots the ratio of firms' holdings of intermediary debts to households' holdings (Financial Accounts of the United States, 2019). Recession years are marked by shaded areas. The ratio trends upward with cyclical drops in recessions, suggesting that, as a source of funding for intermediaries, corporate liquidity holdings are more procyclical than households'. Next, a model is built to generate both the trends and cyclical fluctuations in intangible share of investment, capital valuation, and corporate liquidity holdings. The model highlights endogenous risk that arises from the reinforcing procyclicality of these variables and becomes increasingly strong along the secular trends. The model also provides a new account of trends in interest rates and the size of intermediation sector, which have been documented extensively.

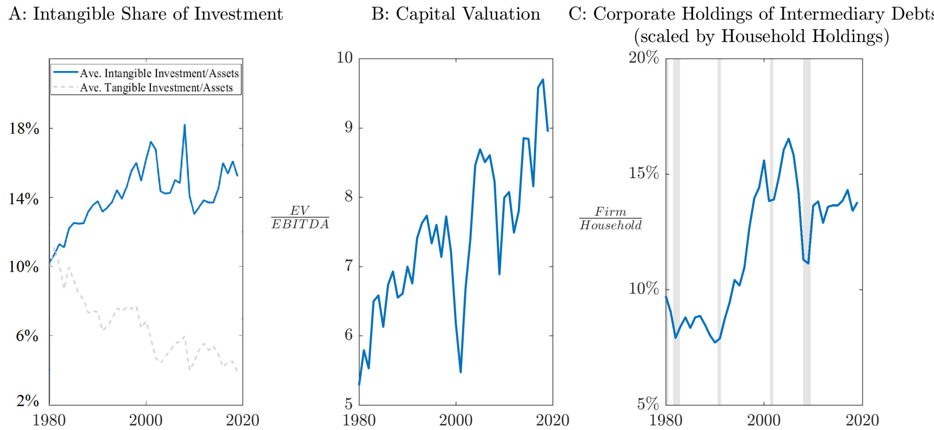

Figure 3. : Intangible Investment, Capital Valuation, and Corporate Savings

III. Model

Consider a continuous-time, infinite-horizon economy. The model fixes an information filtration that satisfies the standard regularity conditions (Protter, 1990). The production sector is set up first with a focus on intangible-driven liquidity demand. Later, bankers and households are introduced.

A. *The Production Sector and Liquidity Demand*

Preferences. There is a unit mass of entrepreneurs. Let $\mathbb{E} = [0, 1]$ denote the set. Let c_t^E denote a representative entrepreneur's *cumulative* consumption up to time t. Throughout this paper, subscripts denote time, and whenever necessary, superscripts are used to denote agents' type, with "E" for entrepreneurs (and later, "B" for bankers and "H" for households). An entrepreneur maximizes the life-time, risk-neutral expected utility with discount rate ρ:

$$\mathbb{E}\left[\int_{t=0}^{\infty} e^{-\rho t} dc_t^E\right]. \tag{1}$$

Capital and production. Each entrepreneur manages a firm that has tangible and intangible capital. Capital represents efficiency units and is counted by its output: One unit of capital produces one unit of non-durable generic goods per unit of time. In aggregate, the economy has K_t^T and K_t^I units of tangible and intangible capital, respectively, at time t that generate a flow of output, $\left(K_t^T + K_t^I\right) dt$ over dt. A fraction $\delta dt - \sigma dZ_t$ of capital are destroyed over dt. The standard Brownian motion Z_t captures aggregate shocks to production capacity.[19]

[19]For parsimony, the stochastic depreciation rates are the same for both types of capital. Introducing

The two types of capital differ in liquidity. Tangible capital is liquid. It can be pledged for financing, and entrepreneurs may sell the capital ownership and dutifully manage the capital on behalf of investors delivering goods produced. Tangible capital represents inventory, equipment, plant, and property. In reality, even though certain tangible assets are not actively traded, the securities backed by their cash flows are traded. In contrast, intangible capital is illiquid. It cannot be pledged for financing, and its ownership cannot be traded. It represents human and organizational capital, customer base, and proprietary technologies that are difficult for investors to repossess.

Investment and liquidity demand. The Poisson arrival of investment needs is independent across entrepreneurs with intensity λ. When hit by the shock, an entrepreneur's firm loses all capital but is endowed with a technology to transform goods into new capital instantaneously.[20] She chooses i_t, the amount of goods invested, and θ_t, the intangible share, to create $\kappa_t^I \theta_t i_t$ units of intangible capital and $\kappa^T (1-\theta_t) i_t$ units of tangible capital. Tangible investment efficiency is constant κ^T. Intangible investment efficiency increases over time, $\kappa_t^I = \kappa^I(t)$. Capital corresponds to a stream of future goods, so an increase of κ_t^I means that intangible investment generates more production capacity. It also captures the shift of consumers' preference towards output generated by intangibles, such as professional and business services (McGrattan, 2020).[21]

Let q_t^I denote the value of intangible capital (denominated in goods). The entrepreneur is indifferent in consumption timing, so she values the goods from intangible capital simply by Gordon growth formula, accounting for normal-time depreciation and Poisson-arriving destruction

$$q_t^I = \frac{1}{\rho + \delta + \lambda} \,. \tag{2}$$

Henceforth, the time subscript is dropped for q^I. As will be emphasized later in the solution, the unit value of tangible capital, denoted by q_t^T, may vary over time and loads on the aggregate shock,

$$dq_t^T = q_t^T \mu_t^T dt + q_t^T \sigma_t^T dZ_t \,. \tag{3}$$

where the drift and diffusion terms will be solved in equilibrium.

Given q^I and q_t^T, an investing entrepreneur maximizes the investment profits:

$$\max_{\{i_t,\theta_t\}} \left[q^I \kappa_t^I \theta_t + q_t^T \kappa^T (1-\theta_t) - F(\theta_t) \right] i_t - i_t \,, \tag{4}$$

different depreciation rates for intangible and intangible capital will not change the mechanism.

[20] This specification reflects the lumpiness of investment at micro levels (e.g., Doms and Dunne, 1998). Due to the idiosyncratic nature of investments, the aggregate investment is smooth (Thomas, 2002).

[21] This paper takes the structural change as exogenous. The literature on the growth of services sector provides several explanations (Kongsamut et al., 2001; Herrendorf et al., 2013; Ngai and Pissarides, 2007).

where a convex $F(\theta_t)$ is introduced to avoid counterfactual corner solutions (i.e., $\theta_t \in \{0,1\}$). Due to the illiquidity of intangible capital, the scale of investment is constrained by tangible value:

$$i_t \leq q_t^T \kappa^T i_t (1-\theta_t). \tag{5}$$

Self-financing, $1 \leq q_t^T \kappa^T (1-\theta_t)$, is ruled out (see details in Appendix A).

Assumption: Investment projects are not self-financed: $\kappa^T \left(\frac{1}{\rho+\delta+\lambda}\right) < 1$.

Under the financial constraint, entrepreneurs would hold liquidity, i.e., assets other than their own capital, immune to the Poisson shocks.[22] Holmström and Tirole (1998) point out a solution that is to pool pledgeable assets (tangible capital) in mutual funds where idiosyncratic shocks are diversified away. Then entrepreneurs hold the mutual-fund shares and use them for investment. Let m_t^E denote an entrepreneur's liquidity holdings, so the constraint (5) becomes

$$i_t \leq q_t^T \kappa^T i_t (1-\theta_t) + m_t^E. \tag{6}$$

However, as shown in Figure 2, firms rarely hold direct claims on other firms but instead hold debt securities largely issued by financial intermediaries. Diversification may require intermediaries' expertise.[23] And, under agency frictions that limit equity issuances (e.g., He and Krishnamurthy, 2013), firms hold intermediaries' debt rather than equity. Intermediated liquidity supply is also motivated by studies on banks as inside money creators (e.g., Kiyotaki and Moore, 2000).

B. *Intermediated Liquidity Supply*

Bankers are introduced to intermediate the supply of liquidity. Entrepreneurs are assumed to hold liquidity in the form of short-term bank debts (referred to as "deposits") that are in turn backed by bankers' holdings of tangible capital. With a slight abuse of notation, m_t^E now represents entrepreneurs' deposit holdings that mature in dt with interests $r_t dt$. I characterize a Markov equilibrium where banks never default, so bank debt is safe and $r_t dt$ is also the realized return.[24]

When the Poisson shocks hit, entrepreneurs use deposits to buy goods as investment inputs. In contrast to the existing macroeconomic models with financial intermediation that emphasize bankers' expertise on lending, this model emphasizes the liability side of bank balance sheets—banks add value to the economy because their debts are held by entrepreneurs as liquidity buffers.

Preferences. There is a unit mass of bankers. Let $\mathbb{B} = [0,1]$ denote the set of

[22] It is well documented that intangible investments rely heavily on firms' internal liquidity (for example, R&D investments in Hall (1992), Himmelberg and Petersen (1994), and Hall and Lerner (2009)).

[23] Intermediation is also be motivated by required expertise in monitoring (Diamond, 1984), restructuring (Bolton and Freixas, 2000), or enforcing collateralized claims (Rampini and Viswanathan, 2019).

[24] Macro-finance models that are built upon diffusion processes typically do not feature bank default (e.g., Brunnermeier and Sannikov, 2014). Default may be introduced through aggregate Poisson shocks.

bankers. A representative banker maximizes the life-time, risk-neutral expected utility with discount rate ρ:

$$\mathbb{E}\left[\int_{t=0}^{\infty} e^{-\rho t} dc_t^B\right], \tag{7}$$

where c_t^B denotes a banker's *cumulative* consumption up to time t.

Balance sheet. A banker incurs interest expenses $r_t dt$ on debt liabilities and earns risky return dr_t^T on her holdings of tangible capital, where r_t^T denotes the *cumulative* return that loads on shocks. To characterize dr_t^T, let k_t^{TB} denote a banker's holdings of tangible capital, with "T" and "B" indicating "tangible" and "banker" respectively. Capital stock depreciates stochastically, so

$$dk_t^{TB} = -k_t^{TB}\left(\delta dt - \sigma dZ_t\right) - k_t^{TB}\lambda dt\,. \tag{8}$$

The last term is from the λdt firms that lose capital due to the Poisson shocks. Through diversification, the banker faces a constant rate of capital destruction.

By Itô's lemma, equations (3) and (8) imply the tangible capital return:

$$dr_t^T = \frac{k_t^{TB} dt}{q_t^T k_t^{TB}} + \frac{d\left(q_t^T k_t^{TB}\right)}{q_t^T k_t^{TB}} = \left(\frac{1}{q_t^T} + \mu_t^T - \delta - \lambda + \sigma_t^T \sigma\right) dt + \left(\sigma_t^T + \sigma\right) dZ_t \tag{9}$$

$1dt/q_t^T$, is dividend yield—production flow, $1dt$, divided by the unit value, q_t^T. $\left(\mu_t^T - \delta - \lambda\right) dt$, account for the expected unit value change, quantity depreciation, and measure of firms hit by the Poisson shocks. $\sigma_t^T \sigma$, is Itô's quadratic covariation. Shock loading consists of σ_t^T, the endogenous return volatility of q_t^T (price risk), and σ, the exogenous volatility of depreciation shock (quantity risk).

Let n_t^B denote a representative banker's wealth with the following law of motion,

$$dn_t^B = x_t^B n_t^B dr_t^T - (x_t^B - 1) n_t^B r_t dt - dc_t^B\,, \tag{10}$$

where $x_t^B \equiv q_t^T k_t^{TB}/n_t^B$ is the asset-to-wealth ratio and debt value is $(x_t^B - 1)n_t^B$.

As shown by (10), intermediation involves risk-taking. Bankers issue safe deposits while holding risky tangible capital. Equity capital buffers risk. An undercapitalized banking sector cannot adequately fulfill its role as liquidity supplier. To capture this idea, I assume that banks cannot issue outside equity, i.e., $dc_t^B \geq 0$ as in Brunnermeier and Sannikov (2014).[25] This can be motivated by agency frictions. As a result, bankers' wealth drives the *intermediation capacity*. In this

[25] By inspecting equation (9), we can see that negative consumption is equivalent to issuing equity to replenish net worth. See also Phelan (2016) and Klimenko, Pfeil, Rochet, and Nicolo (2016) for similar specifications. Note that negative consumption is allowed for entrepreneurs except when liquidity shocks hit. In other words, entrepreneurs are only financially constrained at such Poisson times. Allowing negative consumption is equivalent to assuming large endowments of goods – if goods are non-durable, entrepreneurs always consume to clear the goods market, indifferent between consuming and saving. This fixes their marginal value of wealth at one and required return at ρ.

model, entrepreneurs' liquidity demand from Holmström and Tirole (1998) meets banks' limited balance-sheet capacity from Holmström and Tirole (1997).

C. The Main Mechanism: Trends and Cycles

The main results are in two categories: (1) the economy's response to the increase of κ_t^I over time (i.e. the trends) and (2) the economy's response to the aggregate shock, dZ_t (i.e., the cycles). First, I explain the trends as I characterize the entrepreneurs' intangible-driven liquidity demand.

When hit by the Poisson shock, an entrepreneur maximizes investment profits given by (4) facing the liquidity constraint (6). Let π_t denote the marginal value of liquidity, i.e., the Lagrange multiplier of constraint (6). The Lagrange function summarizes the entrepreneur's problem:

(11)
$$\mathcal{L} = \max_{\{i_t,\theta_t\}} \left[q^I \kappa_t^I \theta_t + q_t^T \kappa^T (1-\theta_t) - F(\theta_t)\right] i_t - i_t + \pi_t \left[m_t^E + q_t^T \kappa^T i_t (1-\theta_t) - i_t\right] .$$

It is assumed that κ^T or κ_t^I is sufficiently high so the constraint (6) binds. The entrepreneur can pledge the value of tangible capital and lever up one unit of liquidity to $1/\left[1 - q_t^T \kappa^T (1-\theta_t)\right]$:

$$i_t = \left(\frac{1}{1 - q_t^T \kappa^T (1-\theta_t)}\right) m_t^E \tag{12}$$

The funds are raised against tangible capital at a fair price so the entrepreneur captures all surplus per unit of investment, i.e., $\left[q_t^I \kappa_t^I \theta_t + q_t^T \kappa^T (1-\theta_t) - F(\theta_t)\right] - 1$.[26] Therefore, the marginal value of liquidity, π_t, is the marginal profit of investment multiplied by the leverage on liquidity:

$$\pi_t = \underbrace{\left\{\left[q^I \kappa_t^I \theta_t + q_t^T \kappa^T (1-\theta_t) - F(\theta_t)\right] - 1\right\}}_{\textit{marginal profit of investment}} \underbrace{\left(\frac{1}{1 - q_t^T \kappa^T (1-\theta_t)}\right)}_{\textit{leverage on liquidity}} \tag{13}$$

The entrepreneur's choice of θ_t is characterized by the first-order condition that equates the marginal values of intangible and tangible investments:

$$q^I \kappa_t^I - F'(\theta_t) = (1+\pi_t)\, q_t^T \kappa^T . \tag{14}$$

Note that on the right side of (14), the marginal value of tangible capital, $q_t^T \kappa^T$, is amplified by π_t, because investing more in tangible capital not only creates more production units but also relaxes the funding constraint (6). The next proposition summarizes the entrepreneur's liquidity-holding and investment decisions with a focus on the value of liquidity. Appendix A provides the proof.

[26] The repayment for funds raised against tangible capital is in the ownership of the tangible capital. The entrepreneur is assumed to dutifully pass the production flows generated by the capital to its owners.

PROPOSITION 1: *Entrepreneurs' investment has the following properties:*
(1) The optimal intangible share of investment, θ_t, in (14) is increasing in κ_t^I;
(2) The marginal value of liquidity, π_t, given by (13), is increasing in κ_t^I and q_t^T, and entrepreneurs accept a deposit rate below ρ:

$$r_t = \rho - \lambda \pi_t \,. \tag{15}$$

Proposition 1 implies several trends in equilibrium. As κ_t^I increases over time, intangible investment creates increasingly more production capacity than tangible investment, so the entrepreneurs optimally choose to tilt investment towards intangibles, i.e., to increase θ_t. As the intangible share increases, the entrepreneurs face a tighter liquidity constraint, so the marginal value of liquidity, π_t, increases, driving down the deposit rate r_t. The entrepreneurs accept $r_t < \rho$. The wedge, $\lambda\pi_t$, depends on the probability of liquidity needs and marginal value of liquidity.

The decline of r_t triggers a feedback mechanism. It lowers bankers' cost of financing and allows them to bid up the price of tangible capital, q_t^T. A higher value of tangible capital enlarges the financing capacity of investment projects, allowing liquidity to be leveraged to larger investments. A higher q_t^T also means investments are more profitable. Therefore, π_t, the marginal value of liquidity holdings, increases further, and r_t drops even lower. The downward trend in r_t and upward trend in q_t^T reinforce each other, generating a corporate savings glut. This savings glut arises endogenously in a closed-economy, distinct from an exogenous savings glut in open economies that has been shown to affect interest rates and asset prices (Caballero, Farhi, and Gourinchas, 2008).

Tangible capital has two sources of value. It produces goods and provides liquidity by backing deposits. The bankers transmit the entrepreneurs' liquidity premium to the value of tangible capital. To fully solve q_t^T, we need a complete characterization of bankers' discount rate, r_t + *risk premium*. For the risk-premium component, we obtain bankers' price of risk from the dynamics of marginal value of wealth. The homogeneity property of bankers' problem implies a linear value function $q_t^B n_t^B$. The marginal value of wealth, q_t^B, evolves in equilibrium

$$\frac{dq_t^B}{q_t^B} = \mu_t^B dt - \gamma_t^B dZ_t, \tag{16}$$

where μ_t^B and $\gamma_t^B d$ will be solved in equilibrium.

PROPOSITION 2: *The equilibrium expected return on tangible capital is*

$$\mathbb{E}_t\left[dr_t^T\right] = r_t dt + \gamma_t^B\left(\sigma_t^T + \sigma\right) dt \,. \tag{17}$$

The equilibrium value of tangible capital satisfies the following equation

$$q_t^T = \frac{1}{\left[r_t + \gamma_t^B\left(\sigma_t^T + \sigma\right)\right] - \left[\mu_t^T + \sigma_t^T \sigma - \delta - \lambda\right]} \,. \tag{18}$$

Appendix A provides the proof. Intuitively, $dZ_t < 0$ reduces bankers' wealth and increases their marginal value of wealth, so the bankers require a risk premium, $\gamma_t^B \left(\sigma_t^T + \sigma\right) dt$, in the expected return on tangible capital.[27] This is a standard asset-pricing result: γ_t^B is the price of risk and $\left(\sigma_t^T + \sigma\right)$ is the quantity of risk, a sum of exogenous risk, σ, and endogenous price risk, σ_t^T (see (3)). In equilibrium, $r_t + \gamma_t^B \left(\sigma_t^T + \sigma\right) \leq \rho$. When both the entrepreneurs, whose discount rate is ρ, and bankers own tangible capital, the expected return is ρ; when only the bankers own tangible capital, the expected return must not be greater than ρ, the entrepreneurs' required return. Being able to issue deposits at interest rate r_t gives the bankers a discount-rate advantage.

Equation (18) resembles the Gordon growth formula. The numerator is cash flow (production). In the denominator, the first component is discount rate and the second is expected growth.[28] As κ_t^I drives up θ_t, the intangible share of investment, and π_t, the marginal value of liquidity, entrepreneurs accept an increasingly low deposit rate $r_t = \rho - \lambda\pi_t$ (see (15)), which drives down the discount rate in (18) and pushes up q_t^T. The bankers transmit the rising liquidity premium on deposits to q_t^T. The transmission is incomplete due to the risk-premium component of their discount rate. The risk premium can be shut down if the bankers were allowed to freely issue equity and thus have unlimited balance-sheet capacity.[29] Comparing (18) and the valuation of illiquid intangible capital (2), we can see that the source of variation in q_t^T is the liquidity value rather than production value. And, the liquidity value varies with the bankers' intermediation capacity.

While the increase in κ_t^I generates the self-enforcing trends in r_t and q_t^T, the endogenous variation of γ_t^B generates the fluctuations along the trends (i.e., the cycles). After positive shocks ($dZ_t > 0$),bankers become wealthier and their price of risk γ_t^B declines, so they bid up q_t^T, which in turn leads to a higher value of liquidity holdings for entrepreneurs (π_t) and a lower r_t. As the bankers' funding cost r_t declines, they push up q_t^T further. As the bankers expand balance sheet and entrepreneurs hold more deposits, investment booms because the entrepreneurs hold more liquidity and can lever up through a higher value of tangible capital.

Endogenous risk accumulates in booms of liquidity creation and investment. As r_t declines, the wedge between the bankers' discount rate, $r_t + \gamma_t^B \left(\sigma_t^T + \sigma\right)$, and entrepreneurs' discount rate, ρ, widens, which makes q_t^T increasingly sensitive to shocks that cause reallocation of tangible capital between the bankers and entrepreneurs. When negative shocks hit, the bankers sell tangible capital back to entrepreneurs who have a higher discount rate. The reallocation causes a

[27]Like Tobin's Q, q_t^B, is a forward looking measure of profits per unit of equity. This offers an alternative view. Due to the negative shocks and their persistent effects under the equity issuance constraint, the whole banking sector becomes undercapitalized and shrinks for a sustained period of time. To clear the markets of tangible capital and deposits, the spread between the expected return on tangible capital and deposit rate will have to widen so that banks would hold tangible capital and issue deposits. As the expected future profits rise, q_t^B increases.

[28]Investment creates new capital instead of grows the existing capital, so it's not in the growth rate.

[29]Under frictionless equity issuance, $q_t^B = 1$ (i.e., no incentive to retain equity), so $\gamma_t^B = 0$.

decline in asset price, q_t^T. Endogenous asset-price volatility has impact on the real economy. Economic growth is directly tied to q_t^T through the leverage on liquidity and scale of investment (see (12)). A vicious cycle ensues. A lower q_t^T reduces investment profits and π_t, discouraging the entrepreneurs from saving for investments. This causes the rise of r_t, the bankers' funding cost, so the bankers' discount rate increases further, causing q_t^T to continue falling. Moreover, the decline of q_t^T erodes the bankers' wealth, further increasing their price of risk, γ_t^B. The risk premium channel and interest rate channel reinforce each other, generating a powerful response to negative shocks.

The accumulation of endogenous risk is asymmetric. Positive shocks trigger the reallocation of tangible capital to the bankers with low discount rates but eventually cause bankers to consume their wealth as q_t^B, the marginal value of wealth, falls to one (when the bankers become indifferent between retaining wealth and consumption). However, negative shocks cause a continuing reallocation of tangible capital to those with high discount rates. Such asymmetry sheds light on the findings that longer booms precede more severe crises.[30] The mechanism differs from the existing models on asymmetric cycles (e.g., Ordoñez, 2013).

The model is built on two frictions. The first is the illiquidity of intangible capital. This leads to demand for liquid assets and links the rising productivity of intangible investment to the decline of interest rate and other trends. The second friction is that the bankers cannot raise external equity frictionlessly.[31] This generates the response of risk price to shocks (He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014; Di Tella, 2017) and endogenous financial cycles. Removing the second friction eliminates the amplification of fluctuations along the trends but does not eliminate the trends. If bankers could raise equity freely to replenish net worth, their marginal value of wealth would be pinned to one and price of risk pinned to zero.[32]

This paper continues the tradition of incorporating financial frictions into macroeconomic models. The financial accelerators amplify both trends (driven by κ_t^I) and cycles (triggered by dZ_t). At the core is firms' savings, which is in contrast to the literature that focuses on firms' borrowing (Kiyotaki and Moore, 1997; Bernanke, Gertler, and Gilchrist, 1999; Gertler and Kiyotaki, 2010). Key to the financial cycle is the procyclical wedge in discount rate between bankers, who supply liquidity and are "natural buyers" of tangible capital, and the rest of the economy. The longer a boom lasts, the sharper asset price falls when negative shocks reduce bankers' wealth. This procyclical discount-rate wedge is distinct from the constant cash-flow wedge between intermediaries and households as as-

[30] Please refer to Baron and Xiong (2017), Jordà, Schularick, and Taylor (2013), Krishnamurthy and Muir (2016), and López-Salido, Stein, and Zakrajšek (2017) among others. The mechanism is consistent with banks' procyclical payout in data (Baron, 2014; Adrian, Boyarchenko, and Shin, 2016).

[31] Allowing limited equity issuance (e.g., He and Krishnamurthy, 2013) changes quantitative performances and causes calibration to deliver different parameter values, but will not change the mechanism.

[32] Without equity issuance friction, the equilibrium of intermediated liquidity supply is the same as the mutual-fund equilibrium that features constant asset price and zero endogenous risk.

set owners in Brunnermeier and Sannikov (2014). Endogenous risk accumulation via discount-rate wedge also differs from recent studies that emphasize belief heterogeneity (Caballero and Simsek, 2020, 2021).

Discussion: Intangible risk. A potential limitation of the model is that intangible capital valuation in (2) does not reflect risk premium. In Eisfeldt and Papanikolaou (2013), the risk of organizational capital from the cyclical variation in key personnel's outside option. Such risk premium may reduce capital valuation and thus discourages firms from intangible investment, counteracting the rise of κ_t^I. However, other forms of intangibles may serve as a hedge and their negative risk premia have a counterbalancing effect. An important type of intangible capital is technology.[33] Technological innovation displaces firms and workers that operate with old technologies and have difficulty to adapt (Kogan, Papanikolaou, Schmidt, and Song, 2020). Displacement risk makes technological innovation a hedge against systematic technological changes (Gârleanu, Kogan, and Panageas, 2012; Bena and Garlappi, 2019; Kogan, Papanikolaou, and Stoffman, 2020).

D. *Aggregation and the Markov Equilibrium*

Households. In reality, households also hold intermediaries' debts. Households' demand is not essential for the main mechanism but it is important to incorporate it for calibration and quantitative analysis. The literature takes a money-in-utility approach, motivated by the role of intermediaries' debts (e.g., deposits) as means of payment (Sidrauski, 1967; Stein, 2012; Van den Heuvel, 2018). Holdings of monetary assets generate utility flows separable from consumption (Poterba and Rotemberg, 1986; Nagel, 2016; Begenau and Landvoigt, 2018) and are complementary to income levels (Begenau, 2019; Krishnamurthy and Vissing-Jørgensen, 2015). Consider a unit mass of households, $\mathbb{H} = [0, 1]$. A representative household has labor that produces w_t^H units of goods. Let W_t^H $(= \int_{i \in \mathbb{H}} w_t^H(i)\, di)$ denote the aggregate labor output, so the total output of the economy is $(K_t^I + K_t^T + W_t^H)dt$. The utility function is specified as

$$\mathbb{E}\left[\int_{t=0}^{\infty} e^{-\rho t}\left(dc_t^H + \frac{\left(w_t^H \beta_t\right)^{\xi}\left(m_t^H\right)^{1-\xi}}{1-\xi}dt\right)\right], \tag{19}$$

where c_t^H is the cumulative consumption process and m_t^H denotes deposit holdings.[34] The scaling variable is a function of time, $\beta_t = \beta(t)$.

The utility function in (19) implies the following optimality condition for m_t^H:

$$\left(\frac{m_t^H}{\beta_t w_t^H}\right)^{-\xi} = \rho - r_t\,, \tag{20}$$

[33]Technology sector is the most relevant as corporate cash holdings mainly reside in "growth sectors" (Begenau and Palazzo, 2021; Graham and Leary, 2018; Pinkowitz, Stulz, and Williamson, 2015).

[34]Appendix B discusses the implications of incorporating risk-averse preferences and finite EIS.

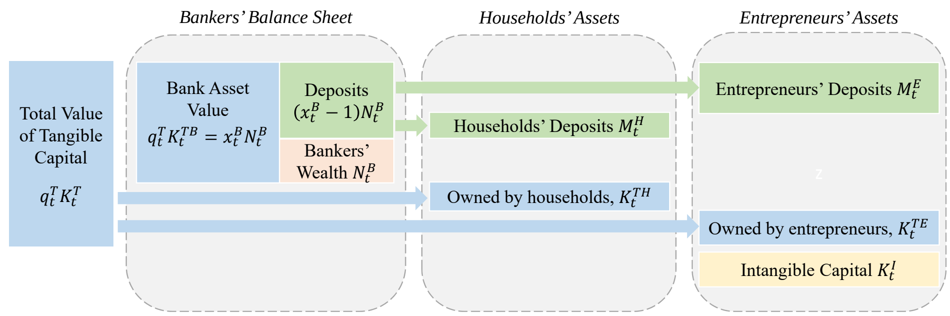

Figure 4. : Model Structure

which equates the marginal utility of holding deposits and marginal cost, i.e., the spread $\rho - r_t$. Rearranging (20) and aggregating over households, we obtain

$$M_t^H = W_t^H \beta_t (\rho - r_t)^{-\frac{1}{\xi}} . \tag{21}$$

To avoid introducing a new state variable, it is assumed that labor output is proportional to that of tangible capital, i.e., $W_t^H = \alpha K_t^T$. In other words, between labor and tangible capital, the labor share of output is a constant, $\alpha/(\alpha+1)$. This is consistent with the finding in Koh, Santaeulàlia-Llopis, and Zheng (2020) that labor share is stable without accounting for output associated with intangibles.[35] Under this assumption, households' deposits demand is given by

$$M_t^H = \alpha K_t^T \beta_t (\rho - r_t)^{-\frac{1}{\xi}} , \tag{22}$$

α only has a scaling effect, so only the calibration of $\beta_t = \beta\,(t)$ is necessary.

The real-financial linkage. Figure 4 summarizes the model. The economy has three markets to clear (goods, the ownership of tangible capital, and deposits). The output is generated by intangible capital, tangible capital, and labor. The λdt entrepreneurs who are hit by the Poisson shocks acquire goods to create new capital, and the remaining goods are consumed by the rest of the economy.[36] The entrepreneurs, bankers, and households can trade the ownership of tangible capital at competitive price q_t^T given the stock K_t^T. In the deposit market, the bankers' supply is equal to the demand from the entrepreneurs and households. As in Caballero, Farhi, and Gourinchas (2008), only a fraction of output is capitalizable—tangible capital output—and the key inefficiency is a shortage of liquid assets. Depending on the bankers' risk-taking capacity (wealth), the

[35]Intangibles include research and development, software, and entertainment, literary, and artistic originals (U.S. Bureau of Economic Analysis, 2019). Analyzing the decline of labor share (e.g., Karabarbounis and Neiman, 2013), Koh, Santaeulàlia-Llopis, and Zheng (2020) show that it is attributed to the incorporation of output related to intangibles.
[36]Under risk-neutral utility, the demand for consumption goods is perfectly elastic.

bankers create liquidity by backing deposits with tangible capital. Entrepreneurs' deposits relax the liquidity constraint (6) on investment. Therefore, economic growth depends on the *intermediated liquidity supply.*

As shown in (12), one unit of liquidity is leveraged up to $1/\left[1-q_t^T\kappa^T\left(1-\theta_t\right)\right]$ units of goods invested. Given the entrepreneurs' aggregate deposits, M_t^E, the aggregate investment comes from the λdt entrepreneurs (hit by the Poisson shocks):

$$\left(\frac{1}{1-q_t^T\kappa^T\left(1-\theta_t\right)}\right)M_t^E\lambda dt\,. \tag{23}$$

The deposit-market clearing condition links the entrepreneurs' liquidity to bankers' wealth:

$$M_t^E=\left(x_t^B-1\right)N_t^B-M_t^H\,, \tag{24}$$

where the right side is the total deposits minus the households' holdings.

The law of motion of intangible capital is

$$dK_t^I=\underbrace{\left(\frac{1}{1-q_t^T\kappa^T\left(1-\theta_t\right)}\right)}_{leverage}\underbrace{\left[\left(x_t^B-1\right)N_t^B-M_t^H\right]}_{entrepreneurs'\ liquidity}\theta_t\kappa_t^I\lambda dt-\underbrace{\left(\delta dt-\sigma dZ_t+\lambda dt\right)K_t^I}_{depreciation,\ Poisson\ destruction}\,, \tag{25}$$

and the law of motion of tangible capital is

$$dK_t^T=\left(\frac{1}{1-q_t^T\kappa^T\left(1-\theta_t\right)}\right)\left[\left(x_t^B-1\right)N_t^B-M_t^H\right]\left(1-\theta_t\right)\kappa^T\lambda dt-\left(\delta dt-\sigma dZ_t+\lambda dt\right)K_t^T\,. \tag{26}$$

Total investment in (23) is split into the tangible and intangible parts by entrepreneurs' choice of intangible share, θ_t. Then investments are multiplied by the productivities, κ_t^I and κ^T.[37].

Equations (25) and (26) highlight the link between intermediation capacity and growth. When bankers are well-capitalized, more deposits are issued. Liquidity can be leveraged up to create capital. Equations (25) and (26) also show how the financial conditions drive economic fluctuations. Entrepreneurs' leverage on liquidity increases in the value of tangible capital, q_t^T. Therefore, the endogenous asset-price volatility, i.e., σ_t^T in (3), feeds into investment dynamics and has a direct impact on the real economy. Moreover, the variation of q_t^T has a levered impact on the bankers' wealth and their capacity of liquidity creation.

State variables. The Markov equilibrium has four state variables, time, which drives κ_t^I and β_t, and the three stock variables, $N_t^B\equiv\int_{i\in\mathbb{B}}n_{i,t}^B di$ (the bankers' aggregate wealth), K_t^I, and K_t^T.[38] These four state variables have a convenient

[37]The shocked entrepreneurs' lost capital is evenly endowed to other entrepreneurs, so the λdt measure of lost capital lost is not in (25) and (26). One interpretation is that the λdt entrepreneurs' customer base is seized by the others through creative destruction (Aghion, Akcigit, and Howitt, 2014)

[38]Capital composition is a key state variable in Eberly and Wang (2008) who study agents' trade-off

hierarchical property. First, apparently, time progresses linearly and has an autonomous law of motion. Second, $\left(N_t^B, K_t^I, K_t^T\right)$ can be equivalently represented by $\left(\eta_t, K_t^I, K_t^T\right)$, where η_t, the intermediation intensity, is defined by

$$\text{(27)} \qquad \textit{Intermediation Intensity}: \; \eta_t \equiv \frac{N_t^B}{K_t^T}\,.$$

It is a ratio of the bankers' wealth to the amount of assets to be intermediated. The next proposition states that its evolution only depends on itself and time, and that the market prices, such as q_t^T and r_t, and the K_t^T-scaled quantities are functions of η_t and time only. To solve the equilibrium, I first focus on the sub-system where η_t and time are the two state variables and solve the market prices and the K_t^T-scaled aggregate quantities, which requires solving a system of differential equations. The solutions of these variables are then fed into the laws of motion of K_t^I and K_t^T (see (25) and (26)) for a complete characterization of equilibrium dynamics. Appendix A provides the proof.

PROPOSITION 3 (Financial System): *The equilibrium law of motion of intermediation intensity is*

$$\text{(28)} \qquad \frac{d\eta_t}{\eta_t} = \mu^\eta\left(\eta_t, t\right)dt + \sigma^\eta\left(\eta_t, t\right)dZ_t\,,$$

for $\eta_t \in (0, \overline{\eta}(t)]$. $\mu^\eta(\eta_t, t)$ *and* $\sigma^\eta(\eta_t, t)$ *are defined in Appendix A, and* $\overline{\eta}(t)$ *is a reflecting boundary where the bankers consume. Prices and* K_t^T*-scaled quantities are functions of* η_t *and* t*: (1) the value of tangible capital,* $q_t^T = q^T(\eta_t, t)$*; (2) the deposit rate,* $r_t = r(\eta_t, t)$*; (3) the* K_t^T*-scaled households' deposits,* $\widetilde{M}_t^H = \widetilde{M}^H(\eta_t, t)$*; (4) the* K_t^T*-scaled entrepreneurs' deposits,* $\widetilde{M}_t^E = \widetilde{M}^E(\eta_t, t)$*; (5) the optimal intangible share of investment,* $\theta_t = \theta(\eta_t, t)$*; (6) bankers' asset-to-wealth ratio,* $x_t^B = x^B(\eta_t, t)$*; (7) the bankers' marginal value of wealth,* $q_t^B = q^B(\eta_t, t)$*.*[39]

IV. Quantitative Analysis

This section starts with calibration and presents the results on trends and cyclical variations due to endogenous financial risk. It ends with counterfactual analysis that demonstrates the quantitative importance of the rise of intangibles.

A. Parameter Calibration

Calibration takes five steps. The guiding principles are explained first. The first step is to calibrate the investment technology to match the trends in intangible

between diversification benefits and reallocation costs when two sectors are available for investment.

[39] $q_t^B \in [1, +\infty)$. At $\eta_t = \overline{\eta}(t)$, $q_t^B = 1$ and bankers consume. Consumption reduces N_t^B, but once q_t^B is above one, consumption stops (retaining wealth is worth $q_t^B > 1$). Thus, $\overline{\eta}(t)$ is a reflecting boundary. Bankers' HJB equation and Eq. (18) imply a system of differential equations for $q^B(\eta_t, t)$ and $q^T(\eta_t, t)$. Once they are solved, the other variables are solved analytically. See Appendix A.

and tangible investments and volatilities along those trends. The productivity of intangible investment, $\kappa^I(t)$, is parameterized as $\kappa_t^I = \kappa_0^I + \kappa_1^I t$, and the cost of adjusting investment portfolio is specified as $F(\theta_t) = \frac{\phi}{2}\theta_t^2$. Thus the investment technology is summarized by four parameters, κ_0^I, κ_1^I, κ^T, and ϕ. As will be shown shortly, these specifications generate realistic investment dynamics.

The choice of intangible share, θ_t, drives firms' liquidity needs. After matching investment dynamics, the second step is to calibrate λ, the arrival rate of investment and liquidity needs, so the response of firms' liquidity holdings to changes in θ_t matches the estimate in Section II.

Third, parameters in households' liquidity utility are calibrated to match the dynamics of household liquidity holdings. This is important for counterfactual analysis where investment technology is adjusted to create scenarios with and without the rise of intangibles while households' liquidity utility is fixed. Fourth, the shock size, σ, is calibrated to generate a volatility of bank asset return in the baseline model that matches the estimate in the literature.

So far, the calibration has been guided by the estimate in Table 1 and data displayed in Figure 3 in Section II. The fifth and last step is to calibrate ρ, discount rate, and δ, capital depreciation rate. The calibration targets have been quantity variables, such as investment and liquidity holdings. Now the focus shifts to the two price variables, interest rate and tangible capital value. However, with only two parameters left, the calibration exercise cannot target different aspects of equilibrium dynamics (the level, trends, volatilities along the trends, etc.) but instead matches the interest rate and capital valuation at the beginning of sample period 1980 to 2019. This leaves the price variables' paths over time completely to the equilibrium forces. Therefore, when examining model performances, whether the dynamics of price variables match data is a stricter criterion than the match of quantity variables, which are calibration targets.

Next, I provide more details on calibration. One unit of time in the model is set to one year. For calibration and later comparing the endogenous variables with empirical counterparts, I extract trends in data through 20-year rolling averages from 1980 to 2019 (the sample period in Section 2).[40] In the model, the variation in η_t generates fluctuation along the trends. To extract trends from the solution, I average out η_t at every t.[41] For example, $\mathbb{E}^\eta[r(\eta, t = 0)]$ is mapped to the first rolling average of interest rates in data, which centers around 1989. The same logic applies to all prices and K_t^T-scaled quantities, which will be used in calibration and, according to Proposition 3, are also functions of η_t and t. The model is solved for $t \in [0, 20]$ because the last moving average in data centers around 2009 (which maps to $t = 20$) and ends in 2019 (the sample end).

[40] Before the 1980s, Regulation Q imposed various restrictions on deposit rates. For example, it prohibited banks from paying interest on demand deposits. This practice is inconsistent with the model specification that the deposit rate, r_t, is the price variable that clears the deposit market.

[41] Instead of averaging over the simulated paths, the η-averages can be calculated using the t-conditional stationary distribution of η_t, implied by (28), and the solved functions of endogenous variables, for example, $q_t^T = q^T(\eta_t, t)$. Appendix A solves the t-conditional stationary distribution of η_t.

Table 2—: Parameter Calibration

Parameters	Symbol	Value	Moment	Model	Data
(1) Intangible investment productivity: Intercept	κ_0^I	1.075	Average $\mathbb{E}^\eta\left[\theta\left(\eta,t\right)\right]$	63.9%	61.6%
(2) Intangible investment productivity: Time coefficient	κ_1^I	0.018	Average annual change of $\mathbb{E}^\eta\left[\theta\left(\eta,t\right)\widetilde{I}\left(\eta,t\right)\right]$	1.6%	1.4%
(3) Tangible investment productivity	κ^T	0.011	Average annual change of $\mathbb{E}\left[\left(1-\theta\left(\eta,t\right)\right)\widetilde{I}\left(\eta,t\right)\right]$	0.0%	-0.1%
(4) Investment cost $F\left(\theta\right)=\frac{\phi}{2}\theta_t^2$	ϕ	9.540	Average $\frac{\text{Vol.}^\eta\left[\theta(\eta,t)\widetilde{I}(\eta,t)\right]}{\text{Vol.}^\eta\left[(1-\theta(\eta,t))\widetilde{I}(\eta,t)\right]}$	1.84	2.06
(5) Investment project arrival rate	λ	0.050	$\frac{\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,20)}{q^T(\eta,20)}\right]-\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,0)}{q^T(\eta,0)}\right]}{\mathbb{E}^\eta\left[\theta\left(\eta,20\right)\right]-\mathbb{E}^\eta\left[\theta\left(\eta,0\right)\right]}$	0.162	0.170
(6) Household deposit demand elasticity to deposit rate	ξ	1.100	Average annual change of $\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)+\widetilde{M}^H(\eta,t)}{q^T(\eta,t)}\right]$	0.0%	0.3%
(7) Household deposit utility scale: Intercept	β_0	0.196	$\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)}{\widetilde{M}^H(\eta,t)}\right], t=0$	9.8%	9.6%
(8) Household deposit utility scale: Time coefficient ($\leq$ 1992)	β_1	0.019	Average annual change of $\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)}{\widetilde{M}^H(\eta,t)}\right], t\leq 2$	0.32%	0.29%
(9) Household deposit utility scale: Time coeff. increase ($>$ 1992)	β_2	0.003	Average annual change of $\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)}{\widetilde{M}^H(\eta,t)}\right], t>2$	0.19%	0.20%
(10) Capital depreciation rate: Vol.	σ	0.020	Vol. of bank asset return	2.9%	2.6%
(11) Agents' discount rate	ρ	0.062	$\mathbb{E}^\eta\left[r\left(\eta,t\right)\right], t=0$	3.2%	3.5%
(12) Capital depreciation rate: Mean	δ	0.088	$\mathbb{E}^\eta\left[q^T\left(\eta,t\right)\right], t=0$	6.6	6.8

The productivity of intangible investment has two parameters, κ_0^I that determines the base rate, and κ_1^I that determines the time trend. κ_0^I is calibrated so the average θ_t matches the sample average of *Intan./Investment* in Section II. κ_1^I is calibrated so the average annual change in the trend of intangible investment/tangible capital, i.e., $\mathbb{E}^\eta[\theta_t I_t/K_t]=\mathbb{E}^\eta[\theta_t\widetilde{I}_t]$, matches data.[42] The productivity of tangible investment, κ^T, is calibrated so the average annual change in the trend of tangible investment/tangible capital, i.e., $\mathbb{E}^{\eta_t}[(1-\theta_t)I_t/K_t] = \mathbb{E}^{\eta_t}[(1-\theta_t)\widetilde{I}_t]$, matches data. The parameter ϕ in $F\left(\theta_t\right)$ governs the cost of adjusting investment composition and its calibration targets the relative volatilities of intangible and tangible investments. At time t, the conditional distribution of η_t (implied by (28)) is used to calculate the volatility ratio of intangible to tangible investment (both scaled by K_t^T), $\frac{\text{Vol}^{\eta_t}\left[\theta\widetilde{I}\right]}{\text{Vol}^{\eta_t}\left[(1-\theta)\widetilde{I}\right]}$, and the ratio is averaged over time to match the volatility ratio of detrended intangible to tangible investment.[43]

Firms' liquidity needs is driven by the random arrival of projects that require intangible investment. The arrival rate λ is calibrated so that the model-implied re-

[42]Each year, I calculate cross-section total asset-weighted average of ratio of intangible investment to tangible capital (PPE) and calculate the twenty-year rolling averages.

[43]Each year, I take the ratio of intangible investment (scaled by PPE) and tangible investment (scaled by PPE) (see also footnote 42). The resulting time series exhibits a linear trend.

sponse of firms' liquidity holdings to the increase of intangible investment matches the estimate in Section 2 (Table 1, Column 8), the change in cash/assets for one unit of change of *Intan./Investment* (θ_t in the model). The model counterpart is $\left(\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^E(\eta,20)}{q^T(\eta,20)}\right] - \mathbb{E}^{\eta}\left[\frac{\widetilde{M}^E(\eta,0)}{q^T(\eta,0)}\right]\right) / \left(\mathbb{E}^{\eta}\left[\theta\left(\eta,20\right)\right] - \mathbb{E}^{\eta}\left[\theta\left(\eta,0\right)\right]\right)$, where the η_t-averages are used as the match focuses on disciplining the trend rather cyclical fluctuations and $\frac{\widetilde{M}^E_t}{q^T_t} = \frac{M^E_t}{q^T_t K^T_t}$ is the ratio of firms' liquidity scaled by tangible capital value that corresponds to the accounting asset value mostly excluding intangibles (e.g., Peters and Taylor, 2017).

Next, I calibrate the households' liquidity utility. The only goal of incorporating the households' liquidity utility is to generate realistic liquidity demand, especially relative to firms', for the purpose counterfactual analysis where the rise of intangibles and associated liquidity demand of firms will be shut down to examine how interest rate, asset valuation, and other variables respond. The value of ξ, households' liquidity demand elasticity, is chosen so that the model generates a stable path over time of the ratio of safe assets (households' and firms' holdings of deposits) to capitalizable assets (tangible capital value), i.e., $\mathbb{E}^{\eta}\left[\frac{M^E(\eta,t)+M^H(\eta,t)}{q^T(\eta,t)K^T_t}\right] = \mathbb{E}^{\eta}\left[\frac{\widetilde{M}^E(\eta,t)+\widetilde{M}^H(\eta,t)}{q^T(\eta,t)}\right]$ in line with the stability in safe asset share (Gorton, Lewellen, and Metrick, 2012).[44] $\xi = 1.1$, close to households' deposit-demand elasticity in other banking models, e.g., 1.4 from Begenau (2019).

The scaling function, $\beta\left(t\right)$, in households' liquidity utility is calibrated to match the trends of households' liquidity holdings relative to firms'. $\beta\left(t\right)$ is specified as

$$\beta_t = \beta_0 + \beta_1 t + \beta_2 t\, \mathbb{I}_{\{t>3\}}\,. \tag{29}$$

In data, the logarithm of households' holdings of intermediary debts has a structural break in its time trend at 1992 ($t = 3$ in the model), detected by supremum Wald test and LR test with p-values below 0.0001 (Andrews, 1993; Perron, 2006). I take logarithm because households' deposits grow exponentially along with capital stock (see (22)) and empirically households' holdings of intermediary debts also exhibit exponential growth.[45] It is important to include the structural break, as, without it, the match of households' liquidity holdings deteriorates significantly. The value of β_0 is chosen so that $\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^E(\eta,0)}{\widetilde{M}^H(\eta,0)}\right]$, i.e., the initial η-average ratio of entrepreneurs' to households' holdings of deposits matches the rolling average of data centering at 1989.[46] The value of β_1 is chosen so the average annual change of $\left\{\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^E(\eta,t)}{\widetilde{M}^H(\eta,t)}\right]\right\}_{t\leq 3}$ matches its empirical counterpart, and β_2 is set so

[44]The empirical counterpart is the ratio of nonfinancial firms' and households' holdings of intermediary debts (listed in Figure 2) to nonfinancial firms' fixed assets from U.S. Bureau of Economic Analysis (2019) (current-cost net stock). I subtract the value of intellectual properties to obtain tangible asset value.

[45]I also use supremum Wald and LR tests on the ratio of households' holdings of intermediary debts to total assets and detect a break in the level at 1992. Figure D.4 in Appendix C reports the data.

[46]Data is from Panel C of Figure 3. Figure 2 list the securities that map to deposits in the model.

Table 3—: Long-Term Trends and Endogenous Financial Risk

Time	Intangible Inv. Share $\mathbb{E}^{\eta}\left[\theta(\eta,t)\right]$	$\frac{\text{Firm Deposits}}{\text{Capital Value}}$ $\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^{E}(\eta,t)}{q^{T}(\eta,t)}\right]$	$\frac{\text{Firm Deposits}}{\text{HH Deposits}}$ $\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^{E}(\eta,t)}{\widetilde{M}^{H}(\eta,t)}\right]$	Interest Rate $\mathbb{E}^{\eta}\left[r\left(\eta,t\right)\right]$	Capital Valuation $\mathbb{E}^{\eta}\left[q^{T}\left(\eta,t\right)\right]$	Financial Risk Multiplier $\max_{\eta}\left\{\frac{\sigma^{T}(\eta,t)+\sigma}{\sigma}\right\}$
$t=0$	55.2%	7.6%	9.8%	3.24%	6.6	2.7
Data '90	54.4%	6.3%	9.6%	3.45%	6.8	
$t=4$	58.7%	8.5%	11.1%	2.11%	6.9	3.2
Data '94	58.2%	7.1%	10.8%	2.59%	6.9	
$t=8$	62.2%	8.2%	10.7%	0.95%	7.3	3.6
Data '98	61.9%	7.9%	12.2%	1.77%	7.3	
$t=12$	65.7%	9.2%	12.2%	-0.20%	7.6	4.0
Data '02	66.0%	8.4%	13.1%	0.97%	7.5	
$t=16$	69.1%	10.2%	13.7%	-1.50%	7.8	4.4
Data '06	69.1%	9.1%	13.8%	0.46%	7.7	
$t=20$	72.6%	10.4%	14.1%	-2.88%	7.9	4.7
Data '10	72.7%	9.7%	14.0%	-0.36%	8.0	

the average annual change of $\left\{\mathbb{E}^{\eta}\left[\frac{\widetilde{M}^{E}(\eta,t)}{\widetilde{M}^{H}(\eta,t)}\right]\right\}_{t>3}$ matches data.

The shock size, σ, is chosen so the model generates a volatility of bankers' return that matches data (Gornall and Strebulaev, 2018). Later, when conducting counterfactual analysis by shutting down the rise of intangibles, I will fix the exogenous risk, σ, and show how endogenous risk responds. The discount factor, ρ, is chosen so $\mathbb{E}^{\eta}\left[r\left(\eta,0\right)\right]$ matches the average rate of intermediary debts in 1989.[47] The capital depreciation rate, δ, is chosen so $\mathbb{E}^{\eta}\left[q^{T}\left(\eta,0\right)\right]$ matches the average EV/EBITDA ratio in 1989.[48] Capital generates one unit of goods per year, so $q_t^T = q_t^T/1$ is the ratio of capital value to its annual output. Because tangible capital produces all capitalizable output, its value maps to firms' enterprise value (EV), which is the present value of cash flows reflected in debt and equity markets. The calibration of ρ and δ fixes the starting points of interest rate and capital valuation but leaves their paths over time to be determined by equilibrium forces.

B. The Rise of Intangibles and Long-Run Trends

The results are in two categories, the economy's response to a rising κ_t^I over time (trends) and response to shocks, dZ_t (cycles). This subsection focuses on

[47] The interest rates are the real rates with CPI deflator from U.S. Bureau of Labor Statistics (1947–2020). The securities include: (1) jumbo and non-jumbo checking deposits, savings deposits, and certificate of deposits; (2) 3-month certificate of deposits; (3) 1-, 2-, and 3-month AA-rated financial commercial papers; (4) 3- and 6-month bankers acceptance; (5) 1-, 2-, and 3-month AA-rated asset-backed commercial papers; (6) Fed fund. The interest rates of these securities are from Board of Governors of the Federal Reserve System (US) (1980–2019). We also include GCF repo rates with Treasury securities, mortgage-backed securities, and agency- and GSE-backed securities as collateral from DTCC (2005–2019).

[48] The average is taken over median EV/EBITDA of 11 Fama-French nonfinanical sectors (Compustat).

the trends. Table 3 reports how the economy evolves over time. According to the calibration of κ_0^I and κ_1^I, the productivity of intangible investment, $\kappa^I(t)$, increases by around 1.6% per year. Firms tilt investment towards intangibles gradually over time, increasing θ_t from 55% to 73% over twenty years. Column 1 shows the model generates a trend in intangible share of investment that matches data closely in every year. Note that the calibration of κ_1^I targets the average rate of change but does not guarantee the match with data every year. The year-by-year match suggests that the model has a proper specification of intangible investment productivity and a proper mapping from investment productivity to the intangible share through the setup of firms' investment problem.

As θ_t increases, firms face a tighter financial constraint and hold more liquidity. The calibration of λ, the arrival rate of investment needs, targets the response of firms' liquidity-to-tangible asset ratio to variation in θ_t. In Column 2 of Table 3, the trend in $\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)}{q^T(\eta,t)}\right] = \mathbb{E}^\eta\left[\frac{M_t^E}{q_t^T K_t^T}\right]$ captures the well documented rise in firms' cash-to-asset ratio before 2010s. The ratio increased from 6.3% by more than 50% to 9.7% in data. In the model, it started at a higher level, 7.6%, and increased to 10.4%.[49] Later in the counterfactual analysis, I will examine how the economy responds when the rise of intangibles is shut down and the trend in firms' liquidity demand is muted. In this scenario, households' liquidity utility becomes the sole driver behind trends in liquidity demand. Therefore, it is important to match the relative dynamics of firms' vs. households' liquidity holdings in the baseline model. It is done through the calibration of households' liquidity utility as explained in Section IV.A. The results are reported in Column 3 of Table 3.

The rising intangible share of investment, θ_t, drives up the marginal value of liquidity, π_t, by tightening firms' financial constraint. The upward trend in π_t in turn leads to a downward trend in r_t, the yield on liquid assets in Column 4 of Table 3. The bankers take advantage of a lower funding cost and push up tangible capital value, q_t^T. Column 5 reports an upward trend in capital valuation that closely matches the data.[50] Importantly, these trends reinforce each other. A rising q_t^T further increases π_t and thereby lowers r_t (see Proposition 1). Multiplicity may arise due to the feedback effects: A solution has low r_t, high q_t^T, high π_t, and high θ_t while the other has high r_t, low q_t^T, low π_t, and low θ_t. The solution with θ_t closest to data is chosen.[51] Multiplicity helps explain why the rise of intangibles and related trends are largely a U.S. phenomenon.

As κ_t^I increases and the economy becomes more intangible-intensive, it also becomes increasingly fragile. By Itô's lemma, the total value of capitalizable

[49]The discrepancy in level is due to the omission of other determinants of firms' liquidity holdings that, unlike intangibles, do not exhibit trends over time. This paper focuses on intangible-induced trends.

[50]Tangible capital represents capitalizable production capacity. The ratio of q_t^T to one unit of goods produced per unit of time (one year) maps to EV-to-EBITDA ratio, since, by definition, enterprise value (EV) is the present value of capitalizable output of a firm, reflected in the debt and equity markets.

[51]Note that θ_t is still endogenous and optimally chosen by firms. If the firms' investment and liquidity management problems have not been properly specified, none of the solutions is likely to match data.

output, $q_t^T K_t^T$, evolves as

$$\frac{d\left(q_t^T K_t^T\right)}{q_t^T K_t^T} = \left(\mu_t^T - \delta - \lambda + \sigma_t^T \sigma\right) dt + \left(\sigma_t^T + \sigma\right) dZ_t \,, \tag{30}$$

A measure of endogenous risk is the ratio of total shock exposure of $q_t^T K_t^T$ (including σ_t^T, the endogenous volatility of q_t^T) to exogenous shock exposure, σ:

$$\textit{Financial Risk Multiplier}: \quad \frac{\sigma_t^T + \sigma}{\sigma} \,. \tag{31}$$

This ratio is a function of t and η_t (see Proposition 3). The last column of Table 3 reports the maximum (over η_t) at $t = 0, 4, ..., 20$. It also reports the corresponding years in data to show the model-implied accumulation of endogenous risk in real time. Over twenty years, the endogenous risk multiplier almost doubled as the economy became increasingly intangible-intensive.

Overall the solution matches data reasonably well except for a lower and more negative r_t in the 2000s. This may be explained by the omission of zero lower bound (ZLB) on nominal rates that binds in reality and, under nominal price rigidity, translates into a lower bound on real rates (Eggertsson and Woodford, 2003; Fischer, 2016; Korinek and Simsek, 2016; Caballero and Simsek, 2020). In fact, the model suggests that the rise of intangibles leads to a strong liquidity demand and thereby widens the wedge between the natural rate without nominal rigidity and the actual rate, exacerbating the liquidity trap at ZLB (Christiano, Eichenbaum, and Rebelo, 2011; Eggertsson and Krugman, 2012; Caballero and Farhi, 2017; Guerrieri and Lorenzoni, 2017). While the rise of intangibles is largely a U.S. phenomenon, the resultant liquidity trap may spread globally (Caballero, Farhi, and Gourinchas, 2021). Appendix C discusses the model mechanism under ZLB and its interactions with the forces in New Keynesian models.

C. Endogenous Financial Risk and Economic Fluctuation

This subsection focuses on economic fluctuations along the trend, driven by the intermediation intensity, η_t. Figure 5 plots six endogenous variables against η_t. The plots are for $t = 20$ (which maps to 2009 in data) and end at $\overline{\eta}(t)$, the endogenous upper boundary of η_t beyond which the bankers optimally consume (see Proposition 3). To understand the economy's response to shocks, first consider positive shocks that move η_t to the right. Panel A of Figure 5 plots the bankers' price of risk (or required Sharpe ratio) for holding tangible capital:

$$\gamma_t^B = \frac{\mathbb{E}_t\left[dr_t^T\right] - r_t}{\sigma_t^T + \sigma} \,, \tag{32}$$

which declines as η_t increases and eventually reaches zero at $\overline{\eta}(t)$. This implies a procyclical intermediation capacity. In Panel B, the discount rate for tangible

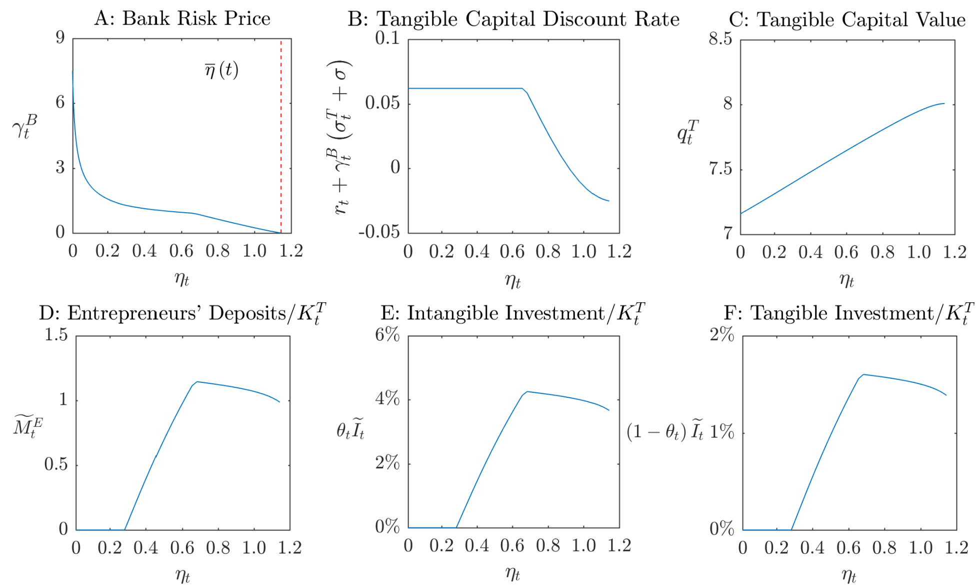

Figure 5. : Financial Cycle

capital, i.e., the expected return $\mathbb{E}\left[dr_t^T\right]$, is at ρ when η_t is low to clear the market by attracting demand from entrepreneurs and households whose discount rate is ρ. However, as η_t increases, bankers eventually hold all tangible capital and the discount rate falls below ρ. Recall that the cash flow of tangible capital is constant, so what drives the variation of q_t^T is the discount rate. Therefore, as the discount rate declines following positive shocks that increase η_t, the value of tangible capital, q_t^T, increases as shown in Panel C. Note that the increase of q_t^T in η_t is smooth even though the decrease of discount rate in η_t is not. Under rational expectation, q_t^T is forward-looking, so any increase of η_t raises the conditional probability of low discount-rate regions, and therefore, increases q_t^T.

As q_t^T increases, a feedback mechanism emerges. Investment becomes more profitable, and the leverage on liquidity is higher, so holding liquidity is more profitable. Therefore, entrepreneurs accept a lower r_t (Proposition 1), holding more deposits as shown in Panel D of Figure 5.[52] A lower r_t further reduces the bankers' discount rate, leading to an even higher q_t^T. In the process, the entrepreneurs hold more liquidity and invest more as shown in Panels E and F. Note that when scaled by K_t^T, the run-up of entrepreneurs' deposits and investments stops when the growth of the bankers' wealth outpaces that of the tangible capital value (bank asset value). When this occurs, bank equity crowds out debt on the balance sheet, causing a reduction in deposits/tangible capital.

[52]When $\eta_t < 0.28$ (1.7% probability), $M_t^E = 0$ and $r_t < \rho - \lambda\pi_t$ (i.e., (15) no longer holds). r_t is solved by equating households' demand and bankers' supply. See Appendix A.2

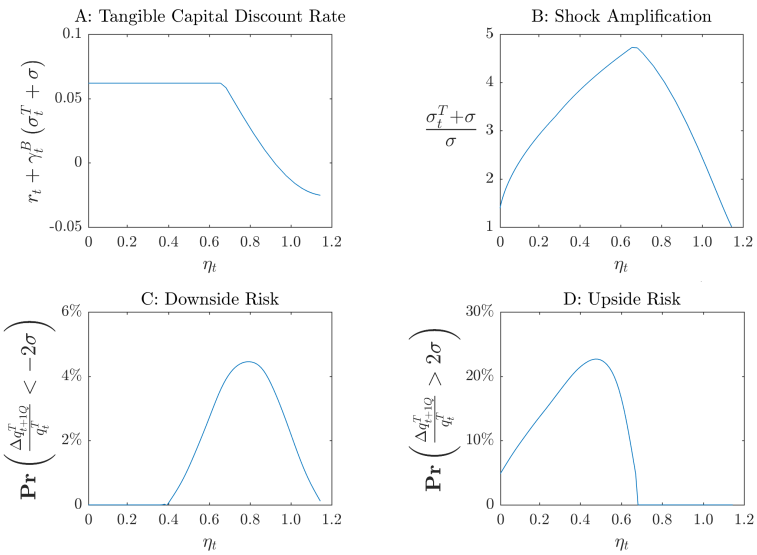

Figure 6. : Endogenous Financial Risk

The upward spiral triggered by positive shocks, $dZ_t > 0$, seems benign, featuring a boom of liquidity creation and investment. However, endogenous risk accumulates. Consider a value of η_t near zero in Panel A of Figure 6 (reproducing Panel B of Figure 5). The discount rate stays at ρ with a large probability. However, as we move to the right, η_t approaches the cutoff point where the discount rate falls below ρ. As a result, even small shocks can cause a large discount-rate change and variation of q_t^T. Therefore, q_t^T becomes more sensitive to shocks (i.e., higher σ_t^T) as η_t moves to the right. This explains why in Panel B of Figure 6, the risk multiplier, $(\sigma_t^T + \sigma)/\sigma$, is increasing in η_t. The amplification becomes stronger as booms prolong, so negative shocks trigger vicious downward spiral.[53] The mechanism eventually subdues as η_t approaches its upper bound where bankers are sufficiently rich and the sensitivity of discount rate to η_t diminishes.

The accumulation of endogenous risk in booms is asymmetric. Positive shocks trigger the reallocation of tangible capital to bankers with low discount rates but eventually cause them to consume wealth at $\overline{\eta}(t)$; in contrast, negative shocks cause a continuing reallocation of tangible capital away from bankers. Panels C and D plot respectively the probabilities of a 2σ decrease and a 2σ increase of q_t^T in one quarter.[54] Note that at sufficiently low (high) values of η_t, a further decrease (increase) by 2σ is impossible as it goes beyond the equilibrium range of q_t^T. Following positive shocks, the probability of a drop in q_t^T increases as η_t

[53]This mechanism offers a new explanation of the findings that long periods of banking expansion often precede severe crises (e.g., Jordà, Schularick, and Taylor, 2013; Baron and Xiong, 2017).

[54]Given the model solution, these probabilities can be calculated using the Feynman–Kac PDEs.

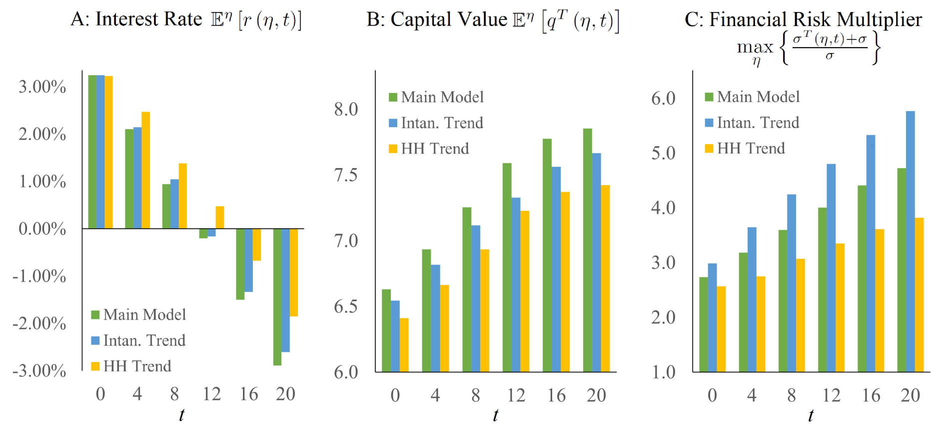

Figure 7. : Counterfactual Analysis

increases. It eventually declines as shock amplification weakens (Panel B). The probability of an increase in q_t^T also rises but declines earlier, suggesting that risk accumulation is downward biased. Following negative shocks, the economy moves leftward. The downside risk in q_t^T rises in Panel C, while the upside risk is relatively insensitive in Panel D. This offers a new explanation of why downside risks rise faster than upside risks as financial conditions deteriorate (Adrian, Boyarchenko, and Giannone, 2019).

D. *Counterfactual Analysis*

I construct two hypothetical scenarios to examine the quantitative importance of the rise of intangibles. In *Intan. Trend*, the increase of intangible investment productivity is kept while the trend in households' liquidity demand is muted (i.e., $\beta_1 = 0$ and $\beta_2 = 0$). In *HH Trend*, the increase of intangible investment productivity is muted (i.e., $\kappa_1^I = 0$) while the trend in households' liquidity demand remains. *HH Trend* sets a benchmark of the literature on households' liquidity demand and its implications on interest rate, asset price, and financial instability (Kiyotaki and Moore, 2000; Krishnamurthy and Vissing-Jørgensen, 2015; Piazzesi and Schneider, 2016; Moreira and Savov, 2017; Begenau and Landvoigt, 2018; Van den Heuvel, 2018; Begenau, 2019; Egan, Lewellen, and Sunderam, 2021).

Panel A and B of Figure 7 show respectively the trends of interest rate, $\mathbb{E}^{\eta}[r(\eta,t)]$, and asset price (tangible capital value), $\mathbb{E}^{\eta}\left[q^T(\eta,t)\right]$ for the three scenarios. A common pattern emerges: Removing the trend in intangibles (*HH Trend*) moderates the downward trend in interest rate and upward trend asset price more than removing the trend in households' liquidity demand (*Intan. Trend*) does. This suggests the trend in firms' demand for liquid assets driven by the rise of intangibles is a more potent force than households' liquidity demand.

The greater quantitative importance of firms' liquidity demand seems puzzling given the fact that firms' liquidity holdings are only 1/7 that of households by $t = 20$ and 1/10 at $t = 0$ both in the baseline model and data. This observation ignores the fact that once the trend in households' liquidity needs is removed, the firms' liquidity holdings will increase in equilibrium and rise faster over time in the absence of households' competition. The counterfactual, *Intan. Trend*, does not and should not fix the equilibrium level of firms' liquidity holdings to that of the main model. What should be fixed are the parameters underlying firms' liquidity management problems; likewise, in *HH Trend*, households' liquidity holdings increase in the absence of firms' competition as the rise of intangibles is shut down while parameters in households' liquidity utility are fixed.

In Panel C of Figure 7, *Intan. Trend* generates the most endogenous risk, the main model the second highest, and *HH Trend* the lowest, and the wedges widen over time as the different trends in the three models unfold. This finding is particularly interesting because one would have expected the main model to generate the most endogenous risk by having both firms' and households' liquidity needs trending up over time and feeding leverage to bankers. The key to understanding this result is the distinct cyclical property of firms' and households' liquidity demand. Consider positive shocks. The subsequent increase in q_t^T encourages the firms to save more as investment becomes more profitable and the leverage on liquidity holdings, backed by tangible capital, increases. The increase of liquidity value, π_t, drives down r_t. As r_t declines, the households' liquidity holdings decrease, counteracting the increase in firms' liquidity demand (see (22)). Following negative shocks, the opposite happens: q_t^T and π_t decline, resulting in a higher r_t that induces households to hold more liquidity, counteracting the decrease in firms' demand. In sum, firms' liquidity demand exhibits procyclicality, while the households' demand features countercyclicality.[55] In the main model, the two forces act against each other, while in *Intan. Trend*, there is only an upward trend in firms' demand for liquid assets so its procyclicality is fully unleashed.

Section 2 provides evidence that firms' liquidity demand increases in asset valuation, i.e., the procyclicality key to the quantitative importance of intangible-driven liquidity needs. Next, I show that households' demand for liquid assets decreases in measures of asset valuation, counteracting the procyclicality in firms' liquidity demand as in the model. For time-series regressions in Panel A of Table 4, the dependent variable is quarterly household holdings of intermediary debts scaled by GDP from 1980 to 2019.[56] The explanatory variables are measures of capital valuation (see Section 2) and housing price-to-rent ratio.[57] Summary statistics are reported in Appendix D. Column (6) shows that financial-market and housing valuations together explain 31% of variation.

[55]The countercycality is in line with flight to safety in crises (Caballero and Krishnamurthy, 2008).

[56]Data is from Financial Accounts of the United States (2019). Intermediary debts are listed in Figure 2 and indirect holdings via money-market funds and mutual funds are attributed to underlying securities.

[57]It is the ratio of two variables: (1) All-Transactions House Price Index for the U.S. from the U.S. Federal Housing Finance Agency (1975–2020); (2) Consumer Price Index for Urban Consumers: Rent of Primary Residence in U.S. City Average from the U.S. Bureau of Labor Statistics (1975–2020).

Table 4—: Asset Valuations and Household Holdings of Intermediaries' Debts

***Panel A**: Regression Analysis of Aggregate Data*

LHS: HH Holdings of Intermediary Debts scaled by GDP	(1)	(2)	(3)	(4)	(5)	(6)
RHS: Financial-Market Valuation Metrics =	Tangible EV/EBITDA	Average EV/EBITDA	Tangible Tobin's Q	Average Tobin's Q		Tangible EV/EBITDA
Financial-Market Valuation	-0.017***	-0.010***	-0.190***	-0.095***		-0.016***
	(0.002)	(0.002)	(0.019)	(0.012)		(0.002)
Housing-Market Valuation (Price/Rent)					-0.142***	-0.060**
					(0.024)	(0.024)
Observations	160	160	160	160	160	160
Adjusted R^2	0.3015	0.1953	0.2880	0.2456	0.0771	0.3138

Heteroscedasticity-consistent standard errors in parentheses
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

***Panel B**: Regression Analysis of Micro Data*

LHS: HH Cash Holdings scaled by Income	(1)	(2)	(3)	(4)	(5)	(6)
Δ ln (Housing Price Index)	-0.059	-0.119***	-0.114***	-0.046	-0.086***	-0.081**
	(0.045)	(0.040)	(0.040)	(0.037)	(0.031)	(0.039)
Controls	No	No	No	Yes	Yes	Yes
Household FE	No	Yes	Yes	No	Yes	Yes
State FE	No	No	Yes	No	No	Yes
Year FE	No	No	Yes	No	No	Yes
Observations	70,442	70,032	70,032	65,280	65,215	65,215
Adjusted R^2	0.0001	0.2389	0.2495	0.1370	0.3438	0.3510

State-time clustered standard errors in parentheses
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

The analysis of aggregate data has a small sample size and does not utilize cross-sectional variations. Next, I use household-level data from Panel Study of Income Dynamics (PSID, 2019).[58] The financial-market valuation metrics do not have regional variation and thus excluded. PSID reports biannual information on households' financials from 1999 to 2017.[59] The dependent variable is the liquidity holdings normalized by household income. The explanatory variable of interest is the log difference of state-level home price index from (Federal Housing Finance Agency (FHFA), 2019).[60] Rent data are unavailable so the log difference is taken to address apparent non-stationarities in these house prices. Panel B of Table 4 reports a statistically significant negative response of households' liquidity holdings to an increase in house prices, robust to different combinations of control

[58]The collection of data used in this study was partly supported by the National Institutes of Health under grant number R01 HD069609 and R01 AG040213, and the National Science Foundation under award numbers SES 1157698 and 1623684.

[59]Liquidity holdings include checking/savings deposits, money market funds, certificates of deposit, Treasury securities (not including I.R.A.). A breakdown into instruments issued by intermediaries and the government is unavailable, but as shown in Figure D.3 in Appendix C, Treasury securities account for less than 15%. Related, to analyze households' mortgage refinancing behavior, Chen, Michaux, and Roussanov (2020) use data from Financial Accounts of the U.S. for time-series analysis and PSID (including households' liquidity holdings) for panel-data analysis. The regression samples starts in 2001 because the calculation of log difference requires housing price.

[60]U.S. state abbreviation and FIPS codes are from Federal Communications Commission (FCC, 2019).

Table 5—: Intangible Capital and Credit Constraint

Leverage = $\frac{\text{Debts}}{\text{Assets}}$	Intangibility = Intan./Assets (decile)			Intangiblity = – PPE/Assets (decile)		
	(1) Total Debts	(2) Asset-Based Loans	(3) Cash Flow-Based Loans	(4) Total Debts	(5) Asset-Based Loans	(6) Cash Flow-Based Loans
Intangibility	-1.219***	-0.745***	-0.715***	-0.914***	-0.728***	-0.158
	(0.092)	(0.083)	(0.197)	(0.090)	(0.076)	(0.118)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	114,626	39,750	39,819	114,608	39,749	39,818
Adjusted R^2	0.2159	0.0891	0.1298	0.2116	0.0934	0.1263

Firm-year clustered standard errors in parentheses
$* \ p < 0.1$ $** \ p < 0.05$ $*** \ p < 0.01$

variables and fixed effects (FE).[61] Including control variables and fixed effects increases the adjusted R^2 to above 34% (in Columns (5) and (6)) by reducing noise, allowing the correlation to emerge between households' liquidity holdings and housing price variation. The evidence suggests that in line with the model setup, households' liquidity holdings respond negatively to asset-price increase, opposite to the positive response in firms' liquidity holdings (see Section 2).

V. Extension: Intangible Capital of Limited Pledgeability

The key friction in the model is limited pledgeability of intangibles. Column (1) and (4) of Table 5 show that more intangible firms borrow less, which indicates tighter credit constraints. The sample is from Section 2 with debt classification data from Lian and Ma (2020b).[62] For different measures of intangibility, Columns (2) and (5) and Columns (3) and (6) show, respectively, that intangible firms are constrained in borrowing backed by both collateral and cash flow.

As the U.S. economy becomes more intangible-intensive, the legal system develops to improve the pledgeability of intangibles. This section presents an extension: When hit by the Poisson shock, an entrepreneur may raise funds from households against χ fraction of intangible capital as collateral.[63] The repayment is in the form of intangible capital ownership.[64] Equivalently, the entrepreneur may sell

[61] Following studies on household consumption-savings decisions and portfolio allocation (Bergstresser and Poterba, 2004; Campbell and Cocco, 2007; Bogan, 2015; Chetty, Sándor, and Sziedl, 2017; Stroebel and Vavra, 2019), I construct the following control variables using PSID data: the log difference of total household income, the log difference of total household wealth, the number of people in a household, the age of household head, the education level of household head, a homeowner dummy, and a couple dummy (equal to one if the household head lives with a partner). I consider household, state, and year fixed effects. Note that the number of observations decline after household FE is added because 65 households only appear once in the panel. Appendix C provides summary statistics.

[62] Control variables are included following Lian and Ma (2020a) who share their loan categorization data: Size (log total assets in 2005 dollars); market-to-book ratio; cash-to-asset ratio; EBITDA-to-asset ratio ([sale – cogs – xsga]/at); net cash receipts-to-asset ratio ([oancf + xint]/at); inventory-to-asset ratio (invt/at). Time fixed effects are added to absorb common variations, such as tax and regulatory changes.

[63] Financing for intangibles often comes from venture capital funds (VC). Akcigit, Dinlersoz, Greenwood, and Penciakova (2019) examine the role of VC in creating endogenous growth.

[64] Alternatively, the entrepreneur can promise to repay all the future goods produced by the intan-

Table 6—: Pledgeable Intangibles and the Reinforcing Trends

Time	Intangible Inv. Share $\mathbb{E}^\eta[\theta(\eta,t)]$	$\frac{\text{Firm Deposits}}{\text{Capital Value}}$ $\mathbb{E}^\eta\left[\frac{\widetilde{M}^E(\eta,t)}{q^T(\eta,t)}\right]$	Interest Rate $\mathbb{E}^\eta[r(\eta,t)]$	Capital Valuation $\mathbb{E}^\eta\left[q^T(\eta,t)\right]$	Financial Risk Multiplier $\max_\eta\left\{\frac{\sigma^T(\eta,t)+\sigma}{\sigma}\right\}$
Model $t=0$	55.2%	7.6%	3.24%	6.6	2.7
Pledgeable Intan.	57.3%	27.3%	2.58%	7.8	3.6
Model $t=4$	58.7%	8.5%	2.11%	6.9	3.2
Pledgeable Intan.	61.8%	30.4%	1.06%	8.5	4.4
Model $t=8$	62.2%	8.2%	0.95%	7.3	3.6
Pledgeable Intan.	66.6%	33.2%	-0.64%	9.2	5.2
Model $t=12$	65.7%	9.2%	-0.20%	7.6	4.0
Pledgeable Intan.	71.6%	36.2%	-2.59%	9.9	6.0
Model $t=16$	69.1%	10.2%	-1.50%	7.8	4.4
Pledgeable Intan.	76.9%	38.8%	-4.81%	10.4	6.8
Model $t=20$	72.6%	10.4%	-2.88%	7.9	4.7
Pledgeable Intan.	82.7%	42.1%	-7.32%	10.7	7.6

intangible capital rather than pledge it as collateral. It is assumed that bankers do not lend against intangibles or own intangibles.[65] In practice, intangibles are mainly financed by non-bank intermediaries (e.g., venture capital funds).

The improved pledgeability of intangibles relax the funding constraint:

$$i_t \leq m_t^E + q_t^T \kappa^T (1-\theta_t)\, i_t + \chi\left(q^I \kappa_t^I \theta_t i_t\right). \tag{33}$$

The calibration of χ is based on the percentage of marketable intangibles. Among different categories of intangible capital, intellectual properties have relatively clear market value (around 16% of patents according to Akcigit, Celik, and Greenwood (2016)). Intellectual properties accounted for 37.7% of intangible investment in the U.S. (Corrado et al., 2016). Therefore, χ is calibrated to be $6.0\% = 37.7\% \times 16\%$. This value is in the same magnitude as the value implied by the findings in Mann (2018): 38% of US patenting firms had previously pledged patents as collateral for financing, and these firms account for 20% of R&D expense and patenting in Compustat, so $\chi = 38\% \times 20\% = 7.6\%$.

Table 6 shows that the improved pledgeability of intangibles amplifies the mechanism. The intangible share of investment is higher, and its increase over time becomes convex. In contrast, the main model produces a linear trend. The differ-

gible, which have the same present value as the intangible capital itself. Given risk-neutral preference, households are indifferent between owning intangible capital now or owning the steam of goods.

[65]Intangible capital is still less liquid than tangible capital due to search friction in patent trading (Akcigit, Celik, and Greenwood, 2016): (1) the market is specialized (often involving lawyers as middlemen); (2) the sensitivity of intellectual property makes potential participants reluctant to reveal information.

ence widens from 2.1% at $t = 0$ to 10.1% by $t = 20$. The improved pledgeability of intangibles increases the leverage on liquidity holdings and the marginal value of liquidity. The feedback mechanism is strengthened, resulting in a much higher level and faster growth of entrepreneurs' liquidity holdings, a sharper decline of the interest rate, and a stronger upward trend in the value of tangible capital. The financial risk multiplier is higher than that of the main model as shown in the last column of Table 6. A lower level of the interest rate widens the discount-rate wedge between bankers and the rest of the economy, making the value of tangible capital more sensitive to shocks that trigger reallocation between the two groups. The concave upward trend in financial risk multiplier in the main model becomes a linear trend once intangibles become more pledgeable. A more volatile tangible capital value translates into more volatile liquidity creation and investment.

VI. Conclusion

The transition towards an intangible-intensive economy has a profound impact on financial system. This paper provides a coherent account of several trends in the U.S. that emerged from the rise of intangibles, such as the accumulation of corporate cash holdings, growth of financial intermediation sector, declining interest rate, and rising valuation of risky assets. At the core of the model is the endogenous supply and demand for liquid assets. To finance intangible investment, firms hold cash in the form of financial intermediaries' debts. Firms' growing demand for liquid assets, driven by intangible investment needs, pushes down the interest rate and feeds cheap leverage to intermediaries, allowing intermediaries to bid up the market value of collateral assets that back debt issuances. The model characterizes a self-enforcing mechanism that connects these trends, and the feedback mechanism also amplifies economic fluctuations along the trends.

An interesting direction for future research is to incorporate nominal frictions. The savings glut leads to a negative real rate in the model that, under low inflation, implies a binding lower bound on the nominal rates. Therefore, the rise of intangibles exacerbates the liquidity trap (Eggertsson and Woodford, 2003; Fischer, 2016; Christiano, Eichenbaum, and Rebelo, 2011; Eggertsson and Krugman, 2012; Caballero and Farhi, 2017; Guerrieri and Lorenzoni, 2017; Caballero and Simsek, 2020). A liquidity trap in one country can spread to the rest of the world (Caballero, Farhi, and Gourinchas, 2021), so the U.S. economy becoming more intangible-intensive has broader implications on the global financial system.

The interaction between industrial structure and financial system deserves more attention in future research. While this paper focuses on how the transition to an intangible-intensive economy affects financial system, a growing financial sector may also affect industrial structure. When financial intermediaries becomes more productive, it extends more credit (asset side of balance sheets) and issues more money-like securities (liability side of balance sheets). The former facilitates tangible investment, which is often credit-financed, while the latter facilitates intangible investment by providing firms with storage of internal funds. A bias in productivity improvement towards the liability side contributes to faster growth of intangible capital. This seems to be the case in the run-up to the global financial crisis, as the development of shadow banking allows more effective creation of near-money assets that firms hold via money market funds and other vehicles.

REFERENCES

Adrian, T., N. Boyarchenko, and D. Giannone (2019). Vulnerable growth. *American Economic Review 109*(4), 1263–89.

Adrian, T., N. Boyarchenko, and H. S. Shin (2016). On the scale of financial intermediaries. Staff Reports 743, Federal Reserve Bank of New York.

Adrian, T. and H. S. Shin (2010). The changing nature of financial intermediation and the financial crisis of 2007-09. Staff Reports 430, Federal Reserve Bank of New York.

Aghion, P., U. Akcigit, and P. Howitt (2014). Chapter 1 - what do we learn from schumpeterian growth theory? In P. Aghion and S. N. Durlauf (Eds.), *Handbook of Economic Growth*, Volume 2 of *Handbook of Economic Growth*, pp. 515 – 563. Elsevier.

Ai, H., M. M. Croce, and K. Li (2013). Toward a quantitative general equilibrium asset pricing model with intangible capital. *The Review of Financial Studies 26*(2), 491–530.

Akcigit, U., M. A. Celik, and J. Greenwood (2016). Buy, keep, or sell: Economic growth and the market for ideas. *Econometrica 84*(3), 943–984.

Akcigit, U., E. Dinlersoz, J. Greenwood, and V. Penciakova (2019). Synergizing ventures. Working Paper 26196, National Bureau of Economic Research.

Almeida, H. and M. Campello (2007). Financial constraints, asset tangibility, and corporate investment. *Review of Financial Studies 20*(5), 1429–1460.

Andrews, D. W. K. (1993). Tests for parameter instability and structural change with unknown change point. *Econometrica 61*(4), 821–856.

Atkeson, A. and P. J. Kehoe (2005). Modeling and measuring organization capital. *Journal of Political Economy 113*(5), 1026–1053.

Bacchetta, P. and K. Benhima (2015). The demand for liquid assets, corporate saving, and international capital flows. *Journal of the European Economic Association 13*(6), 1101–1135.

Bansal, R. and A. Yaron (2004). Risks for the long run: A potential resolution of asset pricing puzzles. *The Journal of Finance 59*(4), 1481–1509.

Baron, M. (2014). Countercyclical bank equity issuance. Working paper, Princeton University.

Baron, M. and W. Xiong (2017). Credit expansion and neglected crash risk. *The Quarterly Journal of Economics 132*(2), 713–764.

Basel Committee on Banking Supervision (2014). Basel III: The Net Stable Funding Ratio. Technical report, Bank for International Settlements.

Bates, T. W., K. M. Kahle, and R. M. Stulz (2009). Why do U.S. firms hold so much more cash than they used to? *The Journal of Finance 64*(5), 1985–2021.

Baumol, W. J. (1967). Macroeconomics of unbalanced growth: The anatomy of urban crisis. *The American Economic Review 57*(3), 415–426.

Begenau, J. (2019). Capital requirements, risk choice, and liquidity provision in a business-cycle model. *Journal of Financial Economics*.

Begenau, J. and T. Landvoigt (2018). Financial regulation in a quantitative model of the modern banking system. Working paper, Stanford and Wharton.

Begenau, J. and B. Palazzo (2021). Firm selection and corporate cash holdings. *Journal of Financial Economics 139*(3), 697–718.

Belo, F., X. Lin, and M. A. Vitorino (2014). Brand capital and firm value. *Review of Economic Dynamics 17*(1), 150 – 169.

Bena, J. and L. Garlappi (2019). Corporate Innovation and Returns. *The Review of Corporate Finance Studies 9*(2), 340–383.

Bergstresser, D. and J. Poterba (2004). Asset allocation and asset location: household evidence from the survey of consumer finances. *Journal of Public Economics 88*(9), 1893 – 1915.

Bernanke, B. S. (2005). The global saving glut and the U.S. current account deficit. Remarks given at the sandridge lecture, Virginia Association of Economists, Richmond, March 10.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). Chapter 21 the financial accelerator in a quantitative business cycle framework. Volume 1 of *Handbook of Macroeconomics*, pp. 1341 – 1393. Elsevier.

Blanchard, O. and J. Simon (2001). The long and large decline in u.s. output volatility. *Brookings Papers on Economic Activity 2001*(1), 135–164.

Board of Governors of the Federal Reserve System (US) (1980–2019). Various interest rates, retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/ (accessed on September 25, 2021).

Bogan, V. L. (2015). Household asset allocation, offspring education, and the sandwich generation. *American Economic Review 105*(5), 611–15.

Bolton, P., H. Chen, and N. Wang (2011). A unified theory of Tobin's q, corporate investment, financing, and risk management. *The Journal of Finance 66*(5), 1545–1578.

Bolton, P. and X. Freixas (2000). Equity, bonds, and bank debt: Capital structure and financial market equilibrium under asymmetric information. *Journal of Political Economy 108*(2), 324–351.

Bolton, P., T. Santos, and J. A. Scheinkman (2018). Savings gluts and financial fragility. Working paper, Columbia University.

Bolton, P., N. Wang, and J. Yang (2019). Optimal contracting, corporate finance, and valuation with inalienable human capital. *The Journal of Finance 74*(3), 1363–1429.

Brunnermeier, M. K. and Y. Sannikov (2014). A macroeconomic model with a financial sector. *American Economic Review 104*(2), 379–421.

Brunnermeier, M. K. and Y. Sannikov (2016). The I theory of money. Working paper, Princeton University.

Caballero, R. J. (2006). On the macroeconomics of asset shortages. Working Paper 12753, National Bureau of Economic Research.

Caballero, R. J. and E. Farhi (2017). The Safety Trap. *The Review of Economic Studies 85*(1), 223–274.

Caballero, R. J., E. Farhi, and P. Gourinchas (2008). An equilibrium model of "global imbalances" and low interest rates. *American Economic Review 98*(1), 358–93.

Caballero, R. J., E. Farhi, and P. Gourinchas (2017a). Rents, technical change, and risk premia: Accounting for secular trends in interest rates, returns on capital, earning yields, and factor shares. Working Paper 23127, National Bureau of Economic Research.

Caballero, R. J., E. Farhi, and P. Gourinchas (2017b). The safe assets shortage conundrum. *Journal of Economic Perspectives 31*(3), 29–46.

Caballero, R. J., E. Farhi, and P.-O. Gourinchas (2021). Global Imbalances and Policy Wars at the Zero Lower Bound. *The Review of Economic Studies 88*(6), 2570–2621.

Caballero, R. J. and A. Krishnamurthy (2006). Bubbles and capital flow volatility: Causes and risk management. *Journal of Monetary Economics 53*(1), 35–53.

Caballero, R. J. and A. Krishnamurthy (2008). Collective risk management in a flight to quality episode. *The Journal of Finance 63*(5), 2195–2230.

Caballero, R. J. and A. Krishnamurthy (2009). Global imbalances and financial fragility. *American Economic Review 99*(2), 584–88.

Caballero, R. J. and A. Simsek (2020). A Risk-Centric Model of Demand Recessions and Speculation. *The Quarterly Journal of Economics 135*(3), 1493–1566.

Caballero, R. J. and A. Simsek (2021). A Model of Endogenous Risk Intolerance and LSAPs: Asset Prices and Aggregate Demand in a "COVID-19" Shock. *The Review of Financial Studies 34*(11), 5522–5580.

Campbell, J. Y. and J. F. Cocco (2007). How do house prices affect consumption? evidence from micro data. *Journal of Monetary Economics 54*(3), 591 – 621.

Carlson, M., B. Duygan-Bump, F. Natalucci, B. Nelson, M. Ochoa, J. Stein, and S. Van den Heuvel (2016). The demand for short-term, safe assets and financial stability: Some evidence and implications for central bank policies. *International Journal of Central Banking 12*(4), 307–333.

Center for Research in Security Prices (CRSP) (2019). *CRSP/CompustatMerged Database*. Wharton Research Data Services.

Chen, H., M. Michaux, and N. Roussanov (2020). Houses as ATMs: Mortgage refinancing and macroeconomic uncertainty. *The Journal of Finance 75*(1), 323–375.

Chen, P., L. Karabarbounis, and B. Neiman (2017). The global rise of corporate saving. *Journal of Monetary Economics 89*, 1–19.

Chetty, R., L. Sándor, and A. Sziedl (2017). The effect of housing on portfolio choice. *The Journal of Finance 72*(3), 1171–1212.

Christiano, L., M. Eichenbaum, and S. Rebelo (2011). When is the government spending multiplier large? *Journal of Political Economy 119*(1), 78–121.

Cochrane, J. (2005a). Financial markets and the real economy. Working Paper 11193, National Bureau of Economic Research.

Cochrane, J. H. (2005b). *Asset Pricing*. Princeton University Press.

Corhay, A., H. Kung, and L. Schmid (2019). Q: Risk, rents, or growth? Working paper.

Corrado, C., J. Haskel, C. Jona-Lasinio, and M. Iommi (2016). Intangible investment in the eu and us before and since the great recession and its contribution to productivity growth. Working Paper 2016/08, European Investment Bank.

Corrado, C., C. Hulten, and D. Sichel (2009). Intangible capital and U.S. economic growth. *Review of Income and Wealth 55*(3), 661–685.

Corrado, C. A. and C. R. Hulten (2010). How do you measure a "technological revolution"? *American Economic Review 100*(2), 99–104.

Crouzet, N. and J. Eberly (2018). Understanding weak capital investment: the role of market concentration and intangibles. Working paper, Northwestern University.

Dang, T. V., G. Gorton, B. Holmström, and G. Ordoñez (2017). Banks as secret keepers. *American Economic Review 107*(4), 1005–29.

Daniel, N. D., L. Naveen, and J. Yu (2018). Changing U.S. economy and investment-cash flow sensitivity. Working paper, 2018 CityU of Hong Kong International Finance Conference.

Décamps, J.-P., T. Mariotti, J.-C. Rochet, and S. Villeneuve (2011). Free cash flow, issuance costs, and stock prices. *The Journal of Finance 66*(5), 1501–1544.

Del Negro, M., D. Giannone, M. Giannoni, and A. Tambalotti (2017). Safety, liquidity, and the natural rate of interest. Staff Reports 812, Federal Reserve Bank of New York.

Dell'Ariccia, G., D. Kadyrzhanova, C. Minoiu, and L. Ratnovski (2018). Bank lending in the knowledge economy. Working paper, International Monetary Fund.

Denis, D. J. and V. Sibilkov (2010). Financial constraints, investment, and the value of cash holdings. *Review of Financial Studies 23*(1), 247–269.

Di Tella, S. (2017). Uncertainty shocks and balance sheet recessions. *Journal of Political Economy 125*(6), 2038–2081.

Diamond, D. W. (1984). Financial intermediation and delegated monitoring. *The Review of Economic Studies 51*(3), 393–414.

Diamond, D. W. and P. H. Dybvig (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy 91*(3), 401–419.

Doms, M. and T. Dunne (1998). Capital adjustment patterns in manufacturing plants. *Review of Economic Dynamics 1*(2), 409 – 429.

Döttling, R. and E. C. Perotti (2017). Secular Trends and Technological Progress. Discussion Papers 12519, CEPR.

DTCC (2005–2019). Various interest rates, retrieved from DTCC, Depository Trust and Clearing Corporation; https://www.dtcc.com/charts/dtcc-gcf-repo-index (accessed on September 25, 2021).

Duchin, R. (2010). Cash holdings and corporate diversification. *The Journal of Finance 65*(3), 955–992.

Duffie, D. (2001). *Dynamic Asset Pricing Theory.* Princeton University Press.

Eberly, J. and N. Wang (2008). Reallocating and pricing illiquid capital: Two productive trees. Working paper, Columbia University.

Egan, M., S. Lewellen, and A. Sunderam (2021, 08). The Cross-Section of Bank Value. *The Review of Financial Studies 35*(5), 2101–2143.

Eggertsson, G. B. and P. Krugman (2012). Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach*. *The Quarterly Journal of Economics 127*(3), 1469–1513.

Eggertsson, G. B., J. A. Robbins, and E. G. Wold (2018). Kaldor and Piketty's facts: The rise of monopoly power in the united states. Working Paper 24287, National Bureau of Economic Research.

Eggertsson, G. B. and M. Woodford (2003). The zero bound on interest rates and optimal monetary policy. *Brookings Papers on Economic Activity 2003*(1), 139–211.

Eisfeldt, A. and A. Rampini (2009). Financing shortfalls and the value of aggregate liquidity. Working paper, Duke University.

Eisfeldt, A. L. (2007). Smoothing with liquid and illiquid assets. *Journal of Monetary Economics 54*(6), 1572 – 1586.

Eisfeldt, A. L. and T. Muir (2016). Aggregate external financing and savings waves. *Journal of Monetary Economics 84*, 116 – 133.

Eisfeldt, A. L. and D. Papanikolaou (2013). Organization capital and the cross-section of expected returns. *The Journal of Finance 68*(4), 1365–1406.

Falato, A., D. Kadyrzhanovaz, J. Sim, and R. Steri (2018). Rising intangible capital, shrinking debt capacity, and the us corporate savings glut. Technical report, Board of Governors of the Federal Reserve System (U.S.).

Farhi, E. and F. Gourio (2018). Accounting for macro-finance trends: Market power, intangibles, and risk premia. Working Paper 25282, National Bureau of Economic Research.

Farhi, E. and J. Tirole (2011). Bubbly Liquidity. *The Review of Economic Studies 79*(2), 678–706.

Federal Communications Commission (FCC) (2019). *State Abbreviation and Federal Information Processing System (FIPS) Codes.*

Federal Housing Finance Agency (FHFA) (2019). *FHFA House Price Index.*

Financial Accounts of the United States (2019). *Financial Reserve Statistical Release Z.1.* Board of Governors of the Federal Reserve System.

Fischer, S. (2016). Monetary policy, financial stability, and the zero lower bound. *American Economic Review 106*(5), 39–42.

Froot, K. A., D. S. Scharfstein, and J. C. Stein (1993). Risk management: Coordinating corporate investment and financing policies. *The Journal of Finance 48*(5), 1629–1658.

Gao, X., T. M. Whited, and N. Zhang (2020, 08). Corporate Money Demand. *The Review of Financial Studies 34*(4), 1834–1866.

Gârleanu, N., L. Kogan, and S. Panageas (2012). Displacement risk and asset returns. *Journal of Financial Economics 105*(3), 491–510.

Gertler, M. and N. Kiyotaki (2010). Chapter 11 - financial intermediation and credit policy in business cycle analysis. Volume 3 of *Handbook of Monetary Economics*, pp. 547 – 599. Elsevier.

Giglio, S. and T. Severo (2012). Intangible capital, relative asset shortages and bubbles. *Journal of Monetary Economics 59*(3), 303 – 317.

Goldstein, I. and A. Pauzner (2005). Demand-deposit contracts and the probability of bank runs. *The Journal of Finance 60*(3), 1293–1327.

Gornall, W. and I. A. Strebulaev (2018). Financing as a supply chain: The capital structure of banks and borrowers. *Journal of Financial Economics 129*(3), 510 – 530.

Gorton, G., S. Lewellen, and A. Metrick (2012). The safe-asset share. *American Economic Review 102*(3), 101–06.

Gorton, G. and G. Ordoñez (2014). Collateral crises. *American Economic Review 104*(2), 343–78.

Gorton, G. and G. Ordoñez (2020). Good Booms, Bad Booms. *Journal of the European Economic Association 18*(2), 618–665.

Gorton, G. and G. Pennacchi (1990). Financial intermediaries and liquidity creation. *The Journal of Finance 45*(1), 49–71.

Gourinchas, P. and H. Rey (2016). Real interest rates, imbalances and the curse of regional safe asset providers at the zero lower bound. Working Paper 22618, National Bureau of Economic Research.

Graham, J. R. and M. T. Leary (2018). The Evolution of Corporate Cash. *The Review of Financial Studies 31*(11), 4288–4344.

Greenwood, R. and D. Scharfstein (2013). The growth of finance. *Journal of Economic Perspectives 27*(2), 3–28.

Guerrieri, V. and G. Lorenzoni (2017). Credit Crises, Precautionary Savings, and the Liquidity Trap. *The Quarterly Journal of Economics 132*(3), 1427–1467.

Gutiérrez, G. and T. Philippon (2017). Declining competition and investment in the u.s. Working Paper 23583, National Bureau of Economic Research.

Hall, B. H. (1992). Investment and research and development at the firm level: Does the source of financing matter? Working Paper 4096, National Bureau of Economic Research.

Hall, B. H. and J. Lerner (2009). The financing of R&D and innovation. Working Paper 15325, National Bureau of Economic Research.

Hansen, L., J. Heaton, and N. Li (2008). Consumption strikes back? measuring long-run risk. *Journal of Political Economy 116*(2), 260–302.

Hansen, L. P., J. C. Heaton, and N. Li (2005). Intangible Risk. In *Measuring Capital in the New Economy*, NBER Chapters, pp. 111–152. National Bureau of Economic Research, Inc.

Hart, O. and J. Moore (1994). A Theory of Debt Based on the Inalienability of Human Capital. *The Quarterly Journal of Economics 109*(4), 841–879.

Hart, O. and L. Zingales (2014). Banks are where the liquidity is. Working paper, Harvard University.

He, Z. and P. Kondor (2016). Inefficient investment waves. *Econometrica 84*(2), 735–780.

He, Z. and A. Krishnamurthy (2013). Intermediary asset pricing. *American Economic Review 103*(2), 732–70.

Herrendorf, B., R. Rogerson, and Ákos Valentinyi (2013). Two perspectives on preferences and structural transformation. *The American Economic Review 103*(7), 2752–2789.

Himmelberg, C. P. and B. C. Petersen (1994). R&D and internal finance: A panel study of small firms in high-tech industries. *The Review of Economics and Statistics 76*(1), 38–51.

Hirano, T. and N. Yanagawa (2017). Asset bubbles, endogenous growth, and financial frictions. *The Review of Economic Studies 84*(1), 406–443.

Holmström, B. and J. Tirole (1997). Financial intermediation, loanable funds, and the real sector. *The Quarterly Journal of Economics 112*(3), 663–691.

Holmström, B. and J. Tirole (1998). Private and public supply of liquidity. *Journal of Political Economy 106*(1), 1–40.

Holmström, B. and J. Tirole (2001). LAPM: A liquidity-based asset pricing model. *The Journal of Finance 56*(5), 1837–1867.

Jordà, O., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking 45*(s2), 3–28.

Karabarbounis, L. and B. Neiman (2013). The Global Decline of the Labor Share*. *The Quarterly Journal of Economics 129*(1), 61–103.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy 105*(2), 211–248.

Kiyotaki, N. and J. Moore (2000). Inside money and liquidity. Working paper, London School of Economics.

Klimenko, N., S. Pfeil, J.-C. Rochet, and G. D. Nicolo (2016). Aggregate bank capital and credit dynamics. Swiss Finance Institute Research Paper Series 16-42.

Kogan, L., D. Papanikolaou, L. D. W. Schmidt, and J. Song (2020). Technological innovation and labor income risk. Working Paper 26964, National Bureau of Economic Research.

Kogan, L., D. Papanikolaou, and N. Stoffman (2020). Left behind: Creative destruction, inequality, and the stock market. *Journal of Political Economy 128*(3), 855–906.

Koh, D., R. Santaeulàlia-Llopis, and Y. Zheng (2020). Labor share decline and intellectual property products capital. *Econometrica 88*(6), 2609–2628.

Kongsamut, P., S. Rebelo, and D. Xie (2001). Beyond balanced growth. *The Review of Economic Studies 68*(4), 869–882.

Korinek, A. and A. Simsek (2016). Liquidity trap and excessive leverage. *American Economic Review 106*(3), 699–738.

Krishnamurthy, A. and T. Muir (2016). How credit cycles across a financial crisis. Working paper, Stanford University Graduate School of Business.

Krishnamurthy, A. and A. Vissing-Jørgensen (2015). The impact of treasury supply on financial sector lending and stability. *Journal of Financial Economics 118*(3), 571 – 600.

Li, S., T. M. Whited, and Y. Wu (2016). Collateral, taxes, and leverage. *Review of Financial Studies 29*(6), 1453–1500.

Lian, C. and Y. Ma (2020a, 09). Anatomy of Corporate Borrowing Constraints*. *The Quarterly Journal of Economics 136*(1), 229–291.

Lian, C. and Y. Ma (2020b). *Replication Data for: 'Anatomy of Corporate Borrowing Constraints'.* Harvard Dataverse.

López-Salido, D., J. C. Stein, and E. Zakrajšek (2017). Credit-Market Sentiment and the Business Cycle*. *The Quarterly Journal of Economics 132*(3), 1373–1426.

Lucas, R. E. (1978). Asset prices in an exchange economy. *Econometrica 46*(6), 1429–1445.

Maggiori, M. (2017). Financial intermediation, international risk sharing, and reserve currencies. *American Economic Review 107*(10), 3038–71.

Mann, W. (2018). Creditor rights and innovation: Evidence from patent collateral. *Journal of Financial Economics 130*(1), 25 – 47.

Martin, A. and J. Ventura (2012). Economic growth with bubbles. *American Economic Review 102*(6), 3033–58.

Marx, M., B. Mojon, and F. Velde (2018). Why have interest rates fallen far below the return on capital. Working Paper 2018-01, Federal Reserve Bank of Chicago.

McGrattan, E. R. (2020). Intangible capital and measured productivity. *Review of Economic Dynamics 37*, S147–S166.

McGrattan, E. R. and E. C. Prescott (2010a). Technology capital and the us current account. *American Economic Review 100*(4), 1493–1522.

McGrattan, E. R. and E. C. Prescott (2010b). Unmeasured investment and the puzzling us boom in the 1990s. *American Economic Journal: Macroeconomics 2*(4), 88–123.

Miao, J. and P. Wang (2018). Asset bubbles and credit constraints. *American Economic Review 108*(9), 2590–2628.

Moreira, A. and A. Savov (2017). The macroeconomics of shadow banking. *The Journal of Finance 72*(6), 2381–2432.

Nagel, S. (2016, 07). The Liquidity Premium of Near-Money Assets. *The Quarterly Journal of Economics 131*(4), 1927–1971.

Ngai, L. R. and C. A. Pissarides (2007, March). Structural change in a multisector model of growth. *American Economic Review 97*(1), 429–443.

Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson (1999). The determinants and implications of corporate cash holdings. *Journal of Financial Economics 52*(1), 3 – 46.

Ordoñez, G. (2013). The asymmetric effects of financial frictions. *Journal of Political Economy 121*(5), 844–895.

Perron, P. (2006). Dealing with structural breaks. In H. Hassani, T. C. Mills, and K. Patterson (Eds.), *Econometric Theory*, Volume I of *Palgrave Handbook of Econometrics*, pp. 278 – 352. Basingstoke, UK: Palgrave.

Peters, R. H. and L. A. Taylor (2017). Intangible capital and the investment-q relation. *Journal of Financial Economics 123*(2), 251 – 272.

Phelan, G. (2016). Financial intermediation, leverage, and macroeconomic instability. *American Economic Journal: Macroeconomics 8*(4), 199–224.

Piazzesi, M. and M. Schneider (2016). Payments, credit and asset prices. Working paper, Stanford University.

Pinkowitz, L., R. M. Stulz, and R. Williamson (2015). Do U.S. firms hold more cash than foreign firms do? *Review of Financial Studies*.

Poterba, J. M. and J. J. Rotemberg (1986). Money in the utility function: An empirical implementation. Working Paper 1796, National Bureau of Economic Research.

Pozsar, Z. (2011). Institutional cash pools and the Triffin dilemma of the U.S. banking system. Working paper WP/11/190, International Monetary Fund.

Pozsar, Z. (2014). Shadow banking: The money view. Working paper 14-04, Office of Financial Research.

Protter, P. E. (1990). *Stochastic Integration and Differential Equations.* New York: Springer-Verlag.

PSID (2019). *Panel Study of Income Dynamics.* The Survey Research Center, Institute for Social Research, University of Michigan.

Quadrini, V. (2017). Bank liabilities channel. *Journal of Monetary Economics 89*, 25 – 44.

Rajan, R. G. and L. Zingales (1998). Financial dependence and growth. *The American Economic Review 88*(3), 559–586.

Rampini, A. A. and S. Viswanathan (2019). Financial Intermediary Capital. *The Review of Economic Studies 86*(1), 413–455.

Riddick, L. A. and T. M. Whited (2009). The corporate propensity to save. *The Journal of Finance 64*(4), 1729–1766.

Sidrauski, M. (1967). Inflation and economic growth. *Journal of Political Economy 75*(6), 796–810.

Stein, J. C. (2012). Monetary policy as financial stability regulation. *The Quarterly Journal of Economics 127*(1), 57–95.

Stroebel, J. and J. Vavra (2019). House prices, local demand, and retail prices. *Journal of Political Economy 127*(3), 1391–1436.

Thomas, J. (2002). Is lumpy investment relevant for the business cycle? *Journal of Political Economy 110*(3), 508–534.

U.S. Bureau of Economic Analysis (2019). *Table 4.1. Current-Cost Net Stock of Private Nonresidential Fixed Assets by Industry Group and Legal Form of Organization.*

U.S. Bureau of Labor Statistics (1947–2020a). Consumer Price Index for All Urban Consumers: All Items in U.S. City Average [CPIAUCSL], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CPIAUCSL (accessed on May 27, 2021).

U.S. Bureau of Labor Statistics (1975–2020b). Consumer Price Index for All Urban Consumers: Rent of Primary Residence in U.S. City Average [CUSR0000SEHA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CUSR0000SEHA (accessed on June 6, 2020).

U.S. Federal Housing Finance Agency (1975–2020). All-Transactions House Price Index for the United States [USSTHPI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/USSTHPI (accessed on June 6, 2020).

Van den Heuvel, S. J. (2018). The welfare effects of bank liquidity and capital requirements. Working paper, Federal Reserve Board.

Woodford, M. (1990). Public debt as private liquidity. *The American Economic Review 80*(2), 382–388.

WRDS (2019). *Financial Ratios Firm Level by WRDS (Beta).* Wharton Research Data Services.