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Financial Intermediation, Investment Dynamics, and Business Cycle Fluctuations†

By Andrea Ajello*

I use micro data to quantify key features of US firm financing. In particular, I establish that a substantial 35 percent of firms' investment is funded using financial markets. I then construct a dynamic equilibrium model that matches these features and fit the model to business cycle data using Bayesian methods. In the model, financial intermediaries enable trades of financial assets, directing funds toward investment opportunities, and charge an intermediation spread to cover their costs. According to the model estimation, exogenous shocks to the intermediation spread explain 25 percent of GDP and 30 percent of investment volatility. (*JEL* D22, D92, E32, G21, G31, G32)

Is the financial sector an important source of business cycle fluctuations? My model analysis suggests that the answer is "yes." I find that financial sector shocks account for 25 percent and 30 percent of output and investment volatility, respectively. These are the implications of a dynamic model estimated using the data for the United States from 1989 to 2008, before the start of the Great Recession.

A key input into the analysis is a characterization of how important financial markets are for fixed investment. To this end, I analyze the cash flow statements of

* Board of Governors of the Federal Reserve System, 20th and C Street NW Washington, DC 20551 (e-mail: andrea.ajello@frb.gov). I am indebted to Larry Christiano and Giorgio Primiceri for their extensive help, guidance, and encouragement throughout this project. I have particularly benefited from discussions with Luca Benzoni, Alejandro Justiniano, and Arvind Krishnamurthy. I thank three anonymous referees for their helpful comments and suggestions. I am grateful to Marco Del Negro, Ferre De Graeve, Nobuhiro Kiyotaki, David López-Salido, Shouyong Shi, and seminar participants at Northwestern University, the Federal Reserve Bank of Chicago, Copenhagen Business School, the University of Lausanne, Ecole Polytechnique Federale de Lausanne (EPFL), the Federal Reserve Bank of Kansas City, Santa Clara University, the Board of Governors of the Federal Reserve System, Rotman School of Business–University of Toronto, Banque de France, Collegio Carlo Alberto, Royal Holloway University of London, the Midwest Finance Conference, the Federal Reserve System Macro Conference, the CEPR-JMCB Conference on Macroeconomics and Financial Intermediation, the Spanish Economic Association Symposium 2011, the Midwest Macroeconomic Meetings 2012 at Notre Dame, the 2012 Summer Meetings of the Econometric Society at Northwestern University and the 2012 European Economic Association and Econometric Society European Meetings for their thoughtful comments and suggestions. Many thanks to Christine Garnier, William Gamber, and Jason Sockin for excellent research assistance. Special gratitude goes to Miguel Acosta, whose programming advice and research assistance were invaluable in the later stages of this project. Acosta rewrote large parts of the replication code for the paper, available on the AER website. All errors and omissions are the author's responsibility alone. The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of anyone else associated with the Federal Reserve System. The author declares that he has no relevant or material financial interest that relate to the research described in this paper.

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all US public nonfinancial companies available in Compustat. I find that 35 percent of the capital expenditures of these firms are funded using financial markets. Of this funding, around 75 percent is raised by issuing debt and equity and 25 percent by liquidating existing assets. My analysis at quarterly frequency suggests that the financial system is crucial in reconciling imbalances between the positive operating cash flows and capital expenditures.

Shocks that affect how efficiently the financial system allocates private savings to productive needs can have large effects on capital accumulation and aggregate activity. To quantify the effects of such disturbances on the business cycle, I build a dynamic general equilibrium model with financial frictions in which entrepreneurs, like firms in the Compustat dataset, issue and trade financial claims to fund their investments. The model builds on Kiyotaki and Moore (2012). In my theoretical framework, the trading of financial assets occurs through banks and exogenous shocks can affect the financial intermediation technology. In contrast to Kiyotaki and Moore (2012), I assume that prices and wages are sticky and show that this feature of the model is essential for the financial shock to generate procyclical movements in labor inputs, consumption, investment, and asset prices.

In my model, entrepreneurs are endowed with random heterogeneous technologies to accumulate capital. Entrepreneurs who receive better technologies issue financial claims to increase their investment capacity. Entrepreneurs with worse investment opportunities instead prefer to buy financial claims and lend to more efficient entrepreneurs, expecting higher rates of return than those generated by their own technologies.

I introduce stylized financial intermediaries (banks) that bear a cost to transfer resources from entrepreneurs with poor capital accumulation technologies to investors with efficient capital production skills. Banks buy financial claims from investors and sell them to other entrepreneurs. In doing so, perfectly competitive banks charge an intermediation spread to cover their costs (Chari, Christiano, and Eichenbaum 1995; Goodfriend and McCallum 2007; Cúrdia and Woodford 2010a). I assume that these intermediation costs vary exogenously over time and interpret these disturbances as financial shocks. When the intermediation costs are higher, the demand for financial assets drops and so does their price. Consequently the cost of borrowing rises for investing entrepreneurs. As a result, aggregate investment and output plunge.

I use Bayesian methods, as in An and Schorfheide (2007) and Smets and Wouters (2007), to estimate a log-linearized version of the model buffeted by a series of random disturbances, including persistent and transitory financial intermediation shock, on a sample of US macroeconomic time series that spans from 1989:I to 2008:II. As an original contribution to the literature on the estimation of DSGE models with financial frictions and financial shocks, I include data on the degree of financial dependence of corporate investment from Compustat (namely the financing gap as a share of aggregate fixed investment, or financing gap share) together with more traditional evidence on the evolution of corporate bond spreads as observables in the estimation to identify the financial shock.

The estimation results show that persistent shocks to financial intermediation costs account for the largest share of fluctuations in output and investment, explaining approximately 25 percent of the variance of output and 30 percent of the variance of investment at business cycle frequencies. I show that the inclusion of the financing gap share data helps the estimation identify the common medium and low frequency changes in credit conditions that affect borrowing costs as well as corporate financial needs for fixed investment and the business cycle. Historical decompositions of output growth, corporate spreads, and the financing gap share reveal that persistent shocks to intermediation costs can reconcile sudden and severe drops in investment and output with the relatively slow mean reversion of corporate spreads after recessions and the subdued pick-up in corporate financial needs during recoveries in my data sample. On the other hand, transitory financial intermediation shocks in the model affect higher-frequency fluctuations of financing spreads but have limited effects on corporate funding for fixed investment and on the rest of the macroeconomy.

The estimation also allows me to quantify the role of the different structural shocks in shaping output dynamics over the sample period. Running counterfactual experiments on the estimated model, I obtain a historical decomposition of output dynamics into fundamental shocks and find that positive financial intermediation shocks played an important role in driving the economic expansion of the 2000s but did not contribute to the boom of the late 1990s. I also find that negative financial shocks can explain a large part of the drop in output growth in the two recessions in the sample (1990–1991, 2001), and after the end of 2007, at the start of the Great Recession.

The historical decomposition analysis reveals that total factor productivity shocks contributed positively to output growth in the 1990s and in the 2000s and negatively to the economic contractions in the sample. Estimates of total factor productivity growth from the model are in line with empirical results in the growth-accounting exercise in Fernald (2012). Monetary policy shocks played a consistent role in driving credit and output dynamics, sustaining corporate borrowing and GDP during recessions while cooling down economic expansions. In particular, the decomposition suggests that the rapid reductions in the federal funds rate helped sustain economic growth during the 2001 recession and at the onset of the Great Recession in 2007 and early 2008.

Why are financial shocks able to explain such a large fraction of business cycle dynamics? The reason lies in the ability of my New Keynesian model to generate both booms and recessions of a plausible magnitude and a positive co-movement among all of the real variables, including consumption, investment, and hours worked, following a financial intermediation shock. I find that nominal rigidities are the key element in delivering this desirable feature of the model. In particular, I document that real wage rigidities are a necessary feature for the model to create amplification of financial shocks, while fitting aggregate wage dynamics in the data. Finally, I show that financial intermediation shocks in the model can act both as shifters of investment demand and of the aggregate investment technology, as in Buera and Moll (2015). However, my estimation results show that the effect of technology shifts in the transmission of financial shocks is very small.

This paper is related to the literature that explores and quantifies the relations between financial imperfections and macroeconomic dynamics. A large part of the literature has focused on the ability of financial market frictions to amplify aggregate fluctuations. In this tradition, Kiyotaki and Moore (1997) first analyzed the macroeconomic implications of the interaction of agency costs in credit contracts and endogenous fluctuations in the value of collateralizable assets. Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999) first introduced similar frictions in dynamic general equilibrium models. These papers did not focus on shocks arising from the financial sector, but rather emphasized the amplification of business cycle fluctuations generated by financial frictions.

My model explores the role of shocks that originate in financial markets as possible drivers of cyclical fluctuations. In this tradition, Christiano, Motto, and Rostagno (2014) estimate a general equilibrium model of the US and euro area economies, in which a financial shock can hit in the form of unexpected changes in the distribution of entrepreneurial net worth and riskiness of credit contracts. They find that this "risk" shock can account for approximately 60 percent of fluctuations in aggregate output.

My model is close in its set-up to Kiyotaki and Moore (2012)—henceforth, KM. They focus on financial market transactions and on the aggregate implications of a shock to the degree of liquidity of private assets. The liquidity shock takes the form of a drop in the fraction of assets that can be liquidated to finance new investment projects. However, their model, in which prices and wages are perfectly flexible, has two unappealing features.

First, while the KM liquidity shock does lead to a reduction in investment, consumption instead rises on impact, and the negative effect on output is limited. As mentioned above, I find that introducing nominal rigidities can correct this feature of the model. In the literature, Jermann and Quadrini (2012) also underline the importance of labor markets in the transmission of financial shocks by calibrating and then estimating a dynamic general equilibrium model where firms issue debt and equity to finance both their investment and their working capital needs. In their set-up, a financial shock corresponds to a tightening of firms' borrowing constraints. If raising equity financing in substitution of debt is costly, reduced borrowing capacity translates into weaker labor demand, which can generate sizable recessions. Bigio (2015) builds and calibrates a model with limited enforcement in contractual agreements and asymmetric information on the quality of capital. In his framework, negative shocks to the dispersion of the quality of capital generate endogenous fluctuations in the degree of liquidity of assets. These shocks also tighten firms' constraints on working capital financing and reduce labor demand as in Jermann and Quadrini (2012), delivering positive co-movement between consumption and investment. Finally, Shourideh and Zetlin-Jones (2012) also find that financial market disturbances are a promising source of business cycle fluctuations in a real model with credit-constrained public and private firms that differ in their ability to self-insure against the arrival of good investment opportunities and whose operations are connected by nonfinancial linkages (e.g., the use of one firm's output as an intermediate input of production of all other firms). In their model, nonfinancial linkages play a key role in the transmission of financial shocks from constrained to unconstrained firms and in generating positive co-movement in the aggregate macro variables.

A second unappealing feature of KM is that the primary impact of their liquidity shock on the price of equity operates through a supply channel, under plausible calibrations of the model parameters. By restricting the supply of financial claims on the market, a negative liquidity shock results in a rise in their price. Shi (2015) carefully described this feature of the KM model, questioning the ability of liquidity shocks to generate meaningful business cycle dynamics. To obtain a positive co-movement of asset prices and output, I instead introduce random disturbances in the financial intermediation technology. I verify that, in contrast to KM's liquidity shocks, the positive co-movement of asset prices over the business cycle is a robust feature of financial intermediation shocks, also in the absence of nominal rigidities.

To conclude, I briefly compare my analysis with that of Del Negro et al. (2010). Their research quantifies the effects of unconventional monetary policy during the Great Recession, in response to liquidity shocks that hit a calibrated KM economy with nominal rigidities. An advantage of my intermediation shock over a liquidity shock is that it corresponds closely to an observed variable, namely, the interest rate spread. In addition, Del Negro et al. (2010) focus on the period of recent financial turmoil and the associated monetary policy challenges. I use Bayesian estimation methods to evaluate the contribution of financial intermediation disturbances to the US business cycles and focus on the precrisis period. In relation to Del Negro et al. (2010), my analysis confirms that financial shocks were the driving force at the onset of the Great Recession. However, I also find that these shocks have been important over the previous 20 years.

The paper is structured so as to offer an empirical description of corporate investment financing from the Compustat quarterly data in Section I. Section II describes the features of the model. Section III discusses the estimation strategy, the prior selection on the model parameters and significant moments, and the posterior estimates. Section IV presents the model estimation results and Section V concludes.

I. Empirical Evidence on Investment Financing: The Compustat Cash-Flow Data

This section is devoted to quantifying the fraction of quarterly corporate investment in fixed capital that firms fund by accessing financial markets as opposed to using current operating cash flows. I also distinguish between the role of primary markets (debt or equity financing) and secondary markets (sales of old assets with different degrees of liquidity) as sources of funds. I analyze quarterly cash flow data of the universe of nonfinancial US firms in Compustat building on work from Chari and Kehoe (2009).

I concentrate on US corporations and refer to the sample period from 1989:I to 2008:II. I focus on Compustat quarterly cash flow data to quantify the extent of companies' short-term cash-flow imbalances that may not be visible at annual frequencies.[1] I start my analysis from the basic cash flow equality for a generic firm e, within a quarter t,

$$\Delta CASH_{e,t} = CF^{O}_{e,t} - \left(CF^{D}_{e,t} + CF^{E}_{e,t}\right) - CF^{I}_{e,t}, \tag{1}$$

that states that the variation of liquid assets on the balance sheet of the firm, $\Delta CASH_{e,t}$, has to equal the difference between the operating cash flow generated by its business operations, $CF^{O}_{e,t}$, and net cash receipts delivered to debt and equity holders, $CF^{D}_{e,t} + CF^{E}_{e,t}$, reduced by the amount of cash used within the period to

[1] Compustat contains cash flow statement data both at annual and at quarterly frequencies for the universe of publicly traded North American companies. Quarterly data are available from 1983, while a consistent breakdown into their components is available since 1989.

carry out net financial or fixed investments, $CF^I_{e,t}$. I decompose investment cash flow, $CF^I_{e,t} = CAPX_{e,t} + NFI_{e,t}$, as the sum of capital expenditures, $CAPX_{e,t}$, and net financial investment, $NFI_{e,t}$. Similarly, I break down the cash flow to equity holders, $CF^E_{e,t} = DIV_{e,t} + CF^{EO}_{e,t}$, into dividends, $DIV_{e,t}$, and other equity net flows, $CF^{EO}_{e,t}$. I consider dividend payments, $DIV_{e,t}$, as unavoidable commitments to shareholders and define the firm-level financing gap, $FG_{e,t}$, as the difference between the non-committed operating cash flows of firm e, $CF^O_{e,t} - DIV_{e,t}$, and capital expenditure $CAPX_{e,t}$ at time t,[2]

$$(2) \qquad FG_{e,t} = \underbrace{\left(CF^O_{e,t} - DIV_{e,t} - CAPX_{e,t}\right)}_{\text{Financing Gap Net of Dividends}}$$
$$= \underbrace{\left(CF^D_{e,t} + CF^{EO}_{e,t}\right)}_{\text{External Sources}} + \underbrace{\left(NFI_{e,t} + \Delta CASH_{e,t}\right)}_{\text{Portfolio Liquidations}}.$$

On the one hand, if $FG_{e,t} > 0$, then firm e reports a financing surplus in period t; it is able to use its operating cash flows to finance its investment in fixed capital and its dividend pay-outs and can use the additional resources to buy back shares and/or pay back its debt obligations ($CF^{EO}_{e,t} + CF^D_{e,t} > 0$). In addition, the firm could use its surplus to increase the stock of financial assets on its balance sheet and/or its cash reserves ($NFI_{e,t} + \Delta CASH_{e,t} > 0$).

On the other hand, if $FG_{e,t} < 0$, then firm e will fund the negative financing gap by relying on external investors to subscribe new debt and/or equity securities ($CF^{EO}_{e,t} + CF^D_{e,t} < 0$), by liquidating assets ($NFI_{e,t} < 0$) and/or depleting deposits and cash-reserves ($\Delta CASH_{e,t} < 0$).

In each quarter, I compute $FG_{e,t}$ for all firms in the dataset and identify those that report a negative financing gap.[3] I then define the total financing gap in each quarter t for the aggregate of Compustat firms as the sum of the absolute value of their deficits,

$$(3) \qquad FG^{TOT}_t = \textstyle\sum_e \left|FG_{e,t}\right| \mathbf{1}\left\{FG_{e,t} < 0\right\}.$$

I also recognize that a fraction of firms report negative financing gaps because they occasionally post negative quarterly operating cash flows ($CF^O_{e,t} < 0$). These firms access financial intermediaries and markets in general to fund part of their operating expenses (i.e., their working capital needs). I choose to concentrate only on financial dependence that arises in connection to the accumulation of fixed capital and hence subtract the absolute value of aggregate negative cash-flows reported in every

[2] La Porta et al. (2000) provide a review of theoretical models and empirical evidence in support of the view of dividend payments as unavoidable commitments arising, for example, from the presence of agency frictions between corporate insiders and minority shareholders. This interpretation of dividend payments reconciles the definition of the financing gap in my paper with the one used in the Flow of Funds Tables, described in online Appendix A. In contrast, Shourideh and Zetlin-Jones (2012) treat dividend payments as discretionary and fully disposable and do not subtract them from the operating cash flows in the definition of the financing gap. For completeness, I provide results computed under both assumptions for the analyses in this section and in the rest of the paper.

[3] Table 1 reports that the average of the per-quarter share of Compustat firms with negative financing gaps computed over my sample is 49 percent.

Table 1—Compustat Evidence on Corporate Investment Financing (*Percent*)

Variable V_t	Mean(V_t)	StdDev(V_t)
FGS_t^{a}	35.89	4.56
FGS_t^{b}–Excluding dividends	25.65	4.45
$\log\left(\frac{FGS_t}{FGS_{ss}}\right)^{c}$	–0.81	12.89
$\Delta\log\left(\frac{FG_t}{P_t \times Pop_t}\right)^{d}$	–0.05	16.35
WKS_t^{e}	32.25	4.57
$LIQS_t^{f}$	22.39	22.50
$CASHS_t^{g}$	19.02	13.67
$\Pr(FG < 0)^{f} = \chi_{k,ss} + \chi_{s,ss}$	49.29	

Notes: Mean and standard deviations of variables across sample period 1989:I–2008:II, if not otherwise specified: (a) Financing gap share of capital expenditure defined in equation (4), total of US corporations in Compustat; (b) financing gap share, excluding dividend payments, total of US corporations; (c) financing gap share of capital expenditure defined in equation (4), log-deviations from sample average FGS_{ss}; (d) quarterly growth rate of per capita, real financing gap (numerator of FGS_t); (e) share of total financing gap due to working capital needs. US corporations; (f) share of financing gap funded by portfolio liquidations. US corporations; (g) share of financing gap funded by variations in cash reserves, US corporations.

Source: Compustat quarterly files

period, WK_t, from the total financing gap in (3). I define the quarterly financing gap share, FGS_t, as the ratio between the total financing gap related to fixed investment and the total capital expenditure across all firms:

$$FGS_t = \frac{FG_t^{TOT} - |WK_t|}{CAPX_t} = \frac{FG_t^{TOT} - \sum_e \left| CF_{e,t}^{O} \right| \mathbf{1}\left\{FG_{e,t} < 0, CF_{e,t}^{O} < 0\right\}}{\sum_e CAPX_{e,t}}. \tag{4}$$

Table 1 shows that from 1989:I to 2008:II, the average of the financing gap share, FGS_t, amounts to 35.89 percent of total investment, with a standard deviation of 4.56 percent:[4]

[4] Table 1 also reports the financing gap share computed under the assumption that dividend payments are fully disposable, " FGS_t–Excluding Dividends." In this case the average financing gap share drops to 25 percent, in line with similar calculations in Shourideh and Zetlin-Jones (2012). Figure 1 shows the financing gap share computed under both assumptions regarding dividend payments. The two series have different sample averages but similar cyclical properties. Both series are seasonally adjusted using the additive X12 Census model on Compustat quarterly data. The table also reports the standard deviation of the log-deviations of the financing gap share from its sample average (used in the model estimation) and the mean and standard deviation of the growth rate of the per capita, real total financing gap.

Table 1 also reports the fraction of the total financing gap defined in (3) that arises due to working capital needs and is excluded from the definition of the financing gap share in (4). I define this ratio as the average over time of the contribution of negative operating cash flows, $CF_{e,t}^{O}$, to the total financing gap, FG_t^{TOT}, in (3):

$$\overline{WKS} = \frac{1}{T}\sum_t \frac{WK_t}{FG_t^{TOT}} = 0.32,$$

and find that around 32 percent of firms' total financial dependence is connected to funding operating expenses.

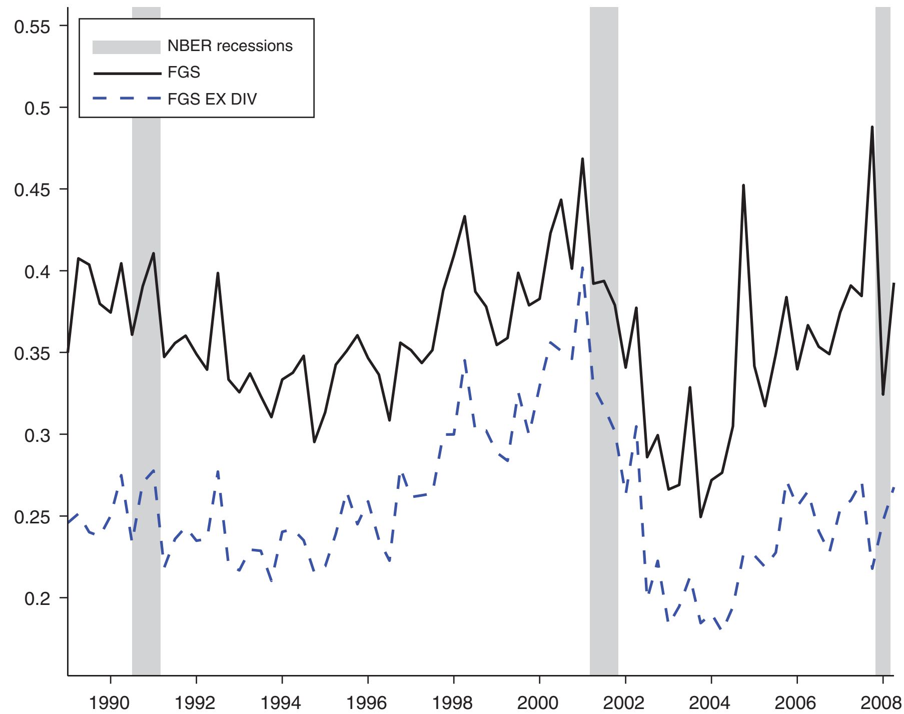

Figure 1. Financing Gap Share

Notes: Financing gap share, as computed in equation (5) (solid line) for the aggregate of US corporations, expressed in percentage points. The series is compared to results obtained by not considering dividends as unavoidable commitments of firms and hence not accounting dividend payments as contributing to the financing gap (dashed line). Sample period: 1989:I–2008:II.

Source: Compustat quarterly files

Figure 1 shows how the financing gap share increases over economic expansions, while recessions start with a drop in the financing gap share and loosely mark the beginning of prolonged periods of decline in the variable that last well into the initial phase of the following economic expansions.

I further break down the aggregate financing gap into the liquidation of assets and use of cash reserves on one side, $NFI_{e,t} + \Delta CASH_{e,t}$, and funds from new equity and debt issuances on the other, $CF^D_{e,t} + CF^E_{e,t}$. I define the liquidation share, $LIQS_t$ as the fraction of the total financing gap covered by liquidation of assets and cash reserves,

$$(5) \qquad LIQS_t = \frac{\sum_e (NFI_{e,t} + \Delta CASH_{e,t}) \, \mathbf{1}\{FG_{e,t} < 0\}}{FG_t^{TOT}}.$$

Table 1 and Figure 2 show that, on average, over the sample period, use of cash reserves and asset liquidations account for around 22 percent of the total financing gap (row 6, $LIQS_t$), of which 19 percent is due to cash reserve depletion and 3 percent to asset liquidations (row 7, cash share, $CASHS_t$). The issuance of new debt and equity claims as a share of the total financing gap, $DES_t = 1 - LIQS_t$, accounts for an average of 78 percent over the sample period, showing that corporations fund

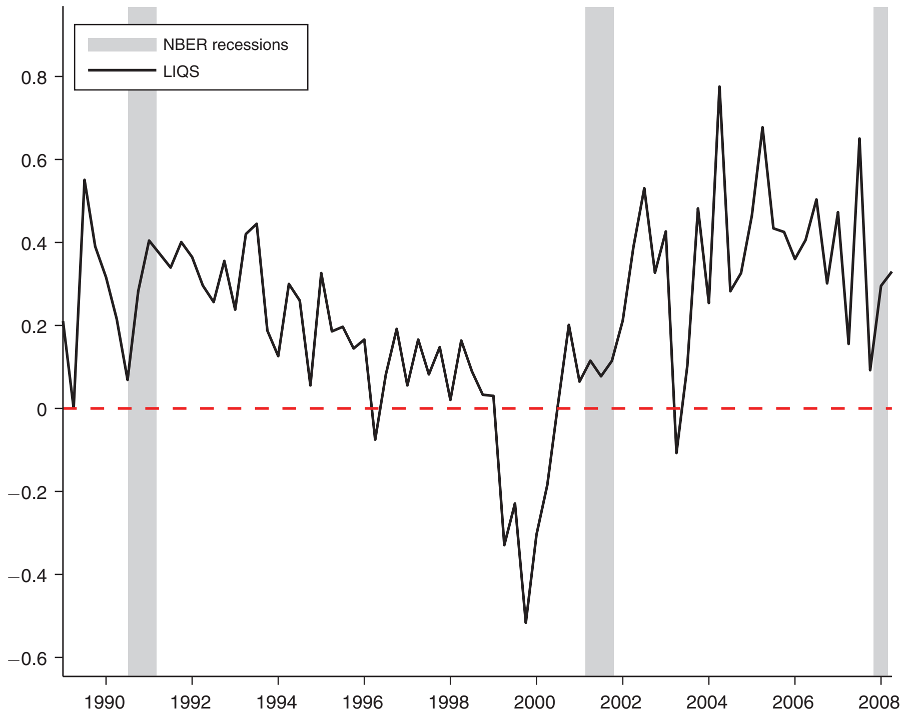

Figure 2. Liquidation Share

Notes: $LIQS_t$: Share of financing gap funded through portfolio liquidations and changes in cash reserves, expressed in percentage points. Sample period: 1989:I–2008:II.

Source: Compustat quarterly files

the majority of their cash-flow imbalances using external sources of finance and, specifically, by frequently accessing primary debt and equity markets.

The financing gap share, FGS_t, in (4) is a measure of the *financial dependence* of firms on funds intermediated by the financial sector and on the depletion of saved assets (liquid or illiquid). Whether the financing gap and the composition of firms' sources of funds are indicative of the presence of firm-level *financial frictions* requires some discussion. On the one hand, firms that report a negative financing gap in the data can raise funds on financial markets or sell part of their assets as an unconstrained efficient financing strategy (i.e., compatible with the indeterminacy of an optimal capital structure under the frictionless world of the Modigliani-Miller theorem). On the other hand, there is empirical evidence that firms in Compustat do face financial frictions. Recent empirical work by Falato, Kadyrzhanova, and Sim (2013) on Compustat data points in that direction. They show that firms' holdings of liquid assets have increased over time since 1970, and that such holdings are positively related to the rise in intangible capital both in the time series dimension and in the cross section of US corporations. The authors rationalize this empirical fact by noting that intangible capital is less pledgeable and/or resaleable (for example, because it is highly customized, as investment in software, or because it has strong complementarities with entrepreneurial and managerial skills or organizational capital in general). Firms with more intangible capital are more likely to be credit or liquidity constrained and to accumulate cash reserves as a form of precautionary savings. In support of their idea, they show evidence that in Compustat the link between the size of cash holdings and intangible capital is stronger for firms that are traditionally more likely to be financially constrained (for example smaller, younger firms that pay lower dividends).

Figure 2 plots the evolution of $LIQS_t$ over the sample period.[5] In line with evidence on cash holdings dynamics in Falato, Kadyrzhanova, and Sim (2013), the graph suggests that the average fraction of the financing gap funded by asset liquidations is low in the boom of the 1990s and high in the expansion of the 2000s. The average $LIQS_t$ is around 20 percent from 1991 to 2001, and 34 percent from 2002 to 2007.

In conclusion, evidence from Compustat cash flow data reveals a significant reliance on financial markets of the corporate sector's funding for capital expenditures. Aggregate shocks, such as disturbances to the operating conditions of financial markets, can affect the cost of external funding as well as the size and composition of the financing gap. These, in turn, can disrupt the accumulation of aggregate fixed capital, and potentially propagate to the dynamics of output growth and shape business cycle fluctuations. To evaluate the role of financial disturbances on aggregate fluctuations, in the next section I introduce and estimate a model that captures the features of firms' investment financing in the Compustat quarterly data and in which the financial intermediation sector is subject to exogenous shocks. In my model, I assume that entrepreneurs incur negative financing gaps due to the arrival of investment opportunities, and that credit and liquidity constraints influence the size and funding composition of the gaps. Credit- and liquidity-constrained entrepreneurs in the model trade and hold liquid assets as precautionary savings against the arrival of good investment opportunities.

II. The Model

This section describes the structure of the model and the maximization problems of its actors. A representative household is composed of heterogeneous members who optimally choose to be entrepreneurs or workers. Entrepreneurs install the capital stock using idiosyncratic technologies, while workers supply differentiated labor inputs in a monopolistically competitive market. Employment agencies recombine differentiated labor inputs in homogeneous work hours. The economy also features perfectly competitive financial intermediaries (banks), competitive producers of a homogeneous consumption good, producers of differentiated intermediate goods who act in a regime of imperfect competition, and capital producers who transform

[5] Positive realizations of the series are quarters in which firms liquidate assets or deplete cash reserves. Negative realizations are episodes in which firms are able to borrow from the market not only to cover their financing gap, but also to acquire new financial assets on secondary markets. Leveraged asset purchases were prevalent before the burst of the dot-com bubble at the end of the 1990s, when the share of corporate mergers and acquisitions had risen to 15 percent of US GDP in 1999 alone, compared to an average of 4 percent during the 1980s (Weston and Weaver 2004).

final goods into ready-to-install investment goods. The government consists of a monetary authority and a fiscal authority.

A. *Household*

The representative household is composed of a measure one of members, indexed by i. Household members are heterogeneous: in every period each of the members leaves the household and receives an idiosyncratic technology $A_{i,t} \sim F(A_{i,t})$ that can be employed to install new investment goods $\iota_{i,t}$ and obtain $A_{i,t}\iota_{i,t}$ new units of capital stock. The distribution $F(A_{i,t})$ is assumed to be lognormal with location parameter μ_A and dispersion σ_A.[6]

The head of the household does not observe members' idiosyncratic technologies and cannot redistribute wealth among members to take advantage of the best technology that maximizes the household's lifetime utility. She can, however, offer directions to household members in the form of contingency plans. At the beginning of the period, each member leaves the household with an identical share of assets and specific instructions to implement the household's optimal decision plan conditional on the possible technology draw he might receive and on the state of the economy.

After observing the state of the economy, household members who receive relatively efficient technologies are instructed to increase the capital stock of the household. Members with efficient technologies can obtain external financing, issuing equity claims $(N_{i,t})$ on their physical assets $(K_{i,t})$ and selling them to financial intermediaries. Alternatively, household members with inefficient technologies are instructed to forgo investment opportunities that are not remunerative. They will instead supply hours worked in exchange for a wage, and purchase financial claims from financial intermediaries on the returns on capital of more efficient entrepreneurs. Household members can also accumulate liquid assets in the form of government bonds $(B_{i,t})$.

At the beginning of the period, a snapshot of each member's balance sheet will include his capital stock, $K_{i,t-1}$, evaluated at price Q_t^K, the claims on other entrepreneurs' capital stock, $N_{i,t-1}^{others}$, evaluated at price Q_t^N and interest bearing government bond holdings, $R_{t-1}^B B_{i,t-1}$ on the assets side. On the liability side, entrepreneurs sell claims on their capital stock to others, so that part of their capital stock $Q_t^K K_{i,t-1}$ is backed by $Q_t^N N_{i,t-1}^{sold}$:

Assets	Liabilities
$Q_t^K K_{i,t-1}$	$Q_t^N N_{i,t-1}^{sold}$
$Q_t^N N_{i,t-1}^{others}$	
$R_{t-1}^B B_{i,t-1}$	Net worth

Each unit of equity in the economy, N_t, represents one unit of homogeneous capital, K_t, so that the two assets share the same expected stream of returns, $\{R_{t+i}^K\}$ for $i = \{0, \ldots, \infty\}$ and trade at the same price $Q_t = Q_t^K = Q_t^N$. This assumption

[6] See online Appendix J for a version of the model with exogenous shocks to the dispersion of the investment technology, σ_A, also discussed in Section IVB.

allows me to define a unique state variable that describes the *net* amount of capital ownership claims held by household member i,

$$N_{i,t} \; = \; K_{i,t} + N_{i,t}^{others} - N_{i,t}^{sold}.$$

At the end of the period, members congregate back at the household to consume final goods. Members share purchased goods and asset holdings so that their consumption streams and net wealth are identical before the start of the new period. In other words, the household provides perfect consumption insurance across its members.

The Maximization Problem.—At the beginning of each period t, the head of the household formulates an optimal plan for consumption, $C_{i,t+s}$, investment goods purchases, $\iota_{i,t+s}$, equity claim purchases and sales, $\Delta N_{i,t+s}^{+}$, $\Delta N_{i,t+s}^{-}$, portfolio allocation of equity and bonds, $N_{i,t+s}$, $B_{i,t+s}$, and wage decisions, $W_{i,t+s}$, for each household member, contingent on the state of the economy and on all possible realizations of the idiosyncratic technology shocks, $A_{i,t} \sim F(A_{i,t})$.

The head of the household chooses members' plans,

$$\mathbf{X}_{i,t+s} \; \equiv \; \left[C_{i,t+s},\, W_{i,t+s},\, \iota_{i,t+s},\, \Delta N_{i,t+s}^{+},\, \Delta N_{i,t+s}^{-},\, N_{i,t+s},\, B_{i,t+s}\right],$$

and aggregate quantities,

$$\mathbf{X}_{t+s} \; \equiv \; \left[C_{t+s}, \iota_{t+s}, \Delta N_{t+s}^{+}, \Delta N_{t+s}^{-}, N_{t+s}, B_{t+s}\right],$$

to maximize the lifetime utility of the collection of its members,

$$\max_{\mathbf{X}_{i,t+s},\,\mathbf{X}_{t+s}} \sum_{s=0}^{\infty} (\beta)^{t+s} b_{t+s} E_t \left[\log(C_{t+s} - hC_{t+s-1}) - \chi_0 \chi_{b,t+s} \frac{L_{t+s}^{(1+\nu)}}{(1+\nu)}\right]. \tag{6}$$

In every period the head of the household will satisfy the set of members' flow of funds constraints:

$$\begin{aligned} &P_t C_{i,t} + P_t^K \iota_{i,t} + Q_t^B \Delta N_{i,t}^{+} - Q_t^A \Delta N_{i,t}^{-} + B_{i,t} \\ &\quad = R_t^K N_{t-1} + W_{i,t} L_{i,t} + R_{t-1}^B B_{t-1} - P_t T_t + P_t D_t. \end{aligned} \tag{7}$$

The head of the household maximizes the expected discounted value of utility generated by the lifetime consumption stream of its members, C_{t+s}, and of the disutility of hours worked, L_{t+s}, supplied in each period by a fraction $\chi_{b,t+s}$ of its members.[7] The household preferences feature habit persistence in consumption with parameter h.

[7] Scaling the disutility of labor by the fraction of members who supply hours worked, $\chi_{b,t+s}$, preserves the standard derivation of the labor market equilibrium conditions both with and without nominal wage rigidities as in Erceg, Henderson, and Levin (2000).

On the right-hand side of the flow of funds constraint (7), each household member receives returns on its equity stock, $R_t^K N_{t-1}$. Members can also supply differentiated hours of labor $L_{i,t}$ remunerated at a monopolistic wage $W_{i,t}$. Members receive returns from holdings of one-period nominal government bonds, $R_{t-1}^B B_{t-1}$, where R_{t-1}^B is the risk-free nominal interest rate paid at time t on bonds issued in $t-1$. The household also pays lump-sum taxes, T_t and receives a sum D_t every quarter, which includes profits from ownership of the productive sector of the economy (capital producers, intermediate good producers, and final good producers) as well as lump-sum rebates of financial intermediation costs from banks.[8]

On the left-hand side of the flow of funds constraint (7), each member employs a combination of asset returns, labor income, and lump-sum transfers to purchase units of consumption good $C_{i,t}$ at price P_t, units of investment goods $\iota_{i,t}$ at price P_t^K, and equity claims on other members' capital stock, $\Delta N_{i,t}^+$, at price Q_t^B. Members can also sell equity claims, $\Delta N_{i,t}^-$, at price $Q_t^A < Q_t^B$.

The head of the household will also satisfy the law of motion of equity for member i, written as

$$N_{i,t} = A_{i,t}\iota_{i,t} + \Delta N_{i,t}^+ - \Delta N_{i,t}^- + (1-\delta)N_{t-1}. \tag{8}$$

Member i's stock of equity at time t is equal to the stock of depreciated equity from the previous period $(1-\delta)N_{t-1}$ plus the new units of installed capital, $A_{i,t}\iota_{i,t}$, and the purchases of equity claims $\Delta N_{i,t}^+$, net of the sales of equity claims $\Delta N_{i,t}^-$.

The optimal plan of the head of the household will also comply with the aggregate flow of funds constraint, obtained summing (7) over household members:

$$\begin{aligned} P_t C_t + P_t^K \iota_t + Q_t^B \Delta N_t^+ - Q_t^A \Delta N_t^- + B_t \\ = R_t^K N_{t-1} + W_t L_t + R_{t-1}^B B_{t-1} - P_t D_t + P_t T_t, \end{aligned} \tag{9}$$

where total household consumption C_t, the wage bill $W_t L_t$, nominal bond holdings B_t, investment goods purchases ι_t, equity purchases ΔN_t^+, and equity sales ΔN_t^- are defined as

$$\begin{aligned} C_t &= \int C_{i,t}\,dF(A_{i,t}),\ W_t L_t = \int W_{i,t} L_{i,t}\,dF(A_{i,t}),\ B_t = \int B_{i,t}\,dF(A_{i,t}), \\ \iota_t &= \int \iota_{i,t}\,dF(A_{i,t}),\ \Delta N_t^+ = \int \Delta N_{i,t}^+\,dF(A_{i,t}),\ \Delta N_t^- = \int \Delta N_{i,t}^-\,dF(A_{i,t}). \end{aligned} \tag{10}$$

Similarly, summing (8) over household members, the aggregate equity stock evolves according to

$$N_t = \int \left[A_{i,t}\iota_{i,t} + \Delta N_{i,t}^+ - \Delta N_{i,t}^-\right] dF(A_{i,t}) + (1-\delta)N_{t-1}. \tag{11}$$

[8] At the beginning of each period t, the household's asset positions $\{N_{i,t-1}, B_{i,t-1}\}$ and lump-sum transfers $\{D_t, T_t\}$ are shared equally across the unit-one measure of household members and are therefore not indexed by i.

The discount factor of the household in (6), βb_t, is subject to an exogenous intertemporal preferences shock that follows an AR(1) process:

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b, \text{ where } \varepsilon_t^b \sim i.i.d.\ N\left(0, \sigma_b^2\right).$$

Financial Frictions.—Household members and financial intermediaries trade equity claims on financial markets. Markets for equity claims are subject to three types of frictions:

- First, I assume that household members trade financial claims through costly financial intermediaries (or banks). Entrepreneurs sell claims to intermediaries at a price Q_t^A, while workers buy claims from intermediaries at a price Q_t^B. Intermediation costs drive a wedge between the resale and purchase price of financial claims. For now, I assume that $Q_t^A \leq Q_t^B$, so that no arbitrage opportunity exists for entrepreneurs on the equity market. This will be derived as an equilibrium result when discussing the role of financial intermediaries in Section IIB.
- Second, household members can issue up to $\iota_{i,t}^{sell}$ equity claims at price Q_t^A to finance a fraction θ of the purchase of investment goods, $P_t^K \iota_{i,t}$:

$$Q_t^A \iota_{i,t}^{sell} \leq \theta P_t^K \iota_{i,t}. \tag{12}$$

  Once members purchase investment goods $\iota_{i,t}$ they can install $A_{i,t}\iota_{i,t}$ units of capital stock. According to the constraint (12), members can only pledge up to a fraction $\left(\theta P_t^K \iota_{i,t}\right)/Q_t^A$ units of their new capital in guarantee of external financing. The parameter θ represents a reduced-form collateral constraint.[9]
- Third, existing financial claims are illiquid. As in KM, I assume that household members can only sell a share ϕ of the equity units on their balance sheet, $\left(1 - \delta\right) N_{t-1}$.[10]

Combining the last two frictions, equity sales, $\Delta N_{i,t}^-$ are subject to the constraint

[9] The borrowing constraint (12) is a reduced-form representation of a financial contract in which amounts borrowed cannot be conditioned (ex ante) on the realization of idiosyncratic technology risk, $A_{i,t}$, but only on the pecuniary value or resources invested. By expressing the value of total borrowing as a percentage of investment demand, the household's Euler equation simplifies considerably and I am able to aggregate it analytically under any distribution, $F(A_{i,t})$. An alternative formulation for the borrowing constraint, adopted in earlier versions of this work, is

$$\iota_{i,t}^{sell} \leq \theta A_{i,t}\iota_{i,t}, \tag{13}$$

and states that household members can only pledge a fraction θ of the new units of installed capital. This alternative constraint effectively conditions demand for funding on the level of the idiosyncratic investment technology draw, $A_{i,t}$. The new borrowing constraint (12) can grant flexibility in the choice of the distribution function $F(A_{i,t})$ (see online Appendix H). For a given distribution with closed-form aggregate first-order conditions, the choice of borrowing constraint (12) over (13) does not affect the main findings of the paper.

[10] KM suggest that the constraint on new equity issuances, θ, may arise when investment requires a (non-collateralizable) effort of the entrepreneurs to be put in place, as in Hart and Moore (1994). Similarly, quantity restrictions, ϕ, that affect the sale and pledgeability of existing assets can be justified assuming a certain degree of specificity of the capital stock that they represent, or can be attributed to the presence of capital reallocation costs (Eisfeldt and Rampini 2006). As suggested in Section I, credit and liquidity constraints can arise when part of the investment and of the existing capital assets are intangible in nature and hence not fully collateralizable or sellable (see Falato, Kadyrzhanova, and Sim 2013).

$$\Delta N^-_{i,t} \leq \theta \frac{P^K_t \iota_{i,t}}{Q^A_t} + \phi(1 - \delta) N_{t-1}, \tag{14}$$

so that sales do not exceed the sum of collateralizable assets, $\left(\theta P^K_t \iota_{i,t}\right)/Q^A_t$, and the maximum amount of resalable equity, $\phi(1 - \delta) N_{t-1}$.

To sum up, household members face idiosyncratic investment technology risk against which they can only partially insure, due to credit and liquidity frictions that limit the efficient allocation of resources toward the best investment opportunities.[11] As in Woodford (1990), the combination of uninsurable idiosyncratic risk and credit constraints generates an endogenous demand for liquidity as a form of precautionary savings. The household will be willing to pay a premium to hold a positive amount of liquid assets, defined in this model as nominal government bonds B_t, so that household members can take advantage of good investment technologies when they arise. The government is the only issuer of nominal risk-free bonds, as household members are assumed not to issue risk-free debt, so that, for each member i, $B_{i,t} \geq 0$.

Optimality Conditions.—The head of the household maximizes lifetime utility (6), subject to the aggregate and individual flow of funds constraints (9) and (7), the aggregate and individual laws of motion for equity holdings (11) and (8), and the individual liquidity constraint (14). The head of the household will also consider the following nonnegativity constraints on consumption good, investment goods, equity and government bond purchases, and equity sales:

$$C_{i,t+s} \geq 0, \iota_{i,t+s} \geq 0, \Delta N^+_{i,t+s} \geq 0, B_{i,t+s} \geq 0, \Delta N^-_{i,t+s} \geq 0.$$

While online Appendix E provides the derivations of the household first order conditions, here I will provide a summary of the relevant equilibrium conditions and the intuition behind them.

After receiving their idiosyncratic technology shock, $A_{i,t}$, members observe the price at which they can buy investment goods from investment good producers, P^K_t, the price at which they can sell financial claims on installed capital to a bank, Q^A_t, and the price at which they can buy financial claims on other members' installed capital from the bank Q^B_t. Household members compare the relative price of a new unit of capital, $P^K_t/A_{i,t}$ with the price of purchasing equity claims from financial intermediaries, Q^B_t.

Figure 3 shows the partition of household members into the three subsets, based on their technology draw:

- A $\chi_{s,t}$ measure of sellers with $\left(P^K_t/A_{s,t}\right) \leq Q^A_t$, who make use of good technologies, install new capital, and sell equity claims to financial intermediaries to

[11] If household members were able to trade equity claims on the capital stock on frictionless financial markets, the economy could reach a Pareto-efficient equilibrium: the member with the best technology draw, say A^{high}, would purchase and install the optimal amount of investment goods for the entire household and finance his operations by selling claims on his capital stock to the other less efficient members without incurring in financial intermediation costs. In this case the equilibrium resale price of equity, Q^A_t, and the purchase price of equity, Q^B_t, would be identical and equal to the relative price of investment goods of the most efficient entrepreneur:

$$Q^A_t = Q^B_t = \frac{P^K_t}{A^{high}}.$$

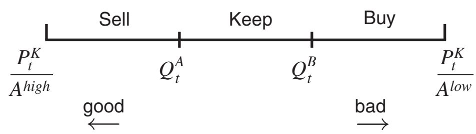

Figure 3. Distribution of Relative Price of Investment Technologies across Entrepreneurs

fund their accumulation of physical assets, until their financial constraint (14) is satisfied with equality.

- A $\chi_{k,t}$ measure of keepers with $Q_t^A < \left(P_t^K/A_{k,t}\right) \leq Q_t^B$, who install new capital but do not borrow from financial intermediaries.
- A $\chi_{b,t}$ measure of buyers with $\left(P_t^K/A_{b,t}\right) > Q_t^B$, who forgo using their less efficient technologies and instead buy equity claims on other members' capital stock from financial intermediaries. Buyers also supply differentiated labor, $L_{i,t}$. The first order conditions for buyers also show that they are the only members to purchase consumption goods and government bonds for the household.

The following paragraphs describe in detail the optimal plans for each group of household members in terms of purchases of consumption goods, $C_{i,t}$, and investment goods, $\iota_{i,t}$, purchases, sales, and holdings of financial assets, $\Delta N_{i,t}^-$, $\Delta N_{i,t}^+$, $N_{i,t}$, and $B_{i,t}$, as well as the wage rate, $W_{i,t}$.

Sellers.—Sellers (indexed by $i = s$) can take advantage of good technology draws. Their relative price of a new unit of capital, $P_t^K/A_{s,t}$, is lower than the resale price of equity claims, Q_t^A, and lower than the price at which they can buy financial claims on the capital stock of other entrepreneurs, Q_t^B. The entrepreneur can then profit from building new physical assets at a relative price $P_t^K/A_{s,t}$ and selling equity claims to the financial intermediaries at price Q_t^A. The optimal decision for the household is to instruct entrepreneurs to forgo purchases of equity claims on the market and to sell the highest amount of equity claims possible to financial intermediaries so that their financial constraint (14) binds with equality:

$$\Delta N_{s,t}^+ = 0, \Delta N_{s,t}^- = \theta \frac{P_t^K \iota_{s,t}}{Q_t^A} + \phi(1-\delta) N_{t-1}. \tag{15}$$

The optimal plan for sellers is to maximize the purchase of investment goods to be used to install and accumulate new capital and to forgo the purchase of consumption goods and government bonds,

$$C_{s,t} = 0, \qquad B_{s,t} = 0.$$

Substituting the values above for $\Delta N_{s,t}^+$, $\Delta N_{s,t}^-$, $C_{s,t}$, and $B_{s,t}$ into the flow of funds constraint (7), allows me to solve for the optimal level of investment goods purchased by seller s:

$$\iota_{s,t} = \frac{1}{P_t^K(1-\theta)}\left[R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t - P_t T_t + Q_t^A \phi(1-\delta) N_{t-1}\right], \tag{16}$$

which depends on aggregate credit conditions through the resale price of equity claims Q_t^A. The seller's optimal equity stock can be written as

$$N_{s,t} = \frac{1}{\tilde{Q}_{s,t}^A}\big[R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t - P_t T_t + Q_t^A \phi(1-\delta)N_{t-1} + \tilde{Q}_{s,t}^A(1-\phi)(1-\delta)N_{t-1}\big],$$

where $\tilde{Q}_{s,t}^A$ is the replacement cost of one unit of internal capital,[12]

$$\tilde{Q}_{s,t}^A = \frac{P_t^K(1-\theta)}{A_{s,t} - \theta\frac{P_t^K}{Q_t^A}},$$

and depends negatively on the idiosyncratic technology $A_{s,t}$ (i.e., the higher the investment technology draw, the lower the cost of replacing existing equity with claims on new capital stock). The fraction of sellers can be computed using the CDF of $A_{i,t}$:

$$\chi_s = Pr\left(A_{i,t} \geq \frac{P_t^K}{Q_t^A}\right) = 1 - F\left(\frac{P_t^K}{Q_t^A}\right).$$

Keepers.—Keepers (indexed by $i = k$) can also take advantage of good technology draws to install new capital, but do not take part in financial markets: the relative price of a new unit of capital, $P_t^K/A_{k,t}$, is higher than what financial intermediaries pay for each equity claim sold, Q_t^A, but lower than the purchase price of equity claims, Q_t^B. As a result, these entrepreneurs will be instructed not to purchase consumption goods and to maximize their purchase of investment goods using only their personal income,

$$C_{k,t} = 0, \iota_{k,t} = \frac{1}{P_t^K}\big[R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t - P_t T_t\big]. \tag{17}$$

They will be instructed neither to issue nor buy equity claims and government bonds that offer a lower rate of return than technology $A_{k,t}$:

$$\Delta N_{k,t}^- = 0, \Delta N_{k,t}^+ = 0,\ B_{k,t} = 0,$$

so that keepers' optimal equity stock will be

$$N_{k,t} = \frac{A_{k,t}}{P_t^K}\left[R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t - P_t T_t + \frac{P_t^K}{A_{k,t}}(1-\delta)N_{t-1}\right].$$

[12] The effective cost of a new unit of equity, $N_{s,t}$, is equal to the cost of one unit of investment goods net of borrowing is, $P_{tK}(1-\theta)$, divided by the number of retained equity claims that can be produced by installing the investment good, $A_{s,t} - \left(\theta P_t^K/Q_t^A\right)$. In other words, each unit of retained new equity needed to replace the assets of seller s requires a down payment of $P_t^K(1-\theta)$. Since $\left(P_t^K/Q_t^A\right) < A_{s,t}$, the shadow price of equity for sellers is lower than the resale market price of equity $\tilde{Q}_t^A < Q_t^A$.

The measure of keepers in the economy is

$$\chi_{k,t} = \Pr\left(Q_t^A \leq \frac{P_t^K}{A_{e,t}} \leq Q_t^B\right) = F\left(\frac{P_t^K}{Q_t^A}\right) - F\left(\frac{P_t^K}{Q_t^B}\right).$$

Buyers.—Buyers (indexed by $i = b$) receive poor investment technology draws. The relative price of a unit of installed capital, $P_t^K/A_{b,t}$, is higher than the purchase market price of equity Q_t^B. Buyers are instructed not to adopt their capital installation technology and instead purchase financial claims at their market price Q_t^B. Buyers will purchase consumption goods so as to satisfy the first order conditions of the household with respect to aggregate consumption,

$$C_t : \mu_t^{\Sigma C} = P_t \lambda_{b,t} = \frac{1}{(C_t - hC_{t-1})} - \beta b_t h E_t\left[\frac{1}{(C_{t+1} - hC_t)}\right],$$

where $\mu_t^{\Sigma C}$ is the household's marginal utility of consumption and $\lambda_{b,t}$ is the Lagrange multiplier on buyer b's budget constraint. Similarly to KM, buyers will purchase equity claims $\Delta N_{b,t}^{+}$ and accumulate government bonds, $B_{b,t}$, so that the Euler equations with respect to the household's holdings of equity, N_t, and bonds, B_t, are satisfied. The optimality condition for equity holdings will be

$$(18)\quad N_t : Q_t^B = \beta b_t E_t\left\{\frac{\mu_{t+1}^{\Sigma C}}{\mu_t^{\Sigma C}} \frac{1}{\pi_{t+1}} \times \left[\chi_{s,t+1}\, E_{A_{i,t+1}}\left[\frac{Q_{t+1}^B}{\tilde{Q}_{s,t+1}^A} \prod_{s,t+1} \middle| \frac{P_{t+1}^K}{A_{s,t+1}} \leq Q_{t+1}^A\right]\right.\right.$$
$$+ \chi_{k,t+1}\, E_{A_{i,t+1}}\left[\frac{Q_{t+1}^B}{\frac{P_{t+1}^K}{A_{k,t+1}}} \prod_{k,t+1} \middle| Q_{t+1}^A \leq \frac{P_{t+1}^K}{A_{k,t+1}} \leq Q_{t+1}^B\right]$$
$$\left.\left. + \chi_{b,t+1}\, E_{A_{i,t+1}}\left(\prod_{b,t+1} \middle| \frac{P_{t+1}^K}{A_{b,t+1}} \geq Q_{t+1}^B\right)\right]\right\},$$

where $\chi_{b,t}$ is the fraction of buyers in the economy:

$$\chi_{b,t} = \Pr\left(\frac{P_t^K}{A_{b,t}} \geq Q_t^B\right) = 1 - \chi_{s,t} - \chi_{k,t},$$

and $\Pi_{s,t+1}, \Pi_{k,t+1}$, and $\Pi_{b,t+1}$ are the equity payoffs for the sellers, keepers, and buyers, respectively,

$$\Pi_{s,t+1} = R_{t+1}^K + \phi Q_{t+1}^A(1 - \delta) + (1 - \phi)\tilde{Q}_{s,t+1}^A(1 - \delta)$$
$$\Pi_{k,t+1} = R_{t+1}^K + \frac{P_{t+1}^K}{A_{k,t+1}}(1 - \delta)$$
$$\Pi_{b,t+1} = R_{t+1}^K + Q_{t+1}^B(1 - \delta).$$

Intuitively from equation (18), buyers will purchase equity claims from financial intermediaries at a nominal price of Q_t^B, equal to the expected discounted value of equity payoffs in period $t+1$ for the different household member types, $\Pi_{s,t+1}, \Pi_{k,t+1}$, and $\Pi_{b,t+1}$. Equity payoffs feature a common component for sellers, keepers, and buyers in the rate of return on capital, R_{t+1}^K, but differ in the continuation value of the claims, depending on the type of household member that receives the asset as part of his endowment at the beginning of period $t+1$. Sellers s will sell a fraction ϕ of their equity to financial intermediaries at the market price Q_{t+1}^A to raise funds for new capital, but they will be forced to hold the remaining fraction $(1-\phi)$ on their balance sheet and evaluate it at the shadow price of inside equity $\tilde{Q}_{s,t+1}^A$. On the other hand, keepers k will neither sell nor buy assets on financial markets and their replacement cost of equity in every period is equal to their relative price of new capital, $P_{t+1}^K / A_{k,t+1}$. Finally, buyers b will be able to replace their equity by purchasing claims from financial intermediaries. The replacement cost of equity for buyers will then equal the purchase price of equity Q_{t+1}^B.

One more consideration in relation to the equity Euler equation pertains to the relative weight assigned to the heterogeneous members in computing the expected discounted value of assets' cash-flows. The solution of the constrained maximization for the household shows that the payoff of each buyer receives a weight of one, while the payoffs that accrue to sellers and keepers receive weights that are higher than one:

$$\frac{Q_{t+1}^B}{\tilde{Q}_{s,t+1}^A} > \frac{Q_{t+1}^B}{\frac{P_{t+1}^K}{A_{k,t+1}}} > 1.$$

It is easy to note that the weight on each household members' payoff is increasing in the idiosyncratic level of technology $A_{i,t}$: intuitively, the same additional payoff is more valuable in the hands of sellers and keepers with better capital installation technologies and above all in the hand of sellers subject to binding financing constraints.

Similar considerations apply to liquid assets holdings. From the Euler equation for bond pricing:

$$\begin{aligned} B_t : 1 \; = \; \beta b_t E_t \Bigg\{ \frac{\mu_{t+1}^{\Sigma C}}{\mu_t^{\Sigma C}} \frac{1}{\pi_{t+1}} \times \Bigg[& \chi_{s,t+1} E_{A_{i,t+1}} \left(\frac{Q_{t+1}^B}{\tilde{Q}_{s,t+1}^A} \middle| \frac{P_{t+1}^K}{A_{s,t+1}} \leq Q_{t+1}^A \right) \\ & + \chi_{k,t+1} E_{A_{i,t+1}} \left(\frac{Q_{t+1}^B}{\frac{P_{t+1}^K}{A_{k,t+1}}} \middle| Q_{t+1}^A \leq \frac{P_{t+1}^K}{A_{k,t+1}} \leq Q_{t+1}^B \right) \\ & + \chi_{b,t+1} E_{A_{i,t+1}} \left(1 \middle| \frac{P_{t+1}^K}{A_{b,t+1}} \geq Q_{t+1}^B \right) \Bigg] R_t^B \Bigg\}. \end{aligned}$$

The payoffs from liquid asset holdings is the nominal risk-free rate R_t^B. Government bonds are liquid assets and can be deployed entirely to purchase and install new capital once a good technology draw is available. Payoffs of liquid assets can help sellers overcome the external funding restrictions imposed by binding borrowing and liquidity constraints on equity and help the household as a whole to direct liquid resources toward members with more productive capital installation technologies.

Buyers also supply differentiated work hours $L_{b,t}$ on a labor market characterized by imperfect competition, in exchange for a monopolistic wage rate $\tilde{W}_{b,t}$. The wage-setting mechanism follows Erceg, Henderson, and Levin (2000). In every period only a fraction $(1 - \xi_w)$ of buyers re-optimizes the nominal wage. A fraction ξ_w is assumed to index their wages $\tilde{W}_{b,t+s}$ in every period $t + s$ according to the rule,

$$\tilde{W}_{b,t+s} = \tilde{W}_{b,t+s-1}\left(\pi_{t+s-1}e^{z_{t+s}-1}\right)^{\iota_w}\left(\pi e^{\gamma}\right)^{1-\iota_w},$$

that describes their evolution of wages as a geometric average of past and steady-state values of inflation and labor productivity.[13] Re-optimizing members set their wage $W_{b,t}$ by maximizing

$$\max_{W_{b,t}} E_t \sum_{s=0}^{\infty} \xi_w^{t+s}\beta^{t+s}\left\{-\frac{\omega}{1+\nu}L_{b,t+s}{}^{1+\nu} + \mu_{t+s}^{\Sigma C}\tilde{W}_{b,t+s}L_{b,t+s}\right\}$$

subject to the labor demand of employment agencies,

$$L_{b,t+s} = \left(\frac{\tilde{W}_{b,t}}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \tag{19}$$

where $\mu_t^{\Sigma C}$ is the marginal utility of one unit of consumption (common across household members).

B. *Financial Intermediaries*

Financial intermediaries (or banks) manage the transfer of resources between entrepreneurs who sell financial claims and buyers. In each period, a multitude of intermediaries indexed by i compete to acquire equity claims, $\Delta N_{i,t}^-$, at price Q_t^A and sell the quantity $\Delta N_{i,t}^+$ to buyers at a price Q_t^B. To do this, they bear an intermediation cost equal to $\tau_t^q Q_t^A$ for each financial claim they process. Banks maximize their nominal profits

$$\Pi_t^{II} = Q_t^B \Delta N_{i,t}^+ - \left(1 + \tau_t^q\right) Q_t^A \Delta N_{i,t}^-, \tag{20}$$

subject to the constraint that the number of claims they buy is the same as the one they sell,

[13] To facilitate notation I define $\tilde{W}_{b,t}$ as being equal to $W_{b,t}$ for $s = 0$ for re-optimizing agents so that

$$\tilde{W}_{b,t} = \begin{cases} W_{b,t}, & \text{with } Pr = 1 - \xi_w \\ \tilde{W}_{b,t+s-1}\left(\pi_{t+s-1}e^{z_{t+s}-1}\right)^{\iota_w}\left(\pi e^{\gamma}\right)^{1-\iota_w}, & \text{with } Pr = \xi_w \end{cases}.$$

$$\Delta N_{i,t}^{+} = \Delta N_{i,t}^{-}. \tag{21}$$

Perfect competition among intermediaries implies that profits are maximized when

$$Q_t^B = \left(1 + \tau_t^q\right) Q_t^A.$$

The "bid" price, Q_t^B, offered to buyers, is equal to the "ask" price, Q_t^A, augmented by an intermediation cost (or spread), τ_t^q.

The financial intermediation spread, τ_t^q, represents the cost that financial intermediaries bear for each unit of financial claims that they transfer from sellers to buyers. The total amount of resources that banks spend to purchase a unit of financial claims from sellers is then equal to $\left(1 + \tau_t^q\right) q_t^A$, where $q_t^A = \left(Q_t^A / P_t\right)$ is the real price of equity. In the literature, Chari, Christiano, and Eichenbaum (1995), Goodfriend and McCallum (2007), and Cúrdia and Woodford (2010b) introduce wedges similar to the one proposed here to model financial market imperfections and the evolution of credit spreads.

Sellers and buyers share the incidence of the intermediation cost. An increase in the cost reduces the expected return on savings to the buyers. At the same time, it lowers the amount of resources that are transferred to investing entrepreneurs for each unit of equity sold. The price of equity claims sold by investing entrepreneurs, Q_t^A, falls and their cost of borrowing rises. The immediate result of negative shocks to τ_t^q is that investment drops with potential effects on output and consumption dynamics, discussed at length in Section IV.

Borrowing costs and corporate financing needs in the data have distinct cyclical features. The evolution of the financing gap share in Figure 1 shows that corporate financial dependence follows a cyclical pattern that lags the macroeconomic cycle by more than one year, while borrowing costs tend to lead the business cycle and to remain elevated for a prolonged period of time following the end of a recession (see cyclical pattern of corporate spreads in the black solid line in Figure 12). While spreads start rising in anticipation of recessions, the financing gap share falls only after the start of the contraction. Recessions tend to have long-lasting effects on the level of spreads and on corporate external financing. The financing gap share starts rising only one or two years after the end of recession episodes, once the level of corporate spreads has subdued. Moreover, the financing gap share increases slowly during economic expansions in conjunction with prolonged periods of low borrowing costs.

To capture the extent of changes in credit conditions that can affect borrowing spreads and financial flows at different frequencies, I assume that the intermediation costs τ_t^q evolves exogenously in response to two kinds of shocks, $\bar{\tau}_t^q$ and $\tilde{\tau}_t^q$, with different degrees of persistence,

$$\tau_t^q = \bar{\tau}_t^q + \tilde{\tau}_t^q.$$

Persistent shocks $\bar{\tau}_t^q$ fluctuate around a steady-state level τ_{ss}^q following an AR(1) process,

$$\bar{\tau}_t^q = (1 - \rho_{\bar{\tau}})\tau_{ss}^q + \rho_{\bar{\tau}}\bar{\tau}_{t-1}^q + \varepsilon_t^{\bar{\tau}},$$

while transitory shocks $\tilde{\tau}_t^q$ have a zero mean and evolve according to the autoregressive process,

$$\tilde{\tau}_t^q = \rho_{\tilde{\tau}} \tilde{\tau}_{t-1}^q + \varepsilon_t^{\tilde{\tau}},$$

where the coefficient $\rho_{\tilde{\tau}}$ is assumed to be lower than $\rho_{\bar{\tau}}$ by a factor ω_τ, so that $\rho_{\tilde{\tau}} = \omega_\tau \rho_{\bar{\tau}}$ with $\omega_\tau < 1$. The two processes are buffeted by i.i.d. shocks $\varepsilon_t^{\bar{\tau}} \sim N(0, \bar{\sigma}_\tau^2)$ and $\varepsilon_t^{\tilde{\tau}} \sim N(0, \sigma_{\tilde{\tau}}^2)$.[14]

C. *Final Good Producers*

At each time t, competitive firms operate to produce a homogeneous consumption good, Y_t, as a combination of differentiated intermediate goods, $Y_t(i)$, through the technology,

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\lambda_{p,t}}} di\right]^{1+\lambda_{p,t}}, \tag{22}$$

where $\lambda_{p,t}$ is the degree of substitutability between the differentiated inputs. The log of $\lambda_{p,t}$ follows an ARMA(1,1) exogenous process

$$\log(1 + \lambda_{p,t}) = (1 - \rho_p)\log(1 + \lambda_p) + \rho_p \log(1 + \lambda_{p,t-1}) + \varepsilon_t^p + \theta_p \varepsilon_{t-1}^p \tag{23}$$

with $\varepsilon_t^p \sim N(0, \sigma_{\lambda_p}^2)$, as in Smets and Wouters (2005).

The standard profit maximization of the final good producers and their zero profit condition determine the price of the final good, P_t, as a CES aggregator of the prices of the intermediate goods, $P_t(i)$:

$$P_t = \left[\int_0^1 P_t(i)^{\frac{1}{\lambda_{p,t}}} di\right]^{\lambda_{p,t}}$$

and the demand for intermediate good i as

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}} Y_t. \tag{24}$$

D. *Intermediate Goods Producers*

Firms in a regime of monopoly use capital and labor inputs, $K_{t-1}(i)$ and $L_t(i)$, to produce differentiated intermediate goods, $Y_t(i)$, using the following technology:

$$Y_t(i) = A_t^\eta K_{t-1}(i)^{1-\eta} L_t(i)^\eta, \tag{25}$$

where A_t represents non-stationary labor-augmenting technological progress. The growth rate of A_t, denoted as $\log(z_t)$, follows an exogenous AR(1) process:

[14] See online Appendix D for a detailed discussion of the differences and similarities between financial intermediation shocks described in this section and liquidity shocks discussed in the KM model and in Del Negro et al. (2010).

$$(26) \qquad \log\left(\frac{A_t}{A_{t-1}}\right) = \log(z_t) = (1-\rho_z)\log(\gamma) + \rho_z \log(z_{t-1}) + \varepsilon_t^z,$$

where γ is the steady-state growth rate of output in the economy and $\varepsilon_t^z \sim N(0, \sigma_z^2)$.

Firms employ homogeneous labor inputs, $L_t(i)$, from households at a nominal wage rate W_t and rent the capital stock, $K_{t-1}(i)$, from entrepreneurs at a competitive rate R_t^K. Firms minimize their costs and maximize their monopolistic profits, knowing that in period t they will only be able to re-optimize their prices with probability $(1-\xi_p)$. The remaining fraction of firms that do not re-optimize, ξ_p, are assumed to update their prices according to the indexation rule

$$P_t(i) = P_{t-1}(i)\,\pi_{t-1}^{\iota_p}\pi^{1-\iota_p},$$

where $\pi_t = (P_t/P_{t-1})$ is the gross rate of inflation and π is its steady-state value (Calvo 1983).

Those firms that can choose their price level will then set $P_t(i)$ optimally by maximizing the present discounted value of their flow of profits,

$$(27) \quad E_t \sum_{s=0}^{\infty} \xi_p^s \beta^s \mu_{t+s}^{\Sigma C}\left[P_t(i)\left[\prod_{j=0}^{s}\pi_{t-1+j}^{\iota_p}\pi^{1-\iota_p}\right]Y_{t+s}(i) - \left[W_t L_t(i) + R_t^k K_t(i)\right]\right],$$

subject to the demand function for good $Y_t(i)$, (24), and to the production function (25). Households own shares of the intermediate firms: current and future profits (27) are evaluated according to the marginal utility of a representative household, $\mu_t^{\Sigma C}$.

E. *Investment Goods Producers*

Investment goods producers operate in a regime of perfect competition and on a national market. Producers purchase units of final goods, Y_t^I at a price P_t, and transform them into aggregate investment goods, I_t, by means of a linear technology,

$$I_t = Y_t^I.$$

Producers then have access to a production technology to produce ι_t units of investment goods from aggregate investment I_t:

$$(28) \qquad \iota_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t,$$

where $S(\cdot)$ is a convex function in I_t/I_{t-1}, with $S = 0$ and $S' = 0$ and $S'' = \theta_I > 0$ in steady state (Christiano, Eichenbaum, and Evans 2005). Producers sell investment goods ι_t to the entrepreneurs on a competitive market at a price P_t^K. In every period they choose the optimal amount of inputs, I_t in order to maximize their profits:

$$(29) \qquad \max_{I_{t+s}} E_t \sum_{s=0}^{\infty} \beta^s E_{t+s}\left\{\mu_{t+s}^{\Sigma C}\left[P_{t+s}^k i_{t+s} - P_{t+s} I_{t+s}\right]\right\},$$

subject to the technology (28). Households own stocks in the capital producers, so that the stream of their future profits is weighted by their marginal utility of consumption, $\mu_t^{\Sigma C}$.

F. *Employment Agencies*

As discussed in Section IIA, members of the household who become buyers (indexed by b) supply differentiated work hours to employment agencies in exchange for a nominal monopolistic wage $W_{b,t}$. A large number of such employment agencies combine the differentiated labor into a homogeneous labor input L_t, by means of the Dixit-Stiglitz technology:

$$L_t = \left[\int_0^{\frac{P_t^K}{Q_t^B}} L_{b,t}^{\frac{1}{1+\lambda_{w,t}}}\, dF(A_{i,t})\right]^{1+\lambda_{w,t}},$$

where $\lambda_{w,t}$ is the degree of substitutability of specialized labor inputs, $L_{b,t}$, and the desired markup of the wage over the marginal disutility of labor required by the specialized household. I assume that the markup evolves according to an exogenous ARMA(1,1) process:

$$\log\left(1+\lambda_{w,t}\right) = \left(1-\rho_w\right)\log\left(1+\lambda_w\right) + \rho_w \log\left(1+\lambda_{w,t-1}\right) + \varepsilon_t^w + \theta_p \varepsilon_{t-1}^w \tag{30}$$

with $\varepsilon_t^w \sim N\left(0, \sigma_{\lambda_w}^2\right)$.

Agencies hire specialized labor, $L_{b,t}$, at monopolistic wages, $\tilde{W}_{b,t}$, and provide homogeneous work hours, L_t, to the intermediate producers, in exchange for a nominal wage, W_t. Similarly to the good production technology, profit maximization delivers a conditional demand for labor input for each employment agency equal to

$$L_{b,t} = \left(\frac{\tilde{W}_{b,t}}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t.$$

The nominal wage paid by the intermediate firms to the employment agencies is an aggregate of the different specialized salaries $\tilde{W}_{b,t}$:

$$W_t = \left[\int_0^{\frac{P_t^K}{Q_t^B}} \tilde{W}_{b,t}^{\frac{1}{\lambda_{w,t}}}\, dF(A_{i,t})\right]^{\lambda_{w,t}}.$$

G. *Monetary Authority*

The central bank sets the level of the nominal interest rate, R_t^B, according to a Taylor-type rule of the kind

$$\frac{R_t^B}{R^B} = \left(\frac{R_{t-1}^B}{R^B}\right)^{\rho_R}\left[\left(\frac{\overline{\pi}_t}{\pi}\right)^{\phi_\pi}\left(\frac{\Delta \overline{Y}_{t-s}}{\gamma}\right)^{\phi_{DY}}\right]^{1-\rho_R} \eta_{mp,t}, \tag{31}$$

where the nominal risk-free rate depends on its lagged realization and responds to deviations of a 4-period trailing inflation index $\bar{\pi}_t = \sum_{s=0}^{3} \pi_{t-s}/4$ from steady-state inflation, π, as well as to the deviations of the average growth rate of GDP, $Y_t = C_t + I_t + G_t$, in the previous year $\Delta \overline{Y}_{t-s} = \sum_{s=0}^{3} (\log Y_{t-s} - \log Y_{t-s-1})/4$ from its steady-state value γ. Moreover, $\eta_{mp,t}$ represents a monetary policy shock

$$\log \eta_{mp,t} = \varepsilon_{mp,t},$$

where $\varepsilon_{mp,t}$ is i.i.d. $N(0, \sigma_{mp}^2)$.[15]

H. *Fiscal Authority*

The fiscal authority issues debt, B_t, and collects lump-sum taxes, T_t, to finance a stream of public expenditures, G_t, and interest payments on the stock of debt that has come to maturity, $R_{t-1}^B B_{t-1}$,

$$B_t + T_t = R_{t-1}^B B_{t-1} + G_t. \tag{32}$$

The share of government spending over total output follows an exogenous process:

$$G_t = \left(1 - \frac{1}{g_t}\right) Y_t,$$

where

$$\log g_t = (1 - \rho^g) g_{ss} + \rho^g \log g_{t-1} + \varepsilon_t^g,$$

and $\varepsilon_t^g \sim$ is i.i.d. $N(0, \sigma^{g2})$.

The government supplies a positive quantity of government bonds to satisfy the demand of liquid assets of the household. Similarly to Leeper, Plante, and Traum (2010), I assume that the share of taxes over total output, T_t/Y_t, departs from its steady-state value, ToY, in response to deviations of the debt to output ratio B_t/Y_t from a specific target, BoY:

$$\frac{T_t/Y_t}{ToY} = \left(\frac{B_t/Y_t}{BoY}\right)^{\varphi_B}. \tag{33}$$

Taxes are assumed to increase when the debt over GDP ratio, B_t/Y_t, increases above its steady-state level, as to keep the stock of public debt stationary ($\varphi_B > 0$).[16]

[15] In the spirit of Taylor (1993, 1999), I estimated versions of the model in which the central bank responds to realized inflation and to the output gap, measured as (i) deviations of output from its natural rate or (ii) deviations of output from its model-consistent HP-filtered trend (Cúrdia et al. 2011). These attempts typically delivered estimated coefficient on the output gap that were small and nonsignificantly different from zero, with no noticeable effect on other results in the paper. This finding is consistent with empirical evidence in Cúrdia et al. (2011), who argue that specifications of the Taylor rule that respond to inflation and the output gap have poor fit in DSGE models.

[16] Restrictions on the sign and magnitude of φB can ensure that fiscal policy is passive, so that it does not conflict with the central bank's Taylor rule in the determination of a unique stable path for the growth rate of the price

I. *Aggregation, Market Clearing, and Model Solution*

Aggregation across sellers, keepers, and buyers is made easy by the large household assumption and by the independence of the realizations of idiosyncratic shocks, $A_{i,t}$, from the state of capital and financial asset holdings, $N_{i,t-1}$ and $B_{i,t-1}$, with which members enter a generic period t.

Summing over the flow of funds constraints of the household, government, financial intermediaries, and all producers in the economy, output at time t, Y_t, is absorbed by household consumption C_t, investment, I_t, and government spending, G_t:

$$Y_t = C_t + I_t + G_t$$

equal to the definition of GDP.[17]

To solve the model, I first rewrite its equilibrium conditions in stationary terms, rescaling variables such as output, Y_t, consumption, C_t, investment, I_t, capital and equity, K_t and N_t, and real wages, W_t/P_t, that inherit the unit root of the total factor productivity stochastic process, A_t. I then compute the steady state of the model and find a log-linear approximation of the stationary equilibrium conditions around it. Finally, I solve the system of log-linear rational expectation equations using the approach in Anderson and Moore (1985) to obtain the model's state-space representation.

III. Estimation

In this section, I describe the estimation of the model on US aggregate time series and evidence on the financing gap share aggregated from the universe of Compustat firms. I use Bayesian methods to estimate the model. I start with a description of the data and of the choice of prior distributions for the model parameters and for selected moments, based on the literature on the estimation of DSGE models and on the micro-data evidence from Compustat. Estimates for the parameters are obtained by maximizing the posterior distribution of the model on observable time series (An and Schorfheide 2007).

level (Woodford 2003).

[17] Online Appendix E contains the complete set of aggregate equilibrium conditions for the model as well as the definition of an equilibrium for this economy. It is worth noting that the assumptions of linearity of the capital installation technologies of household members, $A_{i,t}$, as well as the perfect substitutability of equity claims and units of capital, allow me to prove that the borrowing and liquidity constraints are always binding for sellers, while the nonnegativity constraints on consumption and liquid asset positions are always binding for sellers and keepers. The solution to the household maximization problem in online Appendix E offers a full proof.

A. *Data*

I use Bayesian methods to fit the log-linear approximation of the model solution to a sample of US time series that spans from 1989:I to 2008:II.[18] To estimate the model parameters, I use the following vector of eight observable variables:[19]

$$\left[\Delta\log GDP_t,\ \ \Delta\log I_t,\ \ \Delta\log C_t,\ \ \Delta\log\frac{W_t}{P_t},\ \ \pi_t,\ \ R_t^B,\ \ \log L_t,\ \ Sp_t,\ \ \widehat{FGS}_t\right].$$

The dataset is composed of the log growth rate of real per-capita GDP, GDP_t, investment, I_t, aggregate consumption, C_t, and real hourly wages, $\frac{W_t}{P_t}$. The dataset also includes the growth rate of the GDP price deflator, mapped into the model inflation rate π_t, the federal funds rate, mapped into the model nominal risk-free rate R_t^B, and the log of per-capita hours worked L_t. On top of the macro variables that are standard in the literature, the observables include the spread between the Moody's seasoned Baa-rated corporate bond yield and the ten-year Treasury note yield, Sp_t. The spread can be interpreted as a measure of the extra cost that markets apply to lower-medium grade corporate external financing, netted of term-premium components. The observed spread, Sp_t, maps into the model as the difference between the borrowing cost of sellers and the yield on risk-free government bonds, up to a measurement error $\eta_t^{Sp} \sim N(0, \sigma^2_{ME_{sp}})$,

$$Sp_t \;=\; 400 \times E_t\left[\log\left(\frac{R_{t+1}^K + (1-\delta)\,Q_{t+1}^A}{Q_t^A}\right) - R_t^B\right] + \eta_t^{Sp}.$$

I estimate the model on corporate bond spreads, rather than on the difference between lending and borrowing rates applied by financial intermediaries, because in the United States the majority of corporate sources of funds are channeled through financial markets (by means of corporate bonds as well as equity) rather than through commercial banking (De Fiore and Uhlig 2011). In the same spirit, banks in the model resemble market dealers, buying and selling financial claims to and from household members, than traditional commercial banks. The choice of the lower-medium grade spread series conforms to the evidence that the median bond traded on financial markets in the period that I consider (1989:I to 2008:II) is rated BBB on the S&P scale (Baa on a Moody's scale) and is standard in the literature (see for example Christiano, Motto, and Rostagno 2014). Similarly, I perform the

[18] I follow Christiano, Motto, and Rostagno (2014) and Christiano, Eichenbaum, and Trabandt (2015) and estimate the log-linearized solution of the model on a sample period in which the federal funds rate was higher than its effective lower bound. I truncate the sample period to 2008:II to avoid possible distortions in the estimation results due to the zero-lower bound in place from the end of 2008. Online Appendix F solves and simulates the estimated model to describe features of the Great Recession taking into account the zero lower bound constraint on the monetary policy instrument (see Guerrieri and Iacoviello 2015 for details on the solution method). Table K.3 in the online Appendix shows that the inclusion of the post-2008 period in the sample raises the values of the estimated Calvo price and wage parameters and the persistence of the Taylor Rule (Lindé, Smets, and Wouters 2015) with respect to the baseline estimates in Table 2. Since the beginning of the Great Recession, hours fell considerably while the federal funds rate stayed at its effective lower bound and inflation was fairly unresponsive. The model estimation over the sample extended to 2012:IV matches those three joint data features by favoring higher degrees of nominal rigidities and interest-rate inertia.

[19] See online Appendix C for data sources.

baseline model estimation on ten-year spreads to approximate the empirical evidence in Gilchrist and Zakrajsek (2012) that the average maturity of corporate bonds issued from 1973 and 2010 is around 13 years, and that more recently, since 1996, the average maturity at issuance of corporate bonds has ranged between 7.5 and 16 years (Thomson-Reuters and Sifma).[20] As a robustness check, I also estimate the model substituting the BBB corporate bond spreads with the Excess Bond Premium (EBP) series derived in Gilchrist and Zakrajsek (2012). In their paper, Gilchrist and Zakrajsek (2012) use matched corporation- and bond-level data to decompose corporate spreads in default risk compensation on one side and the EBP on the other. They find that the EBP isolates a component of credit spreads that does not contain firm-specific default risk compensation and correlates highly with the evolution of aggregate financial conditions and in particular with measures of distress of financial intermediaries. Their research also shows that the Excess Bond Premium series has a high-information content in predicting future economic activity (Gilchrist, Yankov, and Zakrajsek 2009). These features make the Excess Bond Premium an excellent candidate to identify financial intermediation shocks. Estimation results obtained mapping the cost of borrowing in the model to the EBP series are in line with the baseline case and described in online Appendix K.

As an original contribution to the literature, I include the log-deviations of the financing gap share from its steady state, $\widehat{FGS}_t = \log(FGS_t) - \log(FGS_{ss})$, among the set of observable variables for the estimation. Following the derivations in online Appendix B, I map the financing gap share in the data to the ratio of sellers' aggregate financing gap, FG_t, over aggregate investment, I_t, up to a measurement error, $\eta_t^{FGS} \sim N(0, \sigma^2_{ME_{fgs}})$:

$$(34)\quad FGS_t = \frac{FG_t^{TOT}}{I_t} \times \eta_t^{FGS}$$

$$= \frac{\int_{\frac{P_t^K}{Q_t^A}}^{\infty} \theta \frac{P_t^K}{Q_t^A} \iota_{i,t}\, dF(A_{i,t}) + (\chi_{s,t} + \chi_{k,t})(Q_t^A \phi(1-\delta) N_t + R_{t-1}^B B_t)}{I_t} \times \eta_t^{FGS}.$$

B. *Priors, Calibrated Parameters, and Posterior Estimates*

The choice of the priors for most parameters of the model is rather standard in the literature (Del Negro et al. 2007; Justiniano, Primiceri, and Tambalotti 2010; Christiano, Motto, and Rostagno 2014) and is summarized in Table 2. Table 2 also reports the mode and 90 percent credible intervals for the posterior estimates of the model parameters. I compute credible intervals by running a Markov chain Monte Carlo (MCMC) exploration of the posterior distribution around the posterior mode.

A few words are necessary to discuss the priors selection and estimates for the parameters that influence entrepreneurs' investment financing decisions and the efficiency of financial intermediation in the model. I set a gamma prior on the steady-state intermediation cost, τ_{ss}^q, with mean 2 percent and standard deviation 0.4 percent,

[20] Figure 30 in the online Appendix compares BBB corporate spreads with maturity 1–5 years, 7–10 years, and average market maturity in the Merrill Lynch Master. The series present similar cyclical patterns and are highly correlated. Estimation results are robust to the choice of different spread maturities and are available upon request.

Table 2—Calibrated Values, Priors, and Posterior Estimates for the Model Parameters

Parameter	Explanation	Prior	Mode	[5% 95%][a]
γ	SS output growth	Calibrated	0.5	[− − −]
$(\beta^{-1} - 1) \times 100$	Discount factor	Gamma(0.75, 0.05)	0.632	[0.579 − 0.708]
δ	Capital depreciation	Calibrated	0.025	[− − −]
ν	Inverse Frisch	Gamma(2, 0.75)	2.38	[1.31 − 3.81]
h	Habit	Beta(0.5, 0.2)	0.843	[0.787 − 0.903]
l_{ss}	Labor supply	Calibrated	0	[− − −]
η	Labor share	Beta(0.6, 0.05)	0.748	[0.73 − 0.766]
λ_p	Price markup	Calibrated	0.15	[− − −]
ξ_p	Calvo prices	Beta(0.66, 0.1)	0.813	[0.768 − 0.869]
ι_p	Index prices	Beta(0.5, 0.15)	0.203	[0.0849 − 0.477]
λ_w	Wage markup	Calibrated	0.15	[− − −]
ξ_w	Calvo wages	Beta(0.66, 0.1)	0.927	[0.877 − 0.957]
ι_w	Index wages	Beta(0.5, 0.15)	0.431	[0.248 − 0.597]
μ_A	Mean idiosyn. technology	Calibrated	0	[− − −]
σ_A	Std. idiosyn. technology	Gamma(0.1, 0.04)	0.0147	[0.0131 − 0.017]
FGS_{ss}	FGS steady state	Calibrated	0.35	[− − −]
θ	Collateral constr.	Collateral Constr.	0.677	[0.576 − 0.758]
Bs_{ss}	Liquidity over GDP	Calibrated	0.02	[− − −]
gs_{ss}	Govt. spend. over GDP	Calibrated	0.17	[− − −]
$\tau_{q_{ss}} \times 100$	SS intermediation cost	Gamma(1, 0.4)	3.52	[3.07 − 4.15]
θ_I	IAC	Gamma(4, 2)	0.755	[0.548 − 1.01]
π_{ss}	SS inflation	Normal(0.5, 0.1)	0.312	[0.232 − 0.425]
ρ_i	Taylor rule inertia	Beta(0.85, 0.1)	0.828	[0.789 − 0.857]
ϕ_π	Taylor rule inflation	Normal(1.7, 0.05)	1.46	[1.37 − 1.55]
ϕ_{DY}	Taylor rule GDP growth	Normal(0.125, 0.1)	0.156	[0.079 − 0.231]
φ_B	Fiscal rule–debt	Normal(0.5, 0.2)	0.236	[0.117 − 0.252]
ρ_z	AR(1) TFP growth shock	Beta(0.5, 0.2)	0.379	[0.222 − 0.526]
ρ_g	AR(1) G shock	Beta(0.5, 0.2)	0.996	[0.993 − 0.998]
$\rho_{\bar{\tau}}$	AR(1) fin. shock pers.	Beta(0.5, 0.2)	0.986	[0.98 − 0.99]
$\omega_{\tilde{\tau}}$	AR(1) fin. shock trans.	Beta(0.5, 0.2)	0.771	[0.701 − 0.823]
ρ_β	AR(1) beta shock	Beta(0.5, 0.2)	0.487	[0.316 − 0.636]
ρ_p	AR(1) P markup shock	Beta(0.5, 0.2)	0.707	[0.382 − 0.822]
ρ_w	AR(1) W markup shock	Beta(0.5, 0.2)	0.159	[0.0284 − 0.43]
θ_p	MA(1) P shock	Beta(0.5, 0.2)	0.194	[0.0319 − 0.535]
θ_w	MA(1) W shock	Beta(0.5, 0.2)	0.148	[0.0349 − 0.37]
σ_z	SD TFP growth shock	InvGamma2(0.5, 1)	0.601	[0.529 − 0.691]
σ_g	SD G shock	InvGamma2(0.5, 1)	0.153	[0.135 − 0.178]
σ_i	SD MP shock	InvGamma2(0.1, 1)	0.121	[0.105 − 0.141]
$\sigma_{\bar{\tau}}$	SD fin. shock pers.	InvGamma2(0.5, 1)	0.143	[0.119 − 0.179]
$\sigma_{\tilde{\tau}}$	SD fin. shock trans.	InvGamma2(0.5, 1)	0.154	[0.128 − 0.188]
σ_β	SD beta shock	InvGamma2(0.5, 1)	2.37	[1.67 − 3.41]
σ_p	SD P markup shock	InvGamma2(0.1, 1)	0.069	[0.0517 − 0.107]
σ_w	SD W markup shock	InvGamma2(0.1, 1)	0.308	[0.228 − 0.36]
$\sigma_{ME_{sp}}$	SD ME spread	InvGamma2(0.05, 0.05)	0.025	[0.0109 − 0.078]
$\sigma_{ME_{fgs}}$	SD ME FGS	InvGamma2(0.05, 0.05)	0.148	[0.129 − 0.17]

Notes: Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model. [a]Posterior percentiles from 3 chains of 100,000 draws generated using a random walk Metropolis-Hasting algorithm. Acceptance rate 21 percent. Burning period: initial 20,000 draws. Statistics computed over 1,000 randomly sampled accepted draws.

Source: Author's calculations

to be consistent with empirical evidence in Philippon (2015) that the average cost of financial intermediation per unit of intermediated asset in the United States has historically been between 1.5 percent to 2.5 percent during our sample period. The estimated cost per unit of intermediated assets is slightly higher and ranges between 3.0 percent and 4.15 percent.

I calibrate the average financing gap share FGS_{ss} to be 0.35, in line with Compustat evidence described in Section I. The gap in steady state will be funded by means of changes in liquid reserves (governed by BoY), sales of illiquid assets (governed by ϕ), and issuance of financial claims (borrowing, governed by θ). In the model, government bonds, B_t, are the liquid assets which entrepreneurs accumulate as precautionary savings to overcome their financial constraints. I decide to match the stock of government debt in the model to the holdings of government-backed liquidity of US corporations (and not to the stock of government bonds in circulation in the whole economy), to be consistent with the role played by liquid assets in the model. The parameter BoY is then calibrated to be 2 percent, loosely in line with Flow of Funds evidence that nonfinancial corporations have in fact held a share of 2.1 percent of GDP in government-backed liquid assets during the sample period 1989:I to 2008:II. I set a beta prior on the borrowing constraint parameter θ with mean 0.75 and standard deviation 0.10, consistent with firms financing more than half of their investments in fixed capital by issuing debt or equity. The estimated value for θ at the mode is around 0.68. The liquidity share ϕ is determined as a residual parameter in steady state, as the share of assets that can be liquidated to fund a 35 percent financing gap share, consistent with use of cash reserves pinned down by BoY and the estimated borrowing constraint θ. I verify that the estimated fraction of the financing gap share funded by asset liquidations (as opposed to new issuances of debt or equity) in steady state, $LIQS_{ss}$, is 25 percent, compared to an average in the Compustat data of 22 percent reported in Section I.

I assume that the household members' capital installation technologies $A_{i,t}$ are distributed according to a lognormal distribution with mean household technology μ_A and standard deviation σ_A. I calibrate the scaling parameter μ_A to zero, and I impose a wide gamma prior with mean 0.2 and standard deviation of 0.4 on the parameter that governs the idiosyncratic investment technology risk, σ_A. The standard deviation of investment technology, σ_A, is very tightly estimated, with a rather low value at the mode of around 1.5 percent. The parameter determines the degree of curvature of the lognormal distribution. Together with the other financial parameters, the curvature σ_A also affects the steady-state and dynamics of the share of household members that take advantage of their investment opportunities and therefore have a negative financing gap. I verify that the steady state probability of installing new capital and incurring a negative financing gap in the model, $\chi_s + \chi_k$, is equal to 50 percent at the posterior mode, comparable with a 49 percent share of firms with negative financing gap in the data (see Table 1).[21]

The economy displays a moderate degree of price rigidities, with prices being updated approximately once every four quarters. Wages are more rigid than prices

[21] By affecting the steady state probability of investment opportunities, the parameter σ_A is also crucial in determining the level of the liquidity premium embedded in government bonds and the equilibrium risk-free rate in steady state. The estimated steady-state annual risk-free rate in the model is around 3 percent.

(renegotiated on average once every two and a half years), but subject to a moderate degree of indexation, with 40 percent of quarterly adjustments reflecting past quarterly TFP growth and inflation dynamics. The price and wage steady-state markups are calibrated to 15 percent to facilitate the steady state calculations.

I choose the steady-state value for $g_{ss} = 0.17$ to match the average share of government expenditures over GDP observed during the sample period. For each level of government debt in steady state, the share of lump-sum transfers to households over GDP is found by solving the government budget constraint (32) in steady state. Transfers dynamics govern the aggregate supply of liquid assets in general equilibrium over time by means of the taxation rule (33). I impose a wide gamma prior with mean 0.5 and standard deviation 0.2 on the absolute value of the fiscal policy parameter φ_B, in line with the estimated elasticities of lump-sum handouts in Leeper, Plante, and Traum (2010). Not directly observing data on tax flows, posterior estimates of φ_B do not diverge considerably from the prior. I pair the prior on transfer policy parameters with standard priors on the coefficients of the Taylor-type rule (in particular the prior on ϕ_π is Normal with mean 1.7 and standard deviation 0.05) so that the estimation favors model solutions with dominant monetary policy and passive fiscal policy. The estimated Taylor-rule coefficients are in line with previous findings in the literature (with $\phi_\pi = 1.46$ and $\phi_{DY} = 0.156$ at the mode). I calibrate the steady state quarterly growth rate of the economy to 0.5 percent (approximately the average of GDP growth in sample), and demean the growth rates of output, consumption, investment, and real wage growth accordingly before the estimation.

The model is buffeted by i.i.d. random innovations,

$$\left[\varepsilon_t^z, \varepsilon_t^g, \varepsilon_t^{mp}, \varepsilon_t^{\bar{\tau}_q}, \varepsilon_t^{\tilde{\tau}_q}, \varepsilon_t^b, \varepsilon_t^p, \varepsilon_t^w\right],$$

that respectively hit exogenous processes for the growth rate of total factor productivity, z_t, the share of government spending over GDP, g_t, deviations of the nominal risk-free rate from the Taylor rule, $\eta_{mp,t}$, the financial intermediation wedge, τ_t^q, the discount factor, b_t, and the price and wage markups, λ_t^p and λ_t^w. I also introduce measurement error in the observation equations for the two financial variables, Sp_t and FGS_t, used in the estimation; these are given by η_t^{FGS} and η_t^{Sp}, respectively.

The priors on the persistence parameters for the exogenous processes are all beta distributions with mean 0.5 and standard deviation 0.2.[22] The persistence of the lower- and higher-frequency processes that compose the financial intermediation shock, $\bar{\tau}_t^q$ and $\tilde{\tau}_t^q$, are governed by the parameters $\rho_{\bar{\tau}}$ and $0 \leq \omega_\tau < 1$. I impose a beta prior with mean 0.5 and standard deviation of 0.2 for $\rho_{\bar{\tau}}$ and for ω_τ so that shocks to $\tilde{\tau}_q$ are 60 percent less persistent than shocks to $\bar{\tau}_q$ at the prior mode. The autoregressive coefficient of the persistent shock to intermediation costs is high, $\rho_{\bar{\tau}} \approx 0.986$, and in line with evidence on exogenous financial disturbances in DSGE models (see for example Christiano, Motto, and Rostagno 2014). The posterior mode estimate of the decay parameter ω_τ implies that the higher-frequency financial intermediation shock, $\tilde{\tau}_t^q$, has a half-life of three quarters ($\rho_{\tilde{\tau}} \approx 0.76$).

[22] The monetary policy shock is assumed to be i.i.d. The Taylor rule allows for autocorrelation in the determination of the risk-free rate.

The priors on the standard deviations of the innovations (expressed in percentage deviations) are inverse-gammas of type 2 with mean 0.5 and standard deviation 1, excluding the shocks to the monetary policy rule, ε_t^{mp}, and so to the price and wage markups, ε_t^{p} and ε_t^{w}, for which the prior has mean 0.10 and standard deviation 1. I set inverse gamma priors on the standard deviations of the measurement error on the log-deviations of the financing gap and on the corporate spread, $\sigma_{ME_{fgs}}$ and $\sigma_{ME_{Sp}}$, with mean 0.05 percent and standard deviation 0.05 percent.

To conclude, I complement the set of exogenous priors by adding a penalty for parameter draws that imply elevated unconditional standard deviations for the financing gap share series. The prior is Gaussian with mean centered around the sample standard deviation of $\widehat{FGS_t}$, 12.58 (see Table 1), and standard deviation of 6 percent. The penalty can be interpreted as a GMM-type endogenous prior on the volatility of the observable (Christiano, Trabandt, and Walentin 2011b).[23]

IV. Results

In this section I discuss the model fit with the data. I describe the impulse responses and the transmission channel of financial intermediation shocks. I show evidence that nominal rigidities are crucial in the model for financial intermediation shocks to play a fundamental role in driving the business cycle in recent US history. I also show that financial intermediation shocks generate endogenous changes in the average investment technology as in Buera and Moll (2015), but the contribution of technology shifts is estimated to be small.

I present the variance decomposition of the observables in the contributions of each fundamental shock. I display the historical decomposition of real GDP growth and the financial variables into the smoothed shocks over the entire sample period. Such decomposition shows that persistent financial intermediation shocks are key drivers of business cycles in the United States. Persistent shocks jointly explain changes in the financing gap share and in the low-frequency level of spreads. Higher frequency changes in spreads are shown to have limited effect on real variables.

A. *Impulse Responses to Financial Intermediation Shocks*

Figure 4 shows the impulse responses to a one standard-deviation persistent increase in intermediation costs, $\overline{\tau}_t^{q}$, evaluated at the posterior parameter. The plots also report the 90 percent credible sets for the impulse response functions.[24]

When financial intermediation costs rise, corporate spreads increase persistently by a relatively small amount (around 15 basis points). The expectation that spreads

[23] Section H in the online Appendix shows that imposing a prior on the volatility of the financing gap shares helps the estimation stay in regions of the parameter space where the log-linear approximation of the model solution is more likely to be accurate. The width of the prior affects the estimated volatility of the financing gap share, as well as the volatility of the growth rate of the total financing gap. A narrower prior can increase the accuracy of the model solution but also decreases the volatility of credit flows in the model in a way that is not consistent with Compustat evidence (see Section IVB and Table 3). The width of the prior however does not alter the key result of the paper that financial intermediation shocks are the main drivers of business cycle fluctuations. I also show that the prior can be substituted with a tight prior centered around low values of the autoregressive coefficient of persistent financial shocks, $\rho_{\overline{\tau}_t^{q}}$, with similar implications for the accuracy of the model solution.

[24] Figures 22 to 27 in the online Appendix report the set of estimated impulse responses for the standard (Smets and Wouters 2003) shocks.

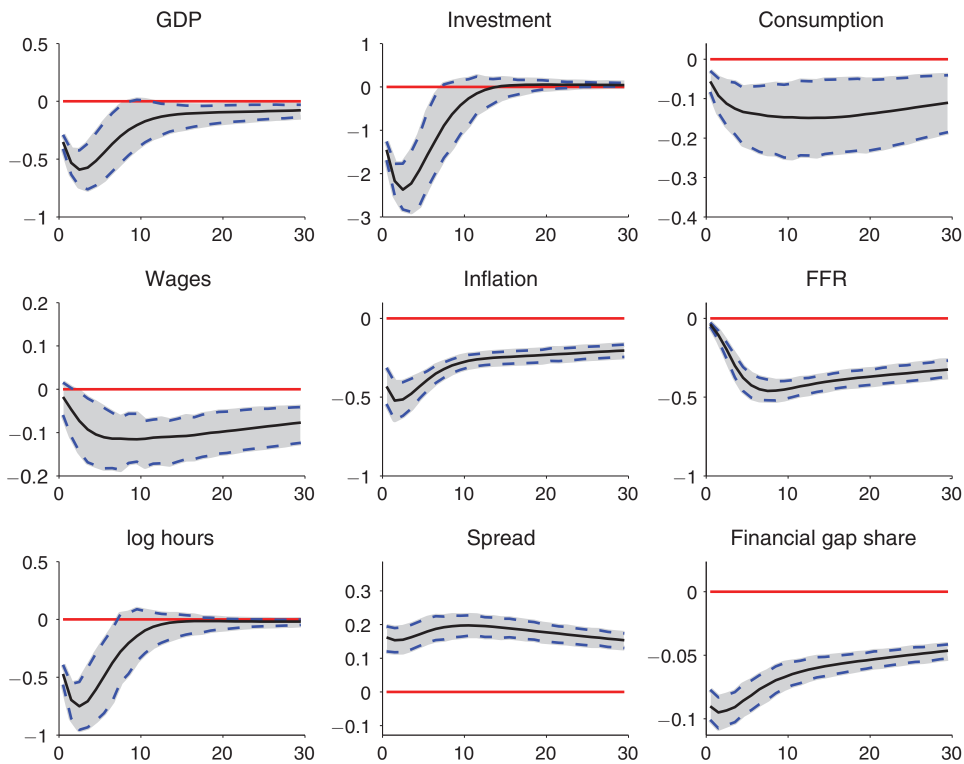

Figure 4. Impulse Response to a Persistent Negative Financial Shock

Notes: Impulse responses to a one standard deviation persistent negative financial shock $\tilde{\tau}_t^q$. The shaded areas represent the 90 percent posterior credible sets around the posterior median.

Source: Author's calculations

will remain elevated for a prolonged period of time causes entrepreneurs in the household to reduce their external financial dependence. The financing gap share falls persistently by around 10 percent of its steady state level (from the steady state level of 35 percent to approximately 31.5 percent). Facing tighter financing conditions, quarterly investment drops by 1.5 percent on impact and by around 2.5 percent at the trough of the cycle.

Annual inflation drops by 0.5 percent and remains persistently under its long-run trend, while the central bank lowers the nominal risk-free rate (FFR) slowly by 0.5 percent over the course of two years and keeps accommodating even after output has reverted back to its long-term trend.

The inertial response of the central bank, paired with the persistent decrease of the inflation rate below its steady-state level, imply that the real risk-free rate increases on impact (shown in the solid black line in quadrant 7 of Figure 6 discussed further below in Section IVA). Higher real rates discourage consumption today so that quarterly consumption drops moderately, together with investment, by around 0.15 percent, and quarterly output falls by 0.6 percent at the trough. The drop in real wages is modest (0.1 percent), since nominal wages and prices are estimated to be sticky.

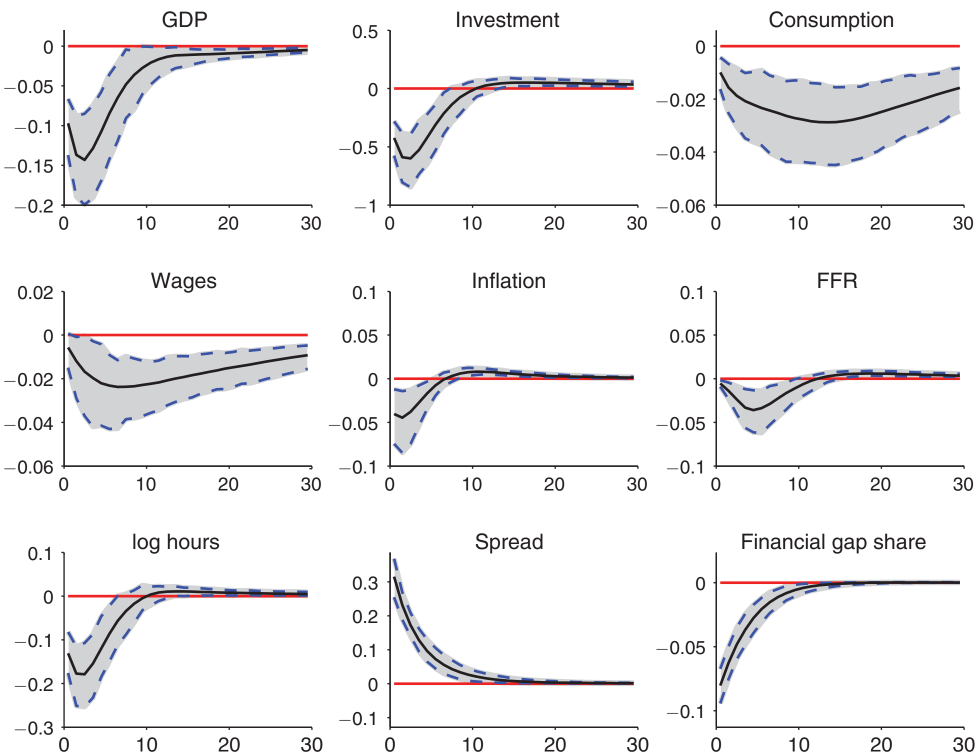

Figure 5. Impulse Response to a Transitory Negative Financial Shock

Notes: Impulse responses to a one standard deviation transitory negative financial shock, $\tilde{\tau}_t^q$. The shaded areas represent the 90 percent posterior credible sets around the posterior median.

Source: Author's calculations

With limited downward adjustment in real wages, hours worked drop persistently by around 0.7 percent over the course of a year in response to lower aggregate demand.

Persistent financial disturbances $\bar{\tau}_t^q$ affect credit flows and have long-lasting effects on the level of inflation and interest rates in the model. Transient shocks $\tilde{\tau}_t^q$ feature similar impulse responses, displayed in Figure 5. The increase in corporate spreads on impact is substantial (around 30 basis points), but perceived to be short-lived. Since the increase in borrowing costs is temporary, sellers reduce their financing gap share by around 8 percent of its steady state value (compared to 10 percent for persistent shocks), while investment drops by around 0.5 percent at the trough of the cycle. The effects of a transitory financial intermediation shock on all variables are significantly different from zero but smaller in size and duration than those of persistent shocks.

Transmission of Financial Intermediation Shocks: the Role of Nominal Rigidities.—Any general equilibrium model that aims to identify the role of non-TFP shocks as possible drivers of business cycle fluctuations has to be able to generate the positive co-movement between consumption, investment, and hours worked observed over business cycles. In an influential article, Barro and King (1984) show how, in a general equilibrium model with flexible prices and wages in the

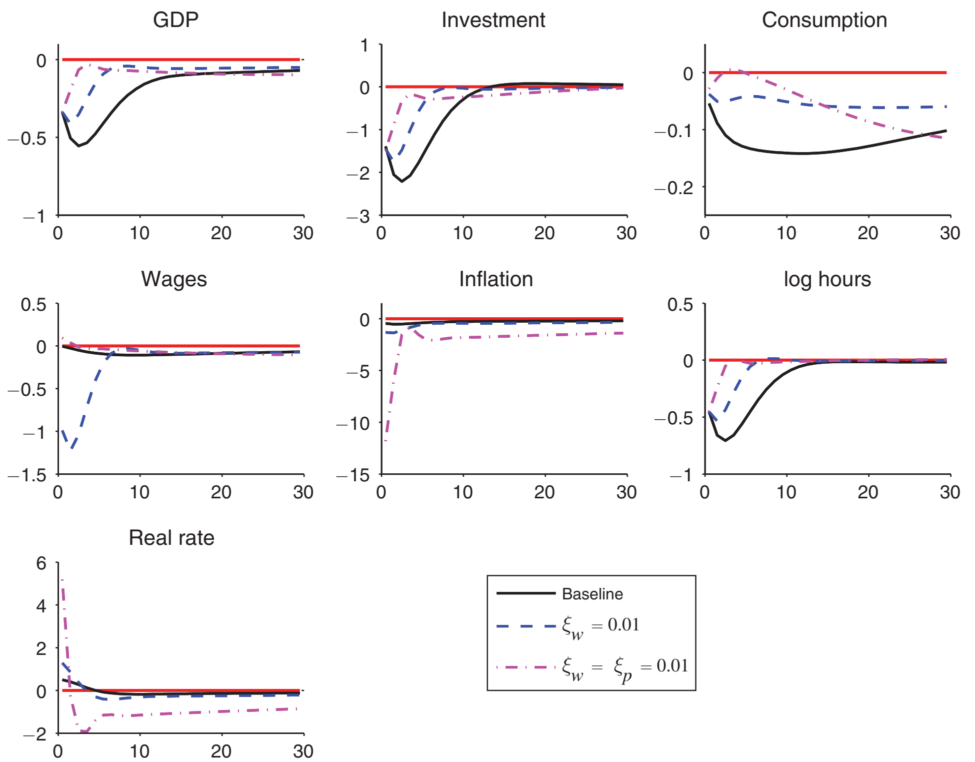

Figure 6. Impulse Response to Negative Financial Shock: Effect of Nominal Rigidities on Transmission

Notes: Impulse response functions to a one standard deviation negative financial shock. Comparison between baseline model (solid lines), and model with flexible prices and sticky wages (dashed lines), and flexible prices and wages (dashed-dotted lines).

Source: Author's calculations

real business cycle tradition, it is hard to detect sources of business cycle fluctuations other than changes in total factor productivity, that can trigger this positive co-movement.[25]

Financial intermediation shocks in my model act as intertemporal wedges (Chari, Kehoe, and McGrattan 2007). Christiano and Davis (2006) and Justiniano, Primiceri, and Tambalotti (2010) argue that nominal price and wage rigidities are central in the transmission and amplification of shocks that hit the intertemporal Euler equation.

Impulse responses in Figure 6 confirm that nominal rigidities amplify financial intermediation shocks, generating the positive co-movement between macro aggregates in my model. The figure shows the impulse responses for aggregate output, investment and consumption, real wages, and hours worked, together with the equilibrium real interest rate to a one standard deviation negative persistent financial

[25] Any shock that increases the equilibrium quantity of hours worked on impact must induce a contemporaneous drop in consumption to maintain the equilibrium equality between the marginal product of labor and the marginal rate of substitution between consumption and hours worked (see Justiniano, Primiceri, and Tambalotti 2010 for further details).

shock for different versions of the model. The impulse response in the black dashed lines are computed at the baseline estimates in Table 2. The figure also reports impulse responses for the model in which the Calvo wage-setting parameter is set to 0.01 so as to mimic the behavior of a model with flexible wages (dashed lines). Finally, the plots include impulse response functions for the estimated flexible-wage model in which the Calvo price-setting parameter is also set to 0.01 so as to mimic the behavior of an economy with flexible prices and wages (dotted lines). The size of the shocks is normalized so that the initial drop in output in all models equals the one observed under the baseline.

When the intermediation cost, τ_t^q, rises, sellers with good investment opportunities observe an increase in their financing spreads and can rely on a reduced amount of external funding to build new capital. As a consequence, investment, I_t, plunges. In the absence of nominal rigidities, prices and wages can adjust freely to clear markets. In particular, after an initial rise, the real rate of interest drops to induce consumption to rise and pick up the slack in the market of final goods, in line with the argument in Barro and King (1984). The impulse responses for the model without nominal rigidities in Figure 6 (dotted lines) also highlight a mild negative co-movement between investment and consumption, in line with the intuition in Barro and King (1984) and with the findings in KM in the case of liquidity shocks (see also online Appendix D).

In the presence of price and wage rigidities, however, the real rate of interest is not free to adjust to clear the goods market. Instead the central bank's decisions on the nominal interest rate and expected inflation dynamics determine the real rate in equilibrium. The central bank's interest rate rule incorporates some degree of inertia so as to account for the observed gradual changes in the federal funds rate. Consequently, the nominal rate does not respond strongly on impact to changes in the outlook for inflation and output. The presence of nominal rigidities implies that marginal costs and final good prices can adjust only slowly in response to the drop in investment. If wages and prices do not adjust instantaneously and are instead subject to prolonged downward pressure, agents in the economy will expect some degree of disinflation. If lower expected inflation, $E_t[\pi_{t+1}]$, is paired with an inertial response of the central bank in reducing the nominal risk-free rate, R_t^B, then the real interest rate, r_t^B, approximately defined as

$$r_t^B \simeq R_t^B - E_t(\pi_{t+1}),$$

will increase instead of dropping, as in the frictionless economy. A higher real rate leads the household to decrease consumption, C_t. Consumption then plummets together with investment. On the supply side, since wages cannot adjust instantaneously, hours worked (and hence output) drop so that the market for final goods stays in equilibrium (see impulse responses of the baseline estimated model in Figure 4).

Figures 7 and 8 show the impulse responses to a financial intermediation shock under the baseline estimates and compare them to two alternative assumptions: (i) wages are very sticky but prices are flexible as in Figure 7 and (ii) wages are flexible but prices are very sticky as in Figure 8. The two figures reveal that either price or wage rigidities can help amplify financial intermediation shocks and match the

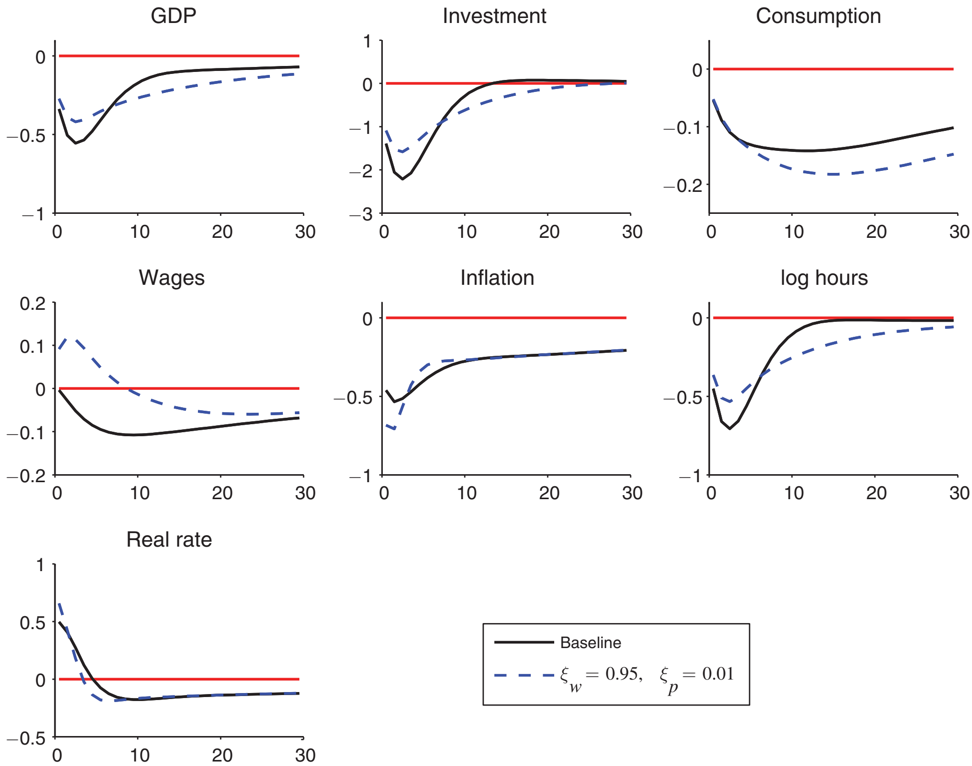

Figure 7. Impulse Response to a Negative Financial Shock: Effect of Sticky Wages on Transmission

Notes: Impulse response functions to a one standard deviation financial shock. Comparison between baseline model (black solid line), and model with high wage stickiness and low price stickiness (dashed line).

Source: Author's calculations

observed joint cyclical behaviors of output, consumption, and hours worked. Sticky wages, however, are important to jointly match the volatility of inflation and of real wage growth in the data.

Figure 7 confirms a well-known fact in the literature: if prices are set as a markup over marginal costs, as in the Dixit-Stiglitz model, nominal wage rigidities translate into inertia in inflation (Erceg, Henderson, and Levin 2000; Christiano, Eichenbaum, and Evans 2005). The impulse responses in Figure 8, however, show that the opposite is not true. Higher price rigidities will dampen fluctuations in inflation but will instead amplify fluctuations in real wages. In the wake of a negative financial shock, nominal wages will be renegotiated down. The stickier the prices, the more real wages will fall.[26]

[26] Statistical criteria confirm that wage stickiness is preferred by the data. Table 17 in the online Appendix shows that the marginal likelihood of the model with sticky wages is −420, more than 30 log-points higher than the one of the same model estimated under the assumption of sticky prices and flexible wages of −454. Similarly to what the impulse responses show, the table also reports that the model with flexible wages and sticky prices generates a volatility of real wage growth relative to GDP growth that is twice as large as in the data sample (2.4 compared to 1.2 in the data), while the estimated standard deviation of hours worked relative to GDP growth is 40 percent lower than in the data (2.9 compared to 4.9 percent in the data). Table 19 in the online Appendix shows that, since the transmission channel on hours worked is dampened, the estimated model with flexible wages attributes only a

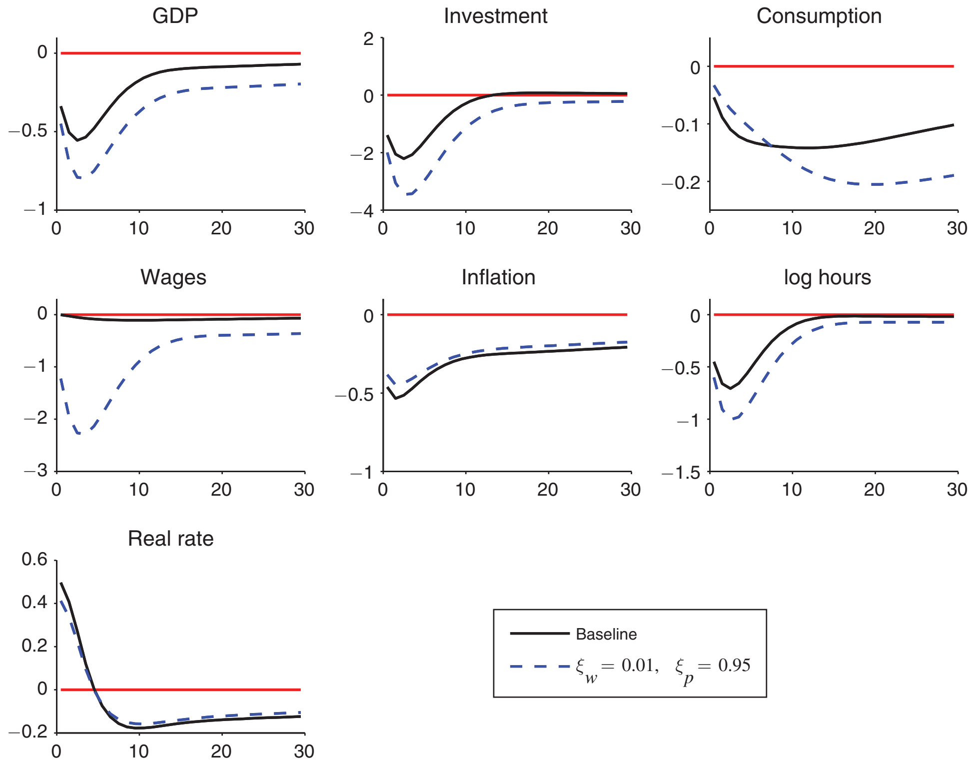

Figure 8. Impulse Response to a Negative Financial Shock: Effect of Sticky Prices on Financial Shock Transmission

Notes: Impulse response functions to a one standard deviation financial shock. Comparison between baseline model (solid line) and model with high price stickiness and low wage stickiness (dashed line).

Source: Author's calculations

Transmission of Financial Intermediation Shocks: the Role of Endogenous Investment Technology Shifts.—Buera and Moll (2015) point out that, in a model with heterogeneous capital accumulation technologies like the one described in this paper, a negative financial shock can induce adverse shifts to the aggregate investment-specific technology. Investment technology shifts act to amplify financial shocks and the two sources of fluctuation cannot be easily separated. In fact, empirical work by Justiniano, Primiceri, and Tambalotti (2010) shows that investment specific technological shocks (ISTSs) can account for large fractions of business cycle fluctuations in output and suggest that these disturbances could originate in financial markets.

In the model I can isolate the effects of financial shocks from investment technology shifts, by keeping the effective average capital accumulation technology, A_t^{eff} (defined in online Appendix G), constant and equal to its steady state value. This is achieved by allowing the location parameter of the lognormal distribution of idiosyncratic technology shocks μ_A to vary over time and offset changes in the aggregate

share of 10 percent financial intermediation shocks in explaining business cycles in output growth, compared to 25 percent of the baseline case with both sticky prices and sticky wages.

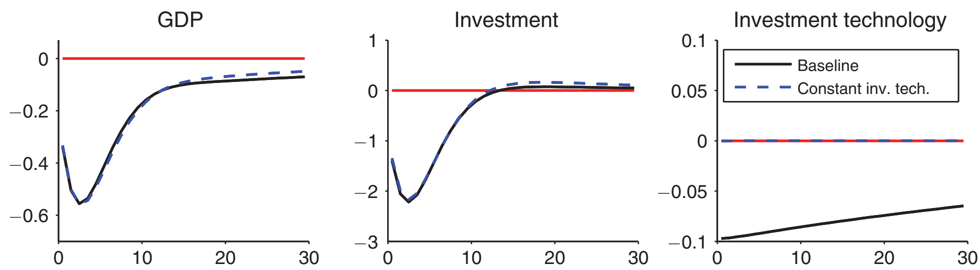

Figure 9. Impulse Response to a Negative Financial Shock: Effect of Endogenous IST

Notes: Impulse response functions to a one standard deviation financial shock. Comparison between baseline model (solid line), and model with constant investment technology (dashed line).

Source: Author's calculations

effective investment technology caused by aggregate disturbances. Figure 9 shows the impulse responses to a one standard deviation persistent shock to financial intermediation costs for output, investment, and the effective level of investment technology A_t^{eff}. The figure shows that negative financial intermediation shocks indeed generate a drop in the level of efficiency of the investment technology, but this adjustment is in fact tiny (around 0.10 percent with respect to the steady state level). Once I shut down the investment technology transmission channel, the impulse responses for output and investment (dashed lines) are very similar to those of the baseline model (solid lines). Online Appendix G reports the modeling details and the impulse responses for all observables of the modified model.

B. *Model Fit and Variance Decomposition*

This section describes the model fit to the data, the variance decomposition of the observables into the contributions of fundamental shocks, and the historical decomposition of output growth and credit variables into the series of smoothed shocks at the posterior mode.

Table 3 reports the standard deviations relative to output growth volatility and the autocorrelation coefficients of order 1 of the macro observables from the 1989:I–2008:II sample used for the estimation, together with median and 90 percent confidence intervals for the same moments implied by the model, simulated to account for parameter uncertainty. The table also reports the same moments computed on a pre-sample of historical data, from 1954:IV to 1988:IV.

The model can produce volatilities and autocorrelations for the macro and financial variables that are largely consistent with features of the history of business cycles in the United States. The absolute volatility of output growth is somewhat higher than what the sample data would suggest but in line with historical evidence. The table shows that the model does a fair job in capturing the relative volatility of the financial variables. In particular the model can generate fluctuations in the financing gap share and in the model-implied growth rate of the total financing gap, $\Delta \log FG_t$, that are largely consistent with the Compustat evidence in Section I.

Table 3—Model Fit: Standard Deviations and Autocorrelations of Order 1

	Standard deviations				Autocorrelation order 1			
Observables	Data	Data(Hist.)	Median	[5%–95%]	Data	Data(Hist.)	Median	[5%–95%]
$\Delta \log GDP_t$	0.56	1.14	0.97	[0.77–1.23]	0.53	0.31	0.60	[0.42–0.72]
$\Delta \log I_t$	3.56	3.56	3.65	[3.21–4.07]	0.45	0.22	0.65	[0.49–0.76]
$\Delta \log C_t$	0.66	0.46	0.53	[0.39–0.70]	0.28	0.31	0.48	[0.28–0.64]
$\Delta \log w_t$	1.29	0.40	0.80	[0.61–1.05]	0.09	0.06	0.30	[0.12–0.47]
π_t	0.40	2.93	0.43	[0.32–0.61]	0.59	0.96	0.82	[0.69–0.91]
R_t^B	0.92	0.57	0.40	[0.24–0.70]	0.96	0.88	0.93	[0.83–0.97]
$\log L_t$	5.17	3.20	3.69	[2.70–4.87]	0.97	0.94	0.92	[0.88–0.95]
Sp_t	0.93	0.61	0.84	[0.54–1.40]	0.89	0.91	0.88	[0.74–0.95]
FGS_t	22.30	—	29.84	[20.08–48.72]	0.62	—	0.87	[0.75–0.94]
$\Delta \log FGS_t$	26.43	—	16.83	[13.51–20.89]	−0.31	—	0.10	[−0.09–0.29]

Notes: Standard deviations and autocorrelation of order 1 of observable variables. Standard deviations are expressed in terms of the volatility of GDP growth in the data in the posterior mode. Model-implied moments compared to data. Sample period: 1989:I–2008:II. Historical data: 1954:IV–1988:IV. Posterior percentiles from 3 chains of 100,000 draws generated using a random walk Metropolis-Hasting algorithm. Acceptance rate 21 percent. Burning period: initial 20,000 draws. Moments computed over 1,000 randomly-selected accepted draws. For each draw, I simulate 1 sample of length equal to the sample period in the data (178 periods, burning the first 100 observations). The table reports the 5th, 50th, and 95th percentile of the distribution of average moments generated by the 1,000 parameter draws.

Source: BEA through Haver Analytics and author's calculations

Table 4 reports the contribution of each shock to the volatility of the observable variables in periodic cycles that range between 6 to 32 quarters in length, as in Stock and Watson (1999).

Columns four and five of Table 4 suggest that persistent and transitory financial intermediation shocks, $\bar{\tau}_t$ and $\tilde{\tau}_t$, are the most important drivers of business cycle fluctuations in the data, explaining together around 25 percent of the unconditional variance of GDP growth, more than 30 percent of the volatility of investment growth and around 22 percent of the variation in hours worked. Persistent shocks play the largest role, explaining more than 22 percent of business cycle volatility in output alone, while transitory shocks explain a residual 2 percent. Persistent shocks are also able to explain more than 40 percent of cyclical movements in inflation and of the nominal risk-free rate. This result suggests an active role of monetary policy through the Taylor rule in response to changes in output and prices induced by financial disturbances.[27]

Column 1 of Table 4 shows how, according to the model estimates, neutral technology shocks explain around 17 percent of the business cycle variation of GDP growth in the sample period, although other supply shocks such as price and wage

[27] Estimating the log-linearized version of the model on data that includes the Great Recession and the zero lower bound regime for the federal funds rate up to 2012:IV, increases the relevance of financial intermediation shocks in explaining output fluctuations from 25 percent to almost 40 percent. Full results are available in online Appendix K.3. In the literature, Christiano, Motto, and Rostagno (2014) find that financial (risk) shocks in a Bernanke, Gertler, and Gilchrist (1999) framework can account for around 60 percent of output fluctuations in the United States, in a sample period that includes data from the Great Recession up to 2010. Christiano, Trabandt, and Walentin (2011a) find that the same shock explains 25 percent of output growth and 75 percent of investment growth in a small open economy like Sweden.

Table 4—Baseline Model with Sticky Wages: Posterior Variance Decomposition

	TFP	Gov't	MP	Fin.(pers.)	Fin.(trans.)	Preference	Price markup	Wage markup
$\Delta \log GDP_t$	16.8	2.4	12.5	22.1	1.7	13.2	19.1	12.2
	[8.9–24.4]	[1.5–3.8]	[7.3–15.8]	[15.7–27.0]	[0.6–2.8]	[9.2–17.7]	[10.7–23.2]	[6.7–21.2]
$\Delta \log I_t$	10.9	0.0	16.7	29.3	2.5	0.8	25.9	13.7
	[5.5–16.8]	[0.0–0.1]	[10.5–21.1]	[21.5–35.4]	[0.9–4.1]	[0.2–2.2]	[16.4–32.3]	[8.8–25.8]
$\Delta \log C_t$	16.0	0.8	1.2	2.3	0.1	74.6	1.8	3.1
	[8.9–24.2]	[0.4–1.2]	[0.4–2.0]	[0.7–3.8]	[0.0–0.1]	[65.4–84.9]	[0.6–2.7]	[1.4–6.0]
$\Delta \log w_t$	9.5	0.0	0.1	0.2	0.0	0.1	10.1	80.0
	[4.4–14.3]	[0.0–0.0]	[0.0–0.5]	[0.1–1.0]	[0.0–0.1]	[0.0–0.6]	[6.3–15.8]	[70.0–86.5]
π_t	3.3	0.0	5.2	41.6	0.4	2.5	33.7	13.4
	[0.9–5.6]	[0.0–0.2]	[1.6–7.8]	[30.2–47.8]	[0.0–0.9]	[0.8–4.3]	[21.0–46.7]	[8.0–20.2]
R_t^B	0.6	0.1	41.3	41.2	0.6	2.7	9.0	4.4
	[0.2–1.3]	[0.0–0.3]	[29.1–49.3]	[30.4–51.2]	[0.1–1.4]	[1.0–5.2]	[4.6–15.7]	[2.1–8.9]
$\log L_t$	3.5	0.5	10.9	20.5	1.3	6.0	32.2	25.1
	[1.7–5.8]	[0.3–1.0]	[5.4–14.4]	[12.8–27.7]	[0.3–2.2]	[3.7–8.9]	[16.7–39.5]	[15.1–44.7]
Sp_t	2.1	0.0	2.8	25.5	53.5	0.3	12.8	2.9
	[0.8–3.5]	[0.0–0.1]	[1.0–4.5]	[17.9–34.0]	[44.2–62.0]	[0.1–0.7]	[5.9–17.8]	[1.4–5.6]
FGS_t	0.7	0.2	1.4	35.5	18.2	0.1	7.1	1.4
	[0.4–1.1]	[0.1–0.4]	[0.7–2.1]	[28.9–43.4]	[12.7–24.4]	[0.0–0.3]	[4.0–10.2]	[0.9–2.5]

Notes: Variance decomposition of the observables, periodic component with cycles between 6 and 32 quarters. Mode values and 90 percent credible intervals. Posterior percentiles obtained from 3 chains of 100,000 draws generated using a random walk Metropolis-Hasting algorithm. Acceptance rate 21 percent. Burning period: 20,000 draws. Statistics computed over 1,000 randomly-chosen accepted draws. Values are percentages. Rows may not sum up to 100 percent due to rounding error. Measurement error (not shown) explains 0.2 percent of S_{pt} (credible interval [0.0–2.1]) and 35.5 percent of FGS_t (credible interval [27.0–41.8]).

Source: Author's calculations

markup shock are estimated to play an important role.[28] Intertemporal preference shocks in column 6 of Table 4 account for less than 15 percent of variations in real GDP growth, by shaping more than 70 percent of fluctuations in consumption growth.[29]

Figure 10 shows the time series representation of the evolution of quarterly GDP growth in the data and decomposes each quarterly realization into the positive (above the x axis) and negative (below the x axis) contributions of the fundamental shocks in the model, listed in the legend on the right-hand side of the graph. Shocks to total factor productivity, ε_t^z, (TFP) show procyclical contributions to both periods of prolonged positive GDP growth (the 1990s and the 2000s) and to the three recessions episodes in the sample (1990–1991, 2001, and the start of the 2007–2009 Great Recession).[30] Positive persistent financial intermediation shocks $\varepsilon_t^{\overline{\tau}_q}$ (FIN) played an important role in driving the economic expansion of the 2000s, while they cannot explain the prolonged expansion of the late 1990s, driven instead by positive

[28] In support of a reduced role for technology shocks in recent history, Shimer (2012) finds no evidence in the last 20 years of US data that labor productivity and real wages are procyclical.

[29] Estimating earlier versions of the model in which seller, buyers and workers are distinct agents in the economy and do not provide each other insurance within a large household, I find that hand-to-mouth constraints on workers can amplify the effect of financial intermediation shocks on aggregate consumption.

[30] Notably, the smoothed process of TFP from the model matches closely the latest estimates of TFP growth in Fernald (2012) (not adjusted for capital utilization, to match the production function assumption in my model), as shown in Figure 31 in the online Appendix. In comparison with Fernald's estimates, my model estimates produce a slightly more volatile process for smoothed TFP growth.

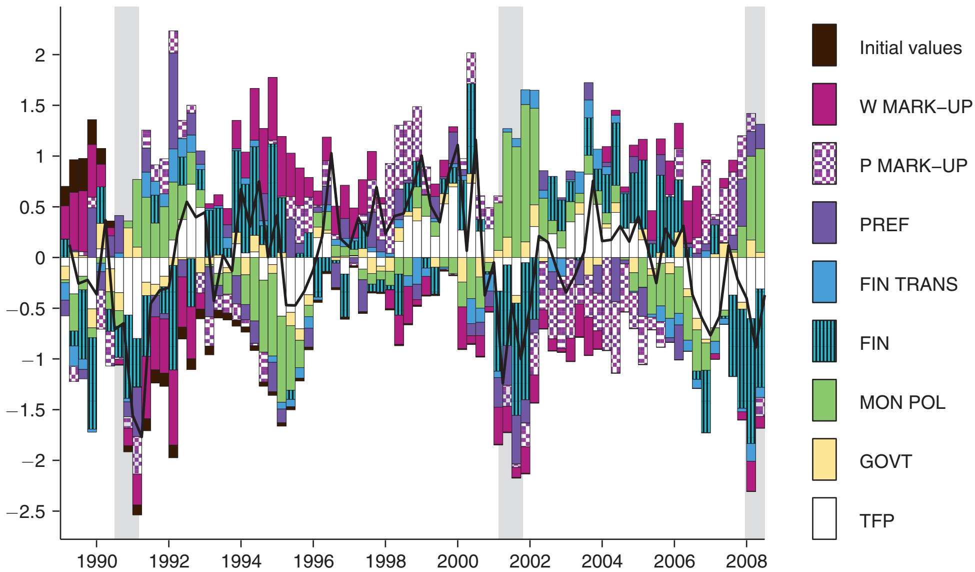

FIGURE 10. HISTORICAL DECOMPOSITION OF QUARTERLY OUTPUT GROWTH INTO STRUCTURAL SHOCKS

Notes: Quarterly de-trended GDP growth in the data (black line) decomposed into contributions of each structural shock through Kalman smoothing at the posterior mode. Gray bands represent NBER recessions. Sample period: 1989:I–2008:II.

Source: BEA through Haver Analytics and author's calculations

TFP shocks. The decomposition also suggests that negative financial intermediation shocks contributed to shape the recessions in the sample (1990–1991, 2001, and the first few quarters of the Great Recession). Negative financial shocks preceded the NBER start dates of 1990–1991 and started hitting the economy in 2007 and early 2008, at the early stages of the financial turmoil before the fall of Lehman Brothers. This is interesting since both episodes are characterized by disruptions on financial markets (the savings and loans failures and the subprime MBS crisis respectively) that predated the drop in aggregate GDP. Transitory financial intermediation shocks (FIN TRANS) play a small role in the historical decomposition of GDP growth, in line with evidence from the variance decomposition.

Monetary policy shocks, ε_t^{mp} (MON POL), have acted as countercyclical drivers of output growth, sustaining economic activity during recessions while cooling down expansions. In particular, the decomposition suggests that the rapid reduction in the federal funds rate engineered after 2007 helped sustain economic growth at the onset of the Great Recession. Government spending shocks (GOVT) have wealth effects in the model. Public sector deficits can be beneficial, as financially constrained household members demand government bonds as a form of precautionary savings to insure against the future arrival of investment opportunities. Increased liquidity supplied through fiscal deficits can sustain private investment and aggregate demand in the spirit of the policy experiments in KM, (Del Negro et al. 2010). The estimation suggests that the contribution of the government spending shocks to GDP growth during the sample period was modest.

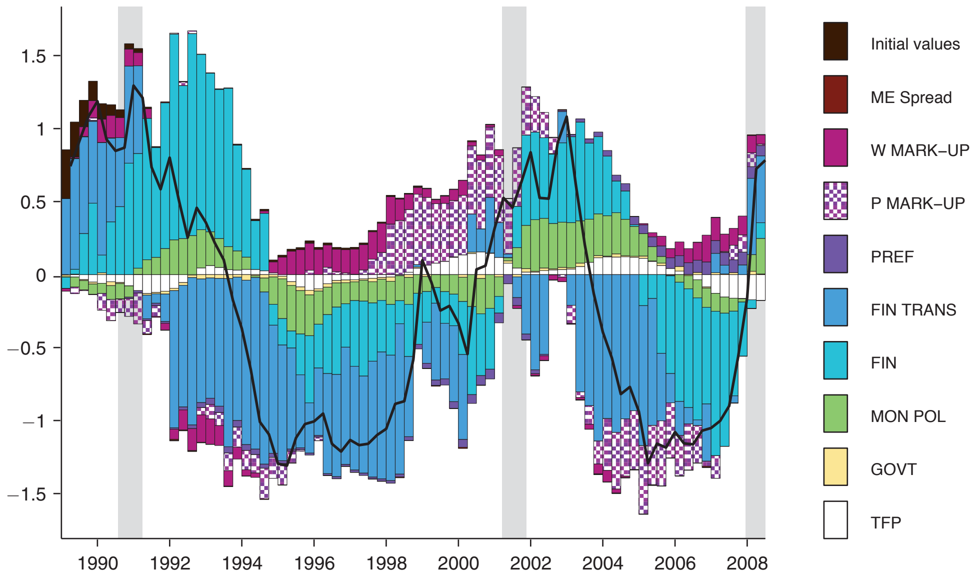

Figure 11. Historical Decomposition of De-Trended Corporate Spreads

Notes: Quarterly de-trended corporate spreads in the data (black line) decomposed into contributions of each structural shock through Kalman smoothing at the posterior mode. Gray bands represent NBER recessions. Sample period: 1989:I–2008:II.

Source: Moody's, Federal Reserve Board, and author's calculations

According to the variance decomposition in Table 4, changes in the financial intermediation wedge, τ_t^q, affect the relative price of external funding for entrepreneurs and their investment and financial decisions in the model. Persistent financial intermediation shocks, $\overline{\tau}_t^q$, explain more than 30 percent of cyclical fluctuations in the financing gap and less than 25 percent of fluctuations in corporate spreads, Sp_t. Transient financial intermediation shocks, $\tilde{\tau}_t^q$, explain around 55 percent of corporate spreads' cyclical fluctuations and less than 20 percent of fluctuations in the financing gap share.

Figures 11 and 12 show the historical decomposition of corporate spreads and the financing gap share into the smoothed structural shocks.[31] The figures confirm the findings of the variance decomposition in Table 4. The historical decompositions show that monetary policy shocks (MON POL) played a small but consistent countercyclical role in shaping credit cycles, constraining borrowing during expansions, and sustaining it in the wake of recessions. Inflationary price markup shocks (P MARK-UP) met by monetary policy tightening have also lowered corporate spreads and negatively affected credit flows, especially during the boom of the 2000s.

[31] The black solid lines in the figures represent the log-deviations, $\hat{x}_t$, of variable x_t from the model trend computed as

$$(\hat{x}_t + 1600(\hat{x}_{t+2} - 4\hat{x}_{t+1} + 6\hat{x}_t - 4\hat{x}_{t-1} + \hat{x}_{t-2})) = 1600(x_{t+2} - 4x_{t+1} + 6x_t - 4x_{t-1} + x_{t-2})$$

using the model-consistent (rational expectations) lead-lag structure to approximate the infinite two-sided moving averages of the data, as described in Cúrdia et al. (2011).

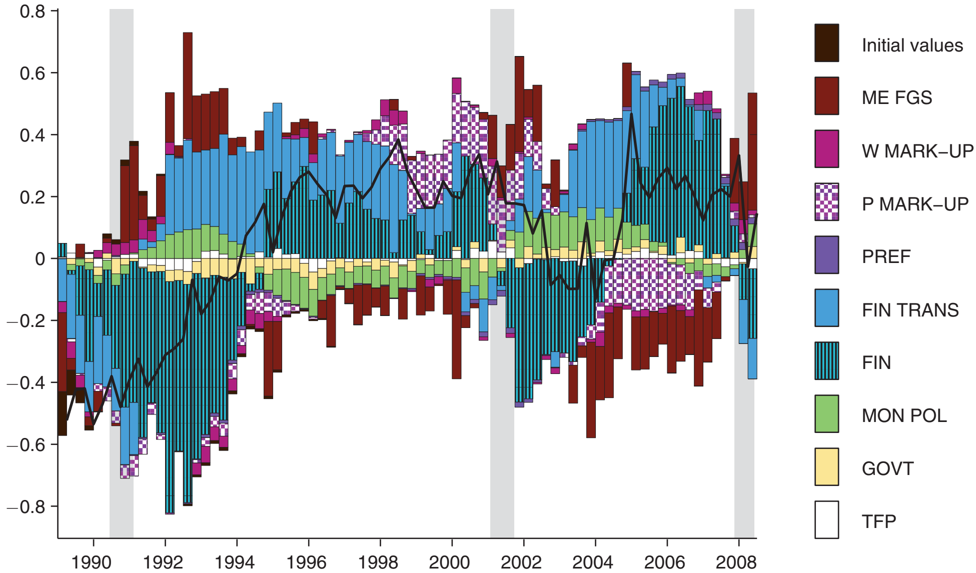

Figure 12. Historical Decomposition of De-Trended Financing Gap Share

Notes: Quarterly de-trended financing gap share in the data (black line) decomposed into contributions of each structural shock through Kalman smoothing at the posterior mode. Gray bands represent NBER recessions. Sample period: 1989:I–2008:II.

Source: Compustat fundamentals quarterly files and author's calculations

The figures also reveal how corporate spreads and the financing gap share are largely driven by shocks to the financial intermediation wedge, τ_t^q. It is important to remember that the financing gap share is defined as the aggregate financial need of corporations to fund capital expenditures, net of working capital needs. Estimating the model jointly on corporate spreads and on data on corporate financing needs for fixed investment isolates the persistent component of financial intermediation shocks that transmit to investment and output via the credit channel. The figure and the variance decomposition table show that transitory financial intermediation shocks, $\tilde{\tau}_t^q$, tend to lead the cycle and to explain high-frequency fluctuations of corporate spreads, but have limited effects on corporate financing needs for fixed investment and macro dynamics in the model. On the other hand, the historical decompositions in Figures 10, 11, and 12 reveal that persistent shocks to the level of intermediation costs, $\bar{\tau}_t^q$, can reconcile sudden and severe drops in investment and output with the relatively slow mean reversion of corporate spreads after recessions and the subdued pick-up in corporate financial needs during recoveries.

These findings suggest that higher-frequency changes in intermediation costs and borrowing spreads do not propagate through corporate investment financing needs, captured by the financing gap share, but does not exclude that they might transmit to the rest of the economy via different propagation mechanisms that are not the focus of this model. External financing needs that arise in connection with working capital gaps, for example, could react to short-term changes in credit conditions and directly affect the corporate demand for labor, similar to what happens in Jermann and Quadrini (2012). The interaction of the working capital and the investment funding channels using Compustat data is left for future investigation.

While the contribution of measurement error to the corporate spread fluctuations is estimated to be small, the variance decomposition in Table 4 (see table notes) and the historical decomposition in Figure 12 reveal that the measurement error on the financing gap share can account for around 35 percent of its business cycle volatility. In Section J of the online Appendix, I present a version of the model that allows for shocks to the dispersion of capital accumulation technologies σ_A to hit the economy. The estimation of the model with technology dispersion shocks confirms that financial intermediation shocks are the largest contributors to business cycle fluctuations. I find that dispersion shocks can account for the residual volatility in the financing gap share that cannot be explained by the baseline model, but account only for less than 5 percent of output growth volatility at business cycle frequencies.

Online Appendix K also reports variance decomposition results for model estimations performed on the same macro observables but on different financial variables than the baseline in Table 4. In particular, I substitute the ten-year BBB corporate spread with a measure of the excess bond premium (EBP) derived by Gilchrist and Zakrajsek (2012). I also perform estimation on a dataset that substitutes the baseline financing gap share with the financing gap share series that does not consider dividend payments as unavoidable commitments of corporations (the dashed line in Figure 1, FGS EX DIV, defined in Section I). I perform these exercises in the spirit of assessing the robustness of the baseline findings under different assumptions on the mapping between the model variables and observable series. The results of the estimations are in line with the baseline model and confirm that, even before the Great Recession, financial intermediation shocks were the largest drivers of business cycle fluctuations in investment and output.

V. Conclusions

In this paper I have addressed the question of how important financial intermediation shocks are in driving the business cycle. In my empirical analysis on Compustat data I document that external financing represents a nontrivial fraction of fixed capital expenditures of US corporations. The main finding of this research is that financial intermediation shocks contribute to cyclical fluctuations in the United States and account for around 25 percent of output and 30 percent of investment volatility, when estimated on a sample period that spans from 1989:I to 2008:II—up to the start of the Great Recession.

In obtaining this result, I have estimated a dynamic general equilibrium model with nominal rigidities and financial frictions in which entrepreneurs rely on external finance and trading of financial claims to fund their investments. The model is estimated to fit macroeconomic variables as well as evidence from Compustat on the degree of dependence of corporate investment on outside sources of funding. Entrepreneurs in the model borrow from financial intermediaries to build new capital and financial intermediaries bear a cost to transfer resources from savers to investors.

Shocks to the financial intermediation costs intuitively map into movements of the interest rate spreads and are able to explain the dynamics of the real variables that shaped the onset of the last recession, as well as the 1990–1991 downturn and the boom of the 2000s. I find that nominal rigidities play an important role in the transmission of the financial shocks. In particular, real wage rigidities allow the model to match the joint behavior of inflation, real wages growth, and hours worked that is observed in the data along the business cycles.

This paper focuses on the degree of firms' financial dependence that arises from the investment in fixed capital and on the effect of shocks that propagate through corporate investment financing to the rest of the economy. I leave the analysis of the business cycle properties of working capital needs (another relevant component of corporate financial needs in Compustat firms), their financing, and their role in amplifying financial intermediation shocks to future research.

REFERENCES

Ajello, Andrea. 2016. "Financial Intermediation, Investment Dynamics, and Business Cycle Fluctuations: Dataset." *American Economic Review.* http://dx.doi.org/10.1257/aer.20120079.

Anderson, Gary, and George Moore. 1985. "A Linear Algebraic Procedure for Solving Linear Perfect Foresight Models." *Economics Letters* 17 (3): 247–52.

An, Sungbae, and Frank Schorfheide. 2007. "Bayesian Analysis of DSGE Models." *Econometric Reviews* 26 (2–4): 113–72.

Barro, Robert J., and Robert G. King. 1984. "Time-separable Preferences and Intertemporal-Substitution Models of Business Cycles." *Quarterly Journal of Economics* 99 (4): 817–39.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics,* Vol. 1C, edited by J. B. Taylor and M. Woodford, 1341–93. Amsterdam: North Holland.

Bigio, Saki. 2015. "Endogenous Liquidity and the Business Cycle." *American Economic Review* 105 (6): 1883–1927.

Buera, Francisco J., and Benjamin Moll. 2015. "Aggregate Implications of a Credit Crunch: The Importance of Heterogeneity." *American Economic Journal: Macroeconomics* 7 (3): 1–42.

Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Carlstrom, Charles T., and Timothy S. Fuerst. 1997. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis." *American Economic Review* 87 (5): 893–910.

Chari, Varadarajan V., and Patrick Kehoe. 2009. "Confronting Models of Financial Frictions with the Data." Paper presented by Society for Economic Dynamics 2009 Meeting Papers series 1083, Stonybrook, NY.

Chari, V. V., Lawrence J. Christiano, and Martin Eichenbaum. 1995. "Inside Money, Outside Money, and Short-Term Interest Rates." *Journal of Money, Credit, and Banking* 27 (4): 1354–86.

Chari, V. V., Patrick J. Kehoe, and Ellen R. McGrattan. 2007. "Business Cycle Accounting." *Econometrica* 75 (3): 781–836.

Christiano, Lawrence J., and Joshua M. Davis. 2006. "Two Flaws In Business Cycle Accounting." National Bureau of Economic Research Working Paper 12647.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113 (1): 1–45.

Christiano, Lawrence J., Martin S. Eichenbaum, and Mathias Trabandt. 2015. "Understanding the Great Recession." *American Economic Journal: Macroeconomics* 7 (1): 110–67.

Christiano, Lawrence J., Roberto Motto, and Massimo Rostagno. 2014. "Risk Shocks." *American Economic Review* 104 (1): 27–65.

Christiano, Lawrence J., Mathias Trabandt, and Karl Walentin. 2011a. "Introducing Financial Frictions and Unemployment into a Small Open Economy Model." *Journal of Economic Dynamics and Control* 35 (12): 1999–2041.

Christiano, Lawrence J., M. Trabandt, and K. Walentin. 2011b. "DSGE Models for Monetary Policy Analysis." In *Handbook of Monetary Economics,* Vol. 3A, edited by Benjamin M. Friedman and Michael Woodford, 285–367. Amsterdam: Elsevier.

Cúrdia, Vasco, Andrea Ferrero, Ging Cee Ng, and Andrea Tambalotti. 2011. "Evaluating Interest Rate Rules in an Estimated DSGE Model." Federal Reserve Bank of New York Staff Report 510.

Cúrdia, Vasco, and Michael Woodford. 2010a. "Conventional and Unconventional Monetary Policy." *Federal Reserve Bank of St Louis Review* 92 (4): 229–64.

Cúrdia, Vasco, and Michael Woodford. 2010b. "Credit Spreads and Monetary Policy." *Journal of Money, Credit, and Banking* 42 (S1): 3–35.

De Fiore, Fiorella, and Harald Uhlig. 2011. "Bank Finance versus Bond Finance." *Journal of Money, Credit, and Banking* 43 (7): 1399–1421.

Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki. 2010. "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities." Federal Reserve Bank of New York Staff Report 520.

Del Negro, Marco, Frank Schorfheide, Frank Smets, and Rafael Wouters. 2007. "On the Fit of New Keynesian Models: Rejoinder." *Journal of Business and Economic Statistics* 25 (2): 159–62.

Eisfeldt, Andrea L., and Adriano A. Rampini. 2006. "Capital Reallocation and Liquidity." *Journal of Monetary Economics* 53 (3): 369–99.

Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–313.

Falato, Antonio, Dalida Kadyrzhanova, and Jae W. Sim. 2013. "Rising Intangible Capital, Shrinking Debt Capacity, and the US Corporate Savings Glut." Finance and Economics Discussion Series 2013–67.

Fernald, John. 2012. "A Quarterly, Utilization-Adjusted Series on Total Factor Productivity." Federal Reserve Bank of San Francisco Working Paper 2012–19.

Gilchrist, Simon, Vladimir Yankov, and Egon Zakrajsek. 2009. "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets." *Journal of Monetary Economics* 56 (4): 471–93.

Gilchrist, Simon, and Egon Zakrajsek. 2012. "Credit Spreads and Business Cycle Fluctuations." *American Economic Review* 102 (4): 1692–1720.

Goodfriend, Marvin, and Bennett T. McCallum. 2007. "Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration." *Journal of Monetary Economics* 54 (5): 1480–1507.

Guerrieri, Luca, and Matteo Iacoviello. 2015. "OccBin: A Toolkit for Solving Dynamic Models with Occasionally Binding Constraints Easily." *Journal of Monetary Economics* 70 (C): 22–38.

Hart, Oliver, and John Moore. 1994. "A Theory of Debt Based on the Inalienability of Human Capital." *Quarterly Journal of Economics* 109 (4): 841–79.

Jermann, Urban, and Vincenzo Quadrini. 2012. "Macroeconomic Effects of Financial Shocks." *American Economic Review* 102 (1): 238–71.

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti. 2010. "Investment Shocks and Business Cycles." *Journal of Monetary Economics* 57 (2): 132–45.

Kiyotaki, Nobuhiro, and John Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105 (2): 211–48.

Kiyotaki, Nobuhiro, and John Moore. 2012. "Liquidity, Business Cycles, and Monetary Policy." National Bureau of Economic Research Working Paper 17934.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert W. Vishny. 2000. "Agency Problems and Dividend Policies around the World." *Journal of Finance* 55 (1): 1–33.

Leeper, Eric M., Michael Plante, and Nora Traum. 2010. "Dynamics of Fiscal Financing in the United States." *Journal of Econometrics* 156 (2): 304–21.

Lindé, Jesper, Frank Smets, and Rafael Wouters. 2015. "Challenges for Macro Models Used at Central Banks." Sveriges Riksbank Working Paper 323.

Moody's Seasoned Baa Corporate Bond Yield©. *Federal Reserve Bank of St. Louis.* https://fred.stlouisfed.org/series/BAA (accessed October 2015).

Philippon, Thomas. 2015. "Has the US Finance Industry Become Less Efficient? On the Theory and Measurement of Financial Intermediation." *American Economic Review* 105 (4): 1408–38.

Shi, Shouyong. 2015. "Liquidity, Assets and Business Cycles." *Journal of Monetary Economics* 70: 116–32.

Shimer, Robert. 2012. "Wage Rigidities and Jobless Recoveries." *Journal of Monetary Economics* 59 (Supplement): S65–S77.

Shourideh, Ali, and Ariel Zetlin-Jones. 2012. "External Financing and the Role of Financial Frictions over the Business Cycle: Measurement and Theory." Carnegie Mellon University GSIA Working Papers 2014-E15.

Smets, Frank, and Raf Wouters. 2003. "An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area." *Journal of the European Economic Association* 1 (5): 1123–75.

Smets, Frank, and Raf Wouters. 2005. "Comparing Shocks and Frictions in US and Euro Area Business Cycles: A Bayesian DSGE Approach." *Journal of Applied Econometrics* 20 (2): 161–83.

Smets, Frank, and Rafael Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review* 97 (3): 586–606.

Stock, James H., and Mark W. Watson. 1999. "Business Cycle Fluctuations in U.S. Macroeconomic Time Series." In *Handbook of Macroeconomics*, Vol. 1A, edited by J. B. Taylor and M. Woodford, 3–64. Amsterdam: Elsevier.

Taylor, John B. 1993. "Discretion versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy* 39 (1): 195–214.

Taylor, John B. 1999. "A Historical Analysis of Monetary Policy Rules." In *Monetary Policy Rules*, edited by John B. Taylor, 319–41. Chicago: University of Chicago Press.

Thomson Reuters (via Sifma). 2015. "US Corporate Bond Issuance: Dataset." http://www.sifma.org/research/statistics.aspx (accessed October 2015).

Weston, J. Fred, and Samuel C. Weaver. 2004. *Mergers & Acquisitions.* NY: McGraw-Hill Education.

Wharton Research Data Service. "Compustat North America Fundamentals Quarterly. Sample period: 1989: Q1–2012: Q4." https://wrds-web.wharton.upenn.edu/ (accessed October 2015).

Woodford, Michael. 1990. "Public Debt as Private Liquidity." *American Economic Review* 80 (2): 382–88.

Woodford, Michael. 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton: Princeton University Press.

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