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Financial Intermediation, Investment Dynamics and Business Cycle Fluctuations

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Abstract

I use micro data to quantify key features of U.S. firm financing. In particular, I establish that a substantial 35% 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 towards investment opportunities, and charge an intermediation spread to cover their costs. According to the model estimation, exogenous shocks to the intermediation spread explain 40% of GDP and 60% of investment volatility.

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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 40% and 60% of output and investment volatility, respectively. These are the implications of a dynamic model estimated using the past 20 years of data for the United States.

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 all U.S. public non-financial companies available in Compustat. I find that 35% of the capital expenditures of these firms are funded using financial markets. Of this funding, around 75% is raised by issuing debt and equity and 25% by liquidating existing assets. My analysis at quarterly frequencies 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 (2008). 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 (2008), 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 granted 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) and 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 Smets and Wouters (2007) and An and Schorfheide (2007), to estimate a log-linearized version of the model buffeted by a series of random disturbances, including the financial intermediation shock, on a sample of U.S. macroeconomic time series that spans from

1989 to 2012. 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 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 approximately 40% of the variance of output and 60% of the variance of investment can be explained by financial intermediation shocks.

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 an 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 all three recessions in the sample (1990-1991, 2001 and 2007-2009), and especially during 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 all three 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 minor but consistent role in driving output dynamics, sustaining GDP during recessions while cooling down economic 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. However, traditional monetary policy interventions became mildly contractionary or ineffective at best once the nominal short term interest rate reached the zero lower bound at the end of 2008. Public sector deficits are beneficial in the model, in the spirit of policy experiments in Kiyotaki and Moore (2008) and Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010): when conditions on financial markets worsen, credit constrained entrepreneurs benefit from holding an increasing stock of government bonds (i.e., liquid assets) that help them self-insure against idiosyncratic risk. Consistently, the estimation suggests that positive innovations in government spending reduced the size of the drop in output by 1% cumulatively over the course of the Great Recession, while restrictive fiscal policy after 2009 negatively affected the recovery.

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 and, in particular, sticky wages (Erceg, Henderson, and Levin (2000)) are the key element in delivering this desirable feature of the model.

In the model, higher financial intermediation costs increase entrepreneurs' external finance premium and reduce aggregate investment. In the absence of nominal rigidities, prices can adjust freely to clear markets. In particular, the real rate of interest can drop instantaneously, inducing consumption to rise and pick up the slack in the goods market. The shock acts as an intertemporal wedge (Chari, Kehoe, and McGrattan (2007) and Christiano and Davis (2006)) that affects investment, substituting present with future consumption. In the presence of nominal rigidities instead, marginal costs and prices may only adjust slowly once investment drops in response to the initial financial intermediation shock. If wages and prices do not adjust instantaneously and are instead subject to prolonged downward pressure, agents expect the economy to endure a period of disinflation. Moreover, if agents expect the central bank to be gradual in lowering the nominal interest rate in response to changes in the outlook for inflation and output due to a financial shock, then expected disinflation can lead to a rise in the real interest rate instead of the sudden drop observed in the frictionless economy. A higher real rate induces consumption to drop, together with investment. In particular I find that wage rigidities are central in amplifying the fall in hours worked and output that allows consumption to drop following a negative financial intermediation shock.To verify the importance of wage rigidities, I re-estimate the model under flexible wages and find that financial disturbances are, in fact, only able to explain 18% of output growth variance at business cycle frequencies, compared to 40%.

Related Literature

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. (2012) estimate a general equilibrium model of the U.S. 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% of fluctuations in aggregate output.[1]

My model is close in its set-up to Kiyotaki and Moore (2008), henceforth referred to as KM.

[1] Christiano, Trabandt, and Walentin (2011b) confirm these findings in the estimation of a small-open economy model of the Swedish economy.

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 and, in particular, sticky wages can correct this feature of the model. Jermann and Quadrini (2011) 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.

More recently, Bigio (2011) 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 (2011), delivering positive co-movement between consumption and investment.

More recently, Shourideh and Zetlin-Jones (2012) find that financial market disturbances are a promising source of business cycle fluctuations in a real model with public and private firms that differ on their ability to self-insure against the arrival of good investment opportunities and whose operations are connected by non-financial linkages (e.g., the use of one firm's output as an intermediate input of production of all other firms). In their model, non-financial 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 (2011) 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, Eggertsson, Ferrero, and Kiyotaki (2010). They work with a liquidity shock modeled as in KM. An advantage of my intermediation shock is that it corresponds closely to an observed variable, namely, the interest rate spread. In addition, Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) focus on the period of recent financial turmoil and the associated monetary policy challenges. I study the past 20 years of data using Bayesian estimation and model evaluation methods. In relation to Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010), my analysis confirms that financial shocks were the driving force in the recent recession. However, I also find that these shocks have been important over the past 20 years.

The paper is structured so as to offer an empirical description of corporate investment financing from the Compustat quarterly data in section 1. Section 2 describes the features of the model. Section 3 discusses the estimation strategy, the prior selection on the model parameters and significant moments. Section 4 presents the model estimation results and section 5 concludes.

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

This section of the paper is devoted to an empirical analysis of the degree of dependence of firms' capital expenditures on financial markets. My objective is to quantify the fraction of quarterly corporate investment in fixed capital that firms fund by accessing financial markets as opposed to using current operative cash flows. Here 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.

For this purpose, I analyze cash flow data of U.S. firms. I build on work from Chari and Kehoe (2009) and rely on micro evidence from Compustat.[2]

I concentrate on U.S. corporations and refer to the sample period from 1989:Q1 to 2012:Q4. 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.[3] 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

[2] Chari and Kehoe (2009) compute a firm-level measure of the annual financing gap for all Compustat firms as the difference between operating cash flow, CF^{O}_{t}, and capital expenditures, $CAPX_t$ reported in each calendar year. They then sum the financing gaps over those firms that do not produce cash flows large enough to cover their investment ($\mathrm{CF}^{O}_{t} - \mathrm{CAPX}_t < 0$). Finally, they take the ratio of the absolute value of this sum and the total capital expenditure for all the firms and report that, from 1971 to 2009, an average of 16% of total corporate investment was funded using financial markets.

[3] 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 1984, while a consistent breakdown into their components is available since 1989.

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 carry out net financial or fixed investments, $CF^I_{e,t}$. I redefine 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 decompose 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 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:[4]

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

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 $CF^O_{e,t}$ to finance its investment in fixed capital and its dividend pay-outs, $DIV_{e,t}$, 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 $FG_{e,t} < 0$, the negative financing gap in period t can be funded 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 ($\Delta CASH_{e,t} < 0$).[5]

In each quarter, I compute $FG_{e,t}$ for all firms in the dataset and identify those that show a negative financing gap. I then add the absolute value of these deficits across the firms, to find a measure of the total financing gap in each quarter t for the aggregate of Compustat firms:

$$FG^{TOT}_t = \sum\nolimits_e |FG_{e,t}|\, \mathbf{1}\left\{FG_{e,t} < 0\right\}. \tag{3}$$

I also recognize that a fraction of firms that report a negative financing gap do so because they occasionally post negative quarterly operating cash flows: firms that report $CF^O_{e,t} < 0$ 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

[4] I interpret dividend payments as unavoidable commitments that arise, for example, from the presence of agency frictions between corporate insiders and minority shareholders (see La Porta, Lopez-de-Silanes, Shleifer and Vishny, (2000) for a summary of theoretical models in this tradition and for empirical evidence). This interpretation is consistent with the Flow of Funds definition of the financing gap reported in 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 report results computed under both assumptions for the analyses in this section and in the rest of the paper.

[5] The Flow of Funds table for corporations (table F.102) reports a measure of financial dependence of the whole corporate sector on transfer of resources from other actors in the economy (e.g., households) defined as the financing gap. I include its definition in appendix A and argue that this aggregate measure is not informative of the degree of dependence of single corporations on financial markets: Firms in deficit are aggregated with firms in surplus and positive values for the aggregate financing gap can coexist with corporations with large deficits at the micro-level.

accumulation of fixed capital and hence subtract the absolute value of aggregate negative cash-flows reported in every period, WK_t, from the total financing gap in (3) and define the quarterly financing gap share, FGS_t, as the ratio of the 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 in the appendix shows that from 1989:Q1 to 2012:Q4, the average of the financing gap share, FGS_t, amounts to 35.2% of total investment, with a standard deviation of 4.7%:[6]

$$\overline{FGS} = \sum\nolimits_t \frac{FGS_t}{T} = 35.2\%$$

Figure 1 shows how the financing gap share features increasing trends along the two economic expansions of the 1990s and 2000s. Moreover, all three 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.[7]

To conclude, the aggregate financing gap amounts to a substantial 35% share of corporate capital expenditures for Compustat firms in the data sample. The financing gap share, FGS_t, is a measure of *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 is indicative of financial frictions is controversial. 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 with the rise in intangible capital both in the time series dimension and in the cross section of U.S. corporations. The authors rationalize

[6]Table 1 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%, in line with similar calculations in Shourideh and Zetlin-Jones (2012).

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):

$$\overline{WKS} = \frac{1}{T}\sum_t \frac{WK_t}{FG_t^{TOT}} = 31.4\%$$

and find that around 31% of firms' total financial dependence is connected to funding operating expenses.

[7]Figure 1 also shows the financing gap share computed under the assumption that dividend payments to shareholders are disposable. 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.

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).

The breakdown of the aggregate financing gap into the liquidation of assets and depletion of cash reserves on one side, $NFI_{e,t}+\Delta CASH_{e,t}$, and funds from new equity and debt issuances on the other, $CF_{e,t}^{D}+CF_{e,t}^{E}$, suggests that internal savings do play a quantitatively important role in funding investment in fixed capital for Compustat firms. I define the Liquidation Share, $LIQS_t$ as the fraction of the total financing gap covered by liquidation of assets and their cash reserves:

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

Table 1 reports that, on average, over the sample period, cash reserves depletion and asset liquidations account for around 25% of the total financing gap (row 4, $LIQS_t$), of which 22% due to cash reserve depletion and 3% to asset liquidations (row 5, Cash Share, $CASHS_t$).[8] 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 75% over the sample period, showing that corporations fund the majority of their cash-flow imbalances using external sources of finance and, specifically, by frequently accessing primary debt and equity markets.

Unexpected shocks 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, disrupt the accumulation of aggregate fixed capital, and potentially affect the dynamics of output growth and business cycle fluctuations.

To evaluate the role of such disturbances on business cycle 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

[8] Figure 2 plots the evolution of $LIQS_t$ over the sample period. The graph suggests that the relative importance of liquidations and cash depletion versus debt and equity intakes has increased since 1989. In line with evidence on cash holdings dynamics in Falato, Kadyrzhanova, and Sim (2013) and with their intuition on the increased relevance of investment in intangible capital, the average fraction of financing gap funded by asset liquidations is lower in the boom of the 1990s, with an average of around 20% from 1991 to 2001, and higher in the expansion of the 2000s, with an average of 34% from 2002 to 2007. 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. This phenomenon is particularly pronounced before the burst of the dotcom bubble at the end of the 1990s, when the share of corporate mergers and acquisitions had risen to 15% of U.S. GDP in 1999 alone, compared to an average of 4% during the 1980s (Weston and Weaver (2004)).

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. In line with evidence in Falato, Kadyrzhanova, and Sim (2013), entrepreneurs in the model trade and hold liquid assets as precautionary savings against the arrival of good investment opportunities to overcome credit and liquidity constraints.

2 The Model

This section describes the structure of the model and the maximization problems of its actors. The economy features perfectly competitive financial intermediaries (banks), competitive producers of a homogeneous consumption good, producers of differentiated intermediate goods who act in regime of imperfect competition, and capital producers who transform final goods into ready-to-install capital goods. 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 homogenous work hours. The government consists of a monetary authority and a fiscal authority.

2.1 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 $A_{i,t} \sim F(A_{i,t})$ with $A_{i,t} \in [A^{low}, A^{high}]$ that can be employed to install new capital goods $\iota_{i,t}$ and obtain $A_{i,t}\iota_{i,t}$ new units of capital stock.[9]

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 and selling equity claims ($N_{i,t}$) on their physical assets ($K_{i,t}$) to financial intermediaries. Alternatively, household members with inefficient technologies are instructed to forgo investment opportunities that are not remunerative and instead supply hours worked in exchange for a wage, and to purchase financial claims from financial intermediaries

[9] The choice of $F(A_{i,t})$ and its parameterization are discussed at length in section 3.2.

on the returns of the assets 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, $N_{i,t-1}^{others}$, evaluate 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

Assuming that 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, $\left\{R_{t+i}^K\right\}$ for $i = \{0, ..., \infty\}$ and trade at the same price $Q_t = Q_t^K = Q_t^N$, it is possible 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 the optimal consumption, $C_{i,t+s}$, capital goods purchase, $\iota_{i,t+s}$, equity claim purchases and sales, ΔN_{t+s}^+, ΔN_{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 of the household members, 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:

$$\{C_{i,t+s},\, W_{i,t+s},\, \iota_{i,t+s},\, \Delta N_{i,t+s}^+,\, \Delta N_{i,t+s}^-,\, N_{i,t+s},\, B_{i,t+s}\}$$

and aggregate quantities:

$$\{C_{t+s}, \iota_{t+s}, \Delta N_{t+s}^+, \Delta N_{t+s}^-, N_{t+s}, B_{t+s}\}$$

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

$$\max_{\substack{C_{t+s},\,\iota_{t+s},\,\Delta N^{+}_{t+s},\,\Delta N^{-}_{t+s},\,N_{t+s},\,B_{t+s},\\ C_{i,t+s},\,W_{i,t+s},\,\iota_{i,t+s},\,\Delta N^{+}_{i,t+s},\,\Delta N^{-}_{i,t+s},\,N_{i,t+s},\,B_{i,t+s}}} \sum_{s=0}^{\infty}(\beta)^{t+s} b_{t+s} E_t \left[log(C_{t+s} - hC_{t+s-1}) - \chi_0 \chi_{b,t} \frac{L_{t+s}^{(1+\nu)}}{(1+\nu)} \right] \tag{6}$$

subject in every period to the set of members' flow of funds constraints:

$$P_t C_{i,t} + P_t^K \iota_{i,t} + Q_t^B \Delta N_{i,t}^{+} - Q_t^A \Delta N_{i,t}^{-} + B_{i,t} = (1-\tau_k) R_t^K N_{t-1} + (1-\tau_l) W_{i,t} L_{i,t} + R_{t-1}^B B_{t-1} + T_t + D_t. \tag{7}$$

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.[10]. The household preferences feature habit persistence in consumption with parameter h. On the right-hand side of the flow of funds constraint (7), each household member receives returns on its equity stock, $R_t^K N_{t-1}$ taxed at rate τ_kl. Members can also supply differentiated hours of labor $L_{i,t}$ remunerated at a monopolistic wage $W_{i,t}$. Labor income $W_{i,t} L_{i,t}$ is taxed at rate τ_l. 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 receives government transfers, T_t and 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.[11]

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 capital 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 $Q_t^A < Q_t^B$.

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 law of motion of equity for member i can be written as:

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

[10]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).

[11]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.

Aggregating (7) over household members, the aggregate flow of funds constraint is:

$$P_tC_t+P_t^K\iota_t+Q_t^B\Delta N_t^+-Q_t^A\Delta N_t^-+B_t=(1-\tau_k)R_t^KN_{t-1}+(1-\tau_l)\int_0^1 W_{i,t}L_{i,t}dF(A_{i,t})+R_{t-1}^BB_{t-1}+P_tD_t+P_tT_t \tag{9}$$

where total household consumption C_t, capital goods purchases ι_t, equity purchases ΔN_t^+, equity sales ΔN_t^-, equity holdings N_t and nominal bond holdings B_t are defined as:

$$C_t=\int_{A^{low}}^{A_t^{high}} C_{i,t}dF(A_{i,t}),\quad B_t=\int_{A^{low}}^{A_t^{high}} B_{i,t}dF(A_{i,t}) \tag{10}$$

$$\iota_t=\int_{A^{low}}^{A_t^{high}} \iota_{i,t}dF(A_{i,t}),\quad \Delta N_t^+=\int_{A^{low}}^{A_t^{high}} \Delta N_{i,t}^+dF(A_{i,t}),\quad \Delta N_t^-=\int_{A^{low}}^{A_t^{high}} \Delta N_{i,t}^-dF(A_{i,t}).$$

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

$$N_t=\int_{A^{low}}^{A_t^{high}} \left[A_{i,t}\iota_{i,t}+\Delta N_{i,t}^+-\Delta N_{i,t}^-\right]dF(A_{i,t})+(1-\delta)N_{t-1} \tag{11}$$

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

$$\log b_t=\rho_b\log b_{t-1}+\varepsilon_t^b$$

where $\varepsilon_t^b\sim$ i.i.d. $\mathrm{N}\big(0,\sigma_b^2\big)$.

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, household members can only issue and sell equity claims to represent a fraction θ of the new capital stock they plan to install, $A_{i,t}\iota_{i,t}$. Household members are then constrained in the amount of resources they can raise externally when installing new capital units (credit constraint). In other words, members can only partially pledge new capital units in guarantee of external financing and the parameter θ represents a reduced form of leverage constraint.

- Second, 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, $(1-\delta)\,N_{t-1}$.[12]

[12] 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 attributed to the presence of capital reallocation costs (Eisfeldt and Rampini (2006)). As suggested in section 1, 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)).

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

$$\Delta N_{i,t}^{-} \leq \theta A_{i,t} i_{i,t} + \phi \left(1-\delta\right) N_{t-1}. \tag{12}$$

so that sales do not exceed the sum of the external finance limit, $\theta A_{i,t} i_{i,t}$, and the maximum amount of resalable equity, $\phi \left(1-\delta\right) N_{t-1}$.

- Third, 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 2.2.

Household members face idiosyncratic investment technology risk that cannot be insured at the family level. Credit and liquidity constraints on financial markets prevent an efficient allocation of resources towards the best investment opportunities.[13] 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. Accumulating liquid assets in the form of government bonds B_t insures that the household can take advantage of good investment technologies when credit is constrained and external funds are not available. The government is the only issuer of nominal risk-free bonds, as household members cannot issue risk-free debt, so that, for each member i $B_{i,t} \geq 0$.

Optimality Conditions

In sum, 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 law of motion for equity holdings (11) and (8), and the individual liquidity constraint (12). The head of the household will also consider the following non-negativity constraints on consumption good, capital good, equity

[13] 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 alone would purchase and install the optimal amount of capital 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_t^A and the purchase price of equity Q_t^B would be identical and equal to the relative price of capital goods of the most efficient entrepreneur:

$$Q_t^A = Q_t^B = \frac{P_t^K}{A^{high}}.$$

and government bond purchases and equity sales:

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

Appendix D 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 capital goods from capital 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, $\frac{P^K_t}{A_{i,t}}$ (the price of purchasing a new capital good at price P^K_t and using technology $A_{i,t}$ to install it), with the price of purchasing old equity claims from financial intermediaries Q^B_t.

When their technology draw is good, the relative price of capital goods $\frac{P^K_t}{A_{i,t}}$ is lower than the purchase price of equity Q^B_t. The head of the household instructs these members to become *entrepreneurs*. Entrepreneurs are differentiated in two categories, *sellers*, indexed by $i = s$, and *keepers* (see figure 3), indexed by $i = k$. Sellers are entrepreneurs whose relative price of new installed capital $\frac{P^K_t}{A_{s,t}}$ is lower than the purchase price of equity Q^B_t as well as lower than the resale price equity Q^A_t. Sellers receive instructions to issue equity claims on their new capital and sell part of their existing equity stock at price Q^A_t to financial intermediaries to profit from their good technology draws. Keepers instead are entrepreneurs whose relative price of new installed capital $\frac{P^K_t}{A_{k,t}}$ is lower than the purchase price of equity Q^B_t but higher than the resale price equity Q^A_t. Keepers install capital goods using their own technology and internal cash flows, but find it too costly to raise external funds through financial intermediaries. Finally, members whose relative price of capital $\frac{P^K_t}{A_{b,t}}$ is higher than the price paid to purchase equity claims on the market Q^B_t, receive instructions to become *buyers*, indexed by $i = b$. Due to their poor technologies, buyers forgo installation of new capital goods and buy claims on the capital stock of other household members from financial intermediaries, thus funding more efficient capital accumulation technologies. I also assume that buyers are the only household members to supply differentiated hours worked, $L_{b,t}$ on the labor market in exchange for a monopolistic wage $W_{b,t}$, while members with active capital accumulation technologies (sellers and keepers) do not take part in the labor market, i.e., $L_{s,t} = L_{k,t} = 0$.

To sum up, figure 3 shows the partition of household members into the three subsets:

- a $\chi_{s,t}$ measure of sellers with $\frac{P^K_t}{A_{s,t}} \leq Q^A_t$, who install new capital and sell equity claims to financial intermediaries until their financial constraint (12) is satisfied with equality.

- a $\chi_{k,t}$ measure of keepers with $Q^A_t < \frac{P^K_t}{A_{k,t}} \leq Q^B_t$, who install new capital but do not access financial intermediaries.

- a $\chi_{b,t}$ measure of buyers with $\frac{P_t^K}{A_{b,t}} > Q_t^B$, who buy equity claims from financial intermediaries and supply differentiated labor, $L_{i,t}$. The first order conditions for buyers also show that they are the only members to purchase government bonds, $B_{b,t}$ as a source of liquidity for the household.

The following paragraphs describe in detail the optimal plans for each group of household members in terms of purchasing consumption goods, $C_{i,t}$, investment goods, $I_{i,t}$, purchases and sales 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 ($i = s$) can take advantage of good technology draws. Their relative price of a unit of installed capital, $\frac{P_t^K}{A_{i,t}}$, 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 $\frac{P_t^K}{A_{i,t}}$ and selling equity claims to the financial intermediaries at price Q_t^A. The optimal decision for the household is to instruct entrepreneurs to sell the highest amount of equity claims possible to financial intermediaries to the point that their financial constraint (12) binds with equality:

$$\Delta N_{s,t}^- = \theta A_{s,t} I_{s,t} + \phi\left(1-\delta\right) N_{t-1} \tag{13}$$

while foregoing purchases of equity claims on the market:

$$\Delta N_{s,t}^+ = 0.$$

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:

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

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 capital goods purchased by seller s:

$$\iota_{s,t} = \frac{1}{(P_t^K - Q_t^A \theta A_{s,t})}[(1-\tau_k)R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t + P_t T_t + Q_t^A \phi(1-\delta)N_{t-1}] \tag{14}$$

and for the seller's optimal equity stock:

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

where $\tilde{Q}^A_{s,t}$ is the replacement cost of one unit of internal capital:

$$\tilde{Q}^A_{s,t} = \frac{(P^K_t - Q^A_t \theta A_{s,t})}{1-\theta}$$

The fraction of sellers can be computed using the CDF of $A_{i,t}$:

$$\chi_s = Pr\left(A_{i,t} \geq \frac{Q^A_t}{P^K_t}\right) = 1 - F\left(\frac{Q^A_t}{P^K_t}\right)$$

Keepers

Keepers ($i = k$) 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 unit of installed capital, $\frac{P^K_t}{A_{k,t}}$, is higher than what the financial market pays for each equity claim sold, Q^A_t, but lower than the price at which buyers can purchase new equity, Q^B_t. As a result, these entrepreneurs will be instructed not to purchase consumption goods:

$$C_{k,t} = 0$$

and to maximize their purchase of investment goods using only their personal wealth:

$$\iota_{k,t} = \frac{1}{P^K_t}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t] \tag{15}$$

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

$$\Delta N^-_{k,t} = 0, \quad \Delta N^+_{k,t} = 0, \quad B_{k,t} = 0.$$

so that keepers' optimal equity stock will be:

$$N_{k,t} = \frac{A_{k,t}}{P^K_t}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t + \frac{P^K_t}{A_{k,t}}(1-\delta)N_{t-1}].$$

The measure of keepers in the economy is:

$$\chi_{k,t} = \Pr\left(Q^A_t \leq \frac{P^K_t}{A_{e,t}} \leq Q^B_t\right) = F\left(\frac{Q^B_t}{P^K_t}\right) - F\left(\frac{Q^A_t}{P^K_t}\right)$$

Buyers

Buyers ($i = b$) receive poor investment technology draws. The relative price of a unit of installed capital, $\frac{P^K_t}{A_{w,t}}$, is higher than the purchase market price of equity Q^B_t. Buyers are instructed not to adopt their capital installation technology and instead purchase financial claims at their market price Q^B_t. 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's b 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:

$$\begin{aligned}
N_t : Q_t^B = \beta b_t E_t & \left\{ \frac{\mu_{t+1}^{\Sigma C}}{\mu_t^{\Sigma C}} \frac{1}{\pi_{t+1}} \times \right. \\
& \times \left[\chi_{s,t+1} E_{A_{i,t+1}} \left[\frac{Q_{t+1}^B}{\tilde{Q}_{i,t+1}^A} \Big((1-\tau_k) R_{t+1}^K + (1-\phi_{t+1}) \tilde{Q}_{i,t+1}^A (1-\delta) + \phi_{t+1} Q_{i,t+1}^A (1-\delta) \Big) \middle| \frac{P_t^K}{A_{i,t}} \leq Q_t^A \right] + \right. \\
& + \chi_{k,t+1} E_{A_{i,t+1}} \left[\frac{Q_{t+1}^B}{\frac{P_{t+1}^K}{A_{i,t+1}}} \left((1-\tau_k) R_{t+1}^K + \frac{P_{t+1}^K}{A_{i,t+1}} (1-\delta) \right) \middle| Q_{t+1}^A \leq \frac{P_{t+1}^K}{A_{i,t+1}} \leq Q_{t+1}^B \right] + \\
& + \left. \left. \chi_{b,t+1} E_{A_{i,t+1}} \left((1-\tau_k) R_{t+1}^K + Q_{t+1}^B (1-\delta) \middle| \frac{P_{t+1}^K}{A_{i,t+1}} \geq Q_{t+1}^B \right) \right] \right\}
\end{aligned} \tag{16}$$

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

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

Intuitively from equation (16), 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. Payoffs for sellers, keepers and buyers rest in round brackets respectively on lines 2, 3 and 4, respectively, of equation (16). Equity payoffs feature a common component for sellers, keepers and buyers in the after-tax rate of return on capital $(1-\tau_k)R_{t+1}^K$ 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, for example, will sell a fraction ϕ_{t+1} 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 $(1-\phi_{t+1})$ on their balance sheet and evaluate it at the shadow price of inside equity $\tilde{Q}_{t+1}^A$. The shadow price of equity for sellers is equal to the replacement cost of their capital:[14]

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

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, $\frac{P_{t+1}^K}{A_{k,t+1}}$. 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, with a weight on buyers' payoffs equal to 1, the payoffs that accrue to sellers and keepers receive weights that are higher than 1:

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

The weight on the sellers' payoffs is also higher than the weight assigned to the payoffs of keepers. 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 members with better capital installation technologies and members subject to financing constraints.

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

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

The payoffs from liquid assets holding is the nominal risk-free rate R_t^B. Returns on liquid assets receive a higher weight in the hands of sellers than for keepers and buyers. Government bonds are liquid assets and can be deployed entirely to purchase and install new capital once a good technology draw is available. Bond payoffs can help sellers to overcome the external funding restrictions imposed

[14] The cost of one unit of equity in terms of consumption goods for seller s is equal to his relative price of new capital $\frac{P_t^K}{A_{s,t}}$ minus the value of the share of equity claims that he can pledge to attract external funding, θQ_t^A. Each unit of retained new equity $(1-\theta)$ needed to replace the assets of seller s requires a down payment of $\frac{P_t^K}{A_{s,t}} - \theta Q_t^A$. Since $\frac{P_t^K}{A_{s,t}} < Q_t^A$, the shadow price of equity for sellers is lower than the resale market price of equity $\tilde{Q}_t^A < Q_t^A$.

by binding borrowing and liquidity constraints on equity. The accumulation of liquid assets helps the household as a whole to direct liquid resources toward members with more productive capital installation technologies and to self-insure against binding credit constraints for its most efficient members.

Buyers will also supply differentiated work hours $L_{b,t}$ on the labor market in exchange for a 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 describe their evolution of wages as a geometric average of past and steady-state values of inflation and labor productivity. The remaining fraction $(1-\xi_w)$ of buyers supplies labor monopolistically.[15] Re-optimizing members sets 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:

$$L_{b,t+s} = \left(\frac{\tilde{W}_{b,t}}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t \tag{17}$$

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

2.2 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 $\tau_t Q_t^A$ for each financial claim they process. Banks maximize their nominal profits:

$$\Pi_t^{II} = Q_t^B \Delta N_{i,t}^{+} - \left(1+\tau_t^q\right) Q_t^A \Delta N_{i,t}^{-} \tag{18}$$

[15] 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:

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

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

$$\Delta N_{i,t}^{+} = \Delta N_{i,t}^{-}. \tag{19}$$

Perfect competition among intermediaries implies that profits are maximized when:

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

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.

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 reduces 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 the negative shock on τ_t^q is that investment drops with potential effects on output and consumption dynamics, discussed at length in section 4.

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.

In my model, I assume that the financial intermediation wedge, τ_t^q, maps into a 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 $(1 + \tau_t^q)\, q_t^A$, where $q_t^A = \frac{Q_t^A}{P_t}$ is the real price of equity. To evaluate the role of financial disturbances as potential drivers of business cycles that are orthogonal to other sources of business fluctuation, I assume that the intermediation costs τ_t follow an exogenous process of the kind:

$$\log(1 + \tau_t^q) = (1 - \rho_\tau)\log(1 + \tau^q) + \rho_\tau \log\left(1 + \tau_{t-1}^q\right) + \varepsilon_t^\tau$$

where $\varepsilon_t^\tau \sim N\left(0, \sigma_\tau^2\right)$.

2.3 Final Good Producers

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

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{1}{1+\lambda_{p,t}}}\, di\right]^{1+\lambda_{p,t}} \tag{20}$$

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:

$$\log(1+\lambda_{p,t}) = \left(1-\rho_p\right)\log(1+\lambda_p) + \rho_p \log(1+\lambda_{p,t-1}) + \varepsilon_t^p + \theta_p \varepsilon_{t-1}^p \tag{21}$$

with $\varepsilon_t^p \sim N\left(0, \sigma_{\lambda_p}^2\right)$, 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:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}} Y_t \tag{22}$$

2.4 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:

$$Y_t(i) = A_t^{1-\alpha} K_{t-1}(i)^{\alpha} L_t(i)^{1-\alpha} \tag{23}$$

A_t represents non-stationary labor-augmenting technological progress. The growth rate of A_t follows an exogenous AR(1) process:

$$\log\left(\frac{A_t}{A_{t-1}}\right) = \log(z_t) = (1-\rho_z)\log(\gamma) + \rho_z \log(z_{t-1}) + \varepsilon_t^z \tag{24}$$

where γ is the steady-state growth rate of output in the economy and $\varepsilon_t^z \sim N\left(0, \sigma_z^2\right)$. Finally, $A_t F$ is a fixed cost indexed by A_t that equalizes average profits across the measure of firms to zero in steady state (Rotemberg and Woodford (1995) and Christiano, Eichenbaum, and Evans (2005)).

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 $\pi_t = \frac{P_t}{P_{t-1}}$ 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:

$$E_t \sum_{s=0}^{\infty} \xi_p^s \beta^s \mu_{t+s}^{\Sigma C} \left\{ \left[P_t(i) \left(\prod_{j=0}^{s} \pi_{t-1+j}^{\iota_p} \pi^{1-\iota_p} \right) \right] Y_{t+s}(i) - \left[W_t L_t(i) + R_t^k K_t(i) \right] \right\} \tag{25}$$

subject to the demand function for good $Y_t(i)$, (22), and to the production function (23). Households own shares of the intermediate firms: current and future profits (25) are evaluated according to the marginal utility of a representative household, $\mu_t^{\Sigma C}$.

2.5 Capital Goods Producers

Capital goods producers operate in 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 investment goods, I_t, by means of a linear technology:

$$I_t = Y_t^I.$$

Producers then have access to a capital production technology to produce ι_t units of capital goods for an amount I_t of investment goods:

$$\iota_t = \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) \right] I_t \tag{26}$$

where $S(\cdot)$ is a convex function in $\frac{I_t}{I_{t-1}}$, with $S = 0$ and $S' = 0$ and $S'' > 0$ in steady state (Christiano, Eichenbaum, and Evans (2005)). Producers sell capital goods 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:

$$\max_{I_{t+s}} E_t \sum_{s=0}^{\infty} \beta^s E_{t+s} \left\{ \mu_{t+s}^{\Sigma C} \left[P_{t+s}^k i_{t+s} - P_{t+s} I_{t+s} \right] \right\} \tag{27}$$

subject to the technology D.7.

I assume that the households own stocks in the capital producers, so that the stream of their future profits is weighted by their marginal utility of consumption, $\mu_t^{\Sigma C}$.

2.6 Employment Agencies

As discussed in section 2.1, 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:

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

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

$$\log\left(1+\lambda_{w,t}\right) = \left(1-\rho_w\right)\log\left(1+\lambda_w\right) + \rho_w \log\left(1+\lambda_{w,t-1}\right) + \varepsilon_t^w + \theta_p \varepsilon_{t-1}^w \tag{28}$$

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 $\tilde{W}_{b,t}$:

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

2.7 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:

$$\frac{R_t^B}{R^B} = \left(\frac{R_{t-1}^B}{R^B} \right)^{\rho_R} \left[\left(\frac{\bar{\pi}_t}{\pi} \right)^{\phi_\pi} \right]^{1-\rho_R} \left(\frac{\Delta \overline{Y}_{t-s}}{\gamma} \right)^{\phi_Y} \eta_{mp,t} \tag{29}$$

where the nominal risk-free rate depends on its lagged realization and responds to deviations of a 4-period trailing inflation index $\bar{\pi}_t = \sum_{s=0}^{3} \frac{\pi_{t-s}}{4}$ 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 $\Delta \overline{Y}_{t-s} = \sum_{s=0}^{3} \frac{\log Y_{t-s} - \log Y_{t-s-1}}{4}$ 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. $N\left(0, \sigma_{mp}^2\right)$.

2.8 Fiscal Authority

The fiscal authority issues debt, B_t and collects distortionary taxes on labor income and capital rents, $\tau^k R_t^k K_{t-1}$ and $\tau^l W_t L_t$, to finance a stream of public expenditures, G_t, lump-sum transfers to households, T_t, and interest payments on the stock of debt that has come to maturity, $R_{t-1}^B B_{t-1}$:

$$B_t + \tau^k R_t^k K_{t-1} + \tau^l W_t L_t = R_{t-1}^B B_{t-1} + G_t + T_t. \tag{30}$$

Following the DSGE empirical literature, 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. $N\left(0, \sigma^{g2}\right)$.

My model requires an empirically plausible description of the dynamics of the supply of liquid assets that originates from the public authority. I then follow Leeper, Plante, and Traum (2010) in their empirical work on the dynamics of fiscal financing in a DSGE model of the US economy.[16] To obtain a fiscal rule that resembles the one in the de-trended model in Leeper, Plante, and Traum (2010) as closely as possible, I assume the share of transfers over total output, T_t/Y_t, to depart from its steady-state value, ToY, in response to deviations of the average growth rate of output in the past quarter from the stable growth path as well as to deviations of the debt to output ratio $\frac{B_t}{Y_t}$ from a specific target, BoY:[17]

$$\frac{T_t/Y_t}{ToY} = \left(\frac{\Delta Y_t}{\gamma}\right)^{-\varphi_Y} \left(\frac{B_t/Y_t}{BoY}\right)^{-\varphi_B} \tag{31}$$

Transfers are countercyclical as they increase when output growth falls below its steady-state value. However, transfers fall when B_t/Y_t increases over its steady-state level, as to keep the stock of public debt stationary.

Notice also that the description of the public provision of liquid assets in the form of government bonds assumes a key role in this model. Fiscal policy is non-Ricardian first due to the presence of distortionary taxation on labor and capital income and second because household members demand public provision of liquid assets to self-insure against binding financial constraints when subject to good idiosyncratic capital accumulation technology shocks (similarly to Woodford (1990)).

[16] Differently from Leeper, Plante, and Traum (2010), I do not allow for taxation on final consumption and do not include correlation among the stochastic components of the fiscal rules.

[17] The latter feature ensures 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 level (Woodford (2003)).

2.9 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 installation technology 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, by the investment, I_t, and by government spending, G_t:

$$Y_t = C_t + I_t + G_t$$

equal to the definition of GDP. Appendix D contains the complete set of aggregate equilibrium conditions for the model as well as the definition of an equilibrium for this economy.[18]

To solve the model, I first rewrite its equilibrium conditions in stationary terms, rescaling variables as output, Y_t, consumption, C_t, investment, I_t, capital and equity, K_t and N_t and real wages, $\frac{W_t}{P_t}$, that inherit the unit root of the total factor productivity stochastic process, A_t. I then compute the steady state of the model expressed in stationary variables 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.

3 Estimation

In this section, I describe the estimation of the model in section 2 on U.S. data using Bayesian methods. I start with a description of the data and of the choice of prior distributions for the model parameters and for certain moments, based on the literature on the estimation of DSGE models and on the micro-data evidence from Compustat reported in section 1. I then discuss the estimates and the features of the impulse response functions to the financial intermediation shock, the model fit, and the variance decomposition of the observables in the fundamental shocks implied by the estimation. I finally present the historical decomposition of GDP growth into the smoothed fundamental shocks and perform some counterfactual exercises to identify the driving forces of the Great Recession.

Estimates for the parameters are obtained by maximizing the posterior distribution of the model

[18] 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 non-negativity constraints on consumption and liquid asset positions are always binding for sellers and keepers. The solution to the household maximization problem in appendix D offers a full proof.

(An and Schorfheide (2007)) over the vector of observables. The posterior function combines the model likelihood function with prior distributions imposed on model parameters and on theoretical moments of specific variables of interest.

3.1 Data

I estimate the model using Bayesian methods on a sample of U.S. time series that span from 1989:Q1 to 2012:Q4. To estimate the model parameters, I use the following vector of eight observable variables:

$$\left[\Delta \log GDP_t,\;\; \Delta \log I_t,\;\; \Delta \log C_t,\;\; \Delta \log \frac{W_t}{P_t},\;\; \pi_t,\;\; R_t^B,\;\; \log L_t,\;\; Sp_t,\;\; FGS_t\right]$$

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 federal funds rate, R_t^B (mapped into the model nominal risk-free rate), the growth rate of the GDP price deflator, π_t (mapped into the model inflation rate) 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 10-year BBB-rated corporate bond yield from the Merrill Lynch's High Yield Master file and the 10-year Treasury note yield, Sp_t. The spread can be interpreted as a measure of the extra cost that markets apply to the 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 $\eta_t^{Sp} \sim N(0, \sigma^2_{ME_{sp}})$:

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

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 U.S. the vast majority of corporate financing happens through financial markets (through corporate bonds as well as equity) rather than through commercial banking. Corporate bond spreads seem to be more informative of the evolution of the external finance premium paid by the universe of U.S. corporations than commercial banking rates. In the same spirit, banks in the model resemble more market dealers, buying and selling financial claims from entrepreneurs / household members, than traditional commercial banks. The choice of the lower-medium grade spread series is conforms to the evidence that the median bond traded on financial markets in the period that I consider (1989:Q1 to 2012:Q4) 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. (2012)).[19]

[19] As a robustness check, I estimate the model substituting the BBB corporate bond spreads with the Excess Bond Premium (EBP) series derived in Gilchrist and Zakrajsek (2011) . In their paper, Gilchrist and Zakrajsek (2011) 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

As an original contribution to the literature, I include the financing gap share, FGS_t, among the set of observable variables for the estimation. As discussed in section 1, this is a measure of dependence of corporate investment on external funds derived from micro-level data in Compustat. Following the derivations in appendix B, I map the financing gap share in the data to the ratio of sellers' aggregate financing gap, FG_t, over aggregate household investment, up to a measurement error, $\eta_t^{FGS} \sim N(0, \sigma^2_{ME_{fgs}})$:

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

3.2 Priors and Calibrated Parameters

The choice of the priors for most parameters of the model is rather standard in the literature (Del Negro, Schorfheide, Smets, and Wouters (2007), Justiniano, Primiceri, and Tambalotti (2010)) and is summarized in table 2.

A few words are necessary to discuss the priors selection on parameters that influence entrepreneurs' investment financing decisions and the efficiency of financial intermediation in the model. These key parameters include the steady-state quarterly intermediation cost, τ_q, the share of new capital that can be pledged to raise funds on financial markets θ, and the degree of liquidity of old equity claims ϕ. I set a Gamma prior on the steady-state quarterly intermediation cost, τ^q_{ss}, with mean .8% and standard deviation .4%, so that the prior mode is approximately centered around .6% and the annualized intermediation spread rests within the range of previous literature estimates between 187 and 298 basis points (see, among others, Christiano, Motto, and Rostagno. (2012), Levin, Natalucci, and Zakrajsek (2004), De Fiore and Uhlig (2005), and Carlstrom and Fuerst (1997)). I choose a Beta prior with mean 30% and standard deviation 15% for the parameter θ that governs the pledgeable share of new capital and a Gamma prior with mean 5% and standard deviation 3% for the degree of liquidity of previously acquired assets, $\phi \times 100$. Both priors on θ and ϕ are fairly flat and uninformative. The identification of these two financial parameters is achieved by the inclusion of the financing gap share, FGS_t, among the set of observables and by the imposition of a prior on the steady-state share of the financing gap that is funded by portfolio liquidations, $LIQS_{ss}$ from equation (B.2), and by depletion of liquid reserves, $CASHS_{ss}$ from equation (B.3), both defined in appendix B. I choose a Beta prior with mean .25 and a standard deviation .025 on $LIQS_{ss}$ and a Beta prior with mean .20 and standard deviation .025 on $CASH_{SS}$, to conform to the Compustat evidence in section 1 in Table 2.

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 are described in section 4.3.

The choice of the distribution of the idiosyncratic capital installation technologies $A_{i,t} \sim f(A_{i,t})$ requires some discussion. In order to facilitate the aggregation of household members' optimality conditions in section 2.1, I assume that the pdf of $A_{i,t}$ can be approximated by a generic quadratic function with parameters a, b and c: $f(A_{i,t}) = a + bA_{i,t} + cA_{i,t}^2$, defined over the support $\left[A^{low}, A^{high}\right]$ (see Gomes, Jermann, and Schmid (2012) for a similar assumption). The cdf of the distribution will then take the form:

$$A_{i,t} \sim F(A_{i,t}) = aA_{i,t} + b\frac{A_{i,t}^2}{2} + c\frac{A_{i,t}^3}{3} + k.$$

I fix the constant k so that $F(A^{low}) = 0$ and a so that $F(A^{high}) = 1$ in steady state. Additionally, I normalize A^{low} to .8 and fix the width of the support of the distribution $d_A = A^{high} - A^{low}$ so that the average technology in use in steady state is $\bar{A}_{SS} = 1$. This ensures that the relative price of capital is equal to 1 in steady state, as in a standard model with a representative agent and standard capital accumulation technology. I estimate parameters b and c to let the data determine the slope and the curvature of the pdf that best fits the data. I assume wide Normal priors on b and c, centered around zero (i.e., under the prior assumption that $A_{i,t} \sim$ Uniform $\left[A^{low}, A^{high}\right]$). In the dynamic equilibrium, I assume that the upper bound of the support be time-varying, $A^{high} = A_t^{high}$, and adjusted so as to keep the average aggregate technology in use across sellers and keepers equal to one in every period, $A_t = 1$.[20]

I calibrate some of the fiscal parameters that govern the government budget constraint 30 in steady state. I rely on work on fiscal policy in DSGE models by Leeper, Plante, and Traum (2010) to calibrate the tax rates on capital returns, $\tau^K = 18\%$, and labor income, $\tau^l = 23\%$. I choose the steady-state value for g_{ss} to match the 19% average share of government expenditures over GDP observed during the sample period.

In the model government bonds are the liquid assets which entrepreneurs accumulate as precau-

[20] If the support of the distribution were fixed, a financial shock that increased the cost of borrowing for the most productive household members (with a high level of investment technology) and reduced the rate of return to savings on financial assets for less efficient household members would induce some of the less efficient members to start using their capital accumulation technology instead of trading assets on financial markets. Referring to Figure 3, higher financial intermediation costs can reduce the amount of external resources available to the most efficient household members and at the same increase the fraction of keepers, so that the average technology in use in the economy is of lower quality.

Buera and Moll (2011) point out that, in a model with heterogenous capital accumulation technologies, a negative financial shock can induce a contemporaneous adverse investment-specific technology shock (ISTSs) and hence that the two sources of aggregate fluctuations cannot be easily separated. Empirical work by Justiniano, Primiceri, and Tambalotti (2010) shows that ISTSs can account for large fractions of business cycle fluctuations in output and suggest that these disturbances could originate in financial markets. Kahn and Thomas (2011) also study the effects of credit market shocks on the allocation of capital across firms with heterogeneous productivity. They find that credit shocks in their model are amplified and propagated through large negative endogenous technology shocks, generated by disruptions to the distribution of capital, away from the most productive firms.

In this paper, I isolate the effects of financial shocks from endogenous ISTSs by keeping the average capital accumulation technology in use in the model constant and equal to 1, $A_t = 1$. Notice that I assume the value of a also varies in response to changes in A_t^{high} in order to keep $F(A_t^{high}) = 1$ at every point in time. I have estimated a version of this model in which the average technology in use in the economy is allowed to fluctuate with financial shocks. When the restriction on $A_t = 1$ is not imposed, the variance decomposition results are quantitatively similar to the ones reported here and are available upon request.

tionary savings to overcome their financial constraints. It would be misleading to match the stock of government bonds in the model to the stock of public debt in circulation in the whole economy and not just to the holdings of government-backed liquidity of U.S. corporations. A close look at Flow of Funds data shows that non-financial corporations stored an average of 2.4% of GDP in government-backed liquid assets during the sample period 1989:Q1 to 2012:Q4.

I set a prior on the share of public debt over GDP, $BoY = B_{SS}/Y_{SS}$ as a Beta with mean 0.3 and a large standard deviation of 0.1. In the model government bonds are the liquid assets which entrepreneurs accumulate as precautionary savings to overcome their financial constraints. It would be misleading to match the stock of government bonds in the model to the stock of public debt in circulation in the whole economy and not just to the holdings of government-backed liquidity of U.S. corporations. A prior mean of 30% is clearly an understatement of the average amount of government-backed liquidity over GDP for the U.S. economy in this sample period, as the public debt share of GDP alone amounts to around 60%. Nonetheless, a close look at Flow of Funds data shows that non-financial corporations stored an average of 2.4% of GDP in government-backed liquid assets during the sample period 1989:Q1 to 2012:Q4. As discussed above, the prior on the steady-state level of liquid resources over sellers' financing gap, $CASHS_{ss}$, chosen to conform to Compustat evidence on the cash flows of investing U.S. corporations, will contribute to the identification of the parameter BoY.

For each level of government debt in steady state, the share of lump-sum transfers to households over GDP is found by solving (30) in steady state. Transfers dynamics govern the aggregate supply of liquid assets in general equilibrium over time by means of the taxation rule 31. I impose wide Gamma priors with mean 1 and standard deviation .5 on the fiscal policy parameters φ_B and φ_Y, to include the estimated transfer rule elasticities in Leeper, Plante, and Traum (2010). Note that transfers are countercyclical (when output growth is lower than its steady state rate, transfers to households increase). Also note that transfers are reduced when debt over GDP is higher than its steady-state value, so as to keep public debt stationary. I pair these priors 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 0.2) so that the estimation favors model solutions with dominant monetary policy and passive fiscal policy.

The model is buffeted by i.i.d. random innovations $\left[\varepsilon_t^z,\ \varepsilon_t^{mp},\ \varepsilon_t^g,\ \varepsilon_t^p,\ \varepsilon_t^w,\ \varepsilon_t^{\tau_q},\ \varepsilon_t^b\right]$ that respectively hit seven exogenous processes: the growth rate of total factor productivity, z_t, deviations of the nominal risk-free rate from the Taylor rule, $\eta_{mp,t}$, the share of government spending over GDP, g_t, the price and wage mark-ups, λ_t^p and λ_t^w, the financial intermediation wedge, τ_t^q and the discount factor, b_t. I also introduce measurement error in the observation equations for the two financial variables, Sp_t and FGS_t, used in the estimation $\left[\eta_t^{FGS},\ \eta_t^{Sp}\right]$.

The priors on the persistence parameters for the exogenous processes are all Beta distributions with mean 0.6 and standard deviation 0.2.[21] The priors on the standard deviations of the innovations (expressed in percentage deviations) are inverse Gammas with mean 0.5 and standard deviation 1, excluding the shocks to the monetary policy rule, ε_t^{mp}, to the price and wage mark-ups, ε_t^p and ε_t^w, and to the discount factor, where 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 spread, $\sigma_{ME_{sp}}$, with mean 0.2% and standard deviation 0.5% and of the measurement error on the financing gap, $\sigma_{ME_{fg}}$, with mean 2% and standard deviation 0.5%.

To conclude, I complement this set of calibrated parameters and exogenous priors, with prior information on the variances of the observed variables computed over a pre-sample that spans from 1954:Q3 to 1988:Q4. Pre-sample data is available for all the series, excluding the spread, Sp_t and the financing gap share, FGS_t. In particular, I follow Christiano, Trabandt, and Walentin (2011a) and set prior distributions on the variance of the observable variables using the asymptotic Normal distribution of their GMM estimator computed over the pre-sample. The introduction of priors on endogenous moments of the model offers historical and pre-dated empirical evidence additional to the one coming from the baseline sample (1989:Q1 to 2012:Q4). I include these priors to downplay the importance of the Great Recession episode in the estimation of the model parameters over the baseline sample alone. The use of moment priors helps direct the estimation towards regions of the parameter space that generate business cycle fluctuations of historically plausible magnitudes. Table 3 reports the means and standard deviations of the moment priors.[22]

4 Results

This section reports the results of the Bayesian estimation of the model parameters, giving particular attention to the coefficients that govern the financial structure of the model. I then discuss the model fit and describe the impulse responses of key variables to a financial intermediation shock. I present the variance decomposition of the observable variables and their historical decomposition for the entire sample and for the Great Recession. I conclude the section with evidence that wage rigidities are the key element that allows the financial intermediation shock to play a fundamental role in driving the business cycle in the past 20 years of data.

[21] 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.

[22] Results described in section 4 are computed with a weight on the variance priors equal to 0.25. A weight attached to the prior distribution reduces the importance of the information contained in the pre-sample relative to the baseline sample in matching the second moments of the data. Estimation results are quantitatively and qualitatively robust to assigning different weights lower than 1 to the moment priors in the computation of the model posterior. Notably, the weight assigned to the variance priors reflects inversely on the width of the credible sets of the estimated impulse response functions (i.e., the more weight is given to the variance priors, the smaller the 90% credible intervals are for the impulse responses to structural shocks).

4.1 Parameter Estimates and Model Fit

Table 2 reports the median and 90% credible intervals for the set of model parameters. I compute the credible interval by running a Markov chain Monte Carlo (MCMC) exploration of the posterior distribution around the posterior mode.

Estimates of standard parameters, such as those governing price and wage rigidities, the investment adjustment cost friction and the degree of persistence and magnitudes of traditional shocks, are in line with previous findings in the literature. I will not discuss them in detail.

The inclusion of the financing gap share, FGS_t, among the observable variables and the imposition of priors on $LIQS_{ss}$ and $CASHS_{ss}$ in line with Compustat evidence in section 1 pin down the estimates of θ (the degree of pledgeability of new capital units), of ϕ (the degree of liquidity of existing financial claims) and of BoY, the steady-state share of liquid assets over GDP. The estimated value for the parameter θ implies that entrepreneurs finance around 20% of new capital units installed in every period through external sources, in line with estimates on investment financing reported in Ross, Westerfield, and Jaffe (2002). The range for ϕ implies that in every quarter firms can liquidate around 0.20% of their assets to raise raise internal resources to use on new investment projects. The estimated ratio of liquid assets over GDP, BoY, is around 2%. This is in line with Flow of Funds evidence that non-financial corporations stored an average of 2.4% of GDP in government-backed liquid assets on their balance sheet during the sample period from 1989:Q1 to 2012:Q4.[23] The estimates of the free parameters b and c of the distribution of $A_{i,t}$ suggest that its pdf is increasing in $A_{i,t}$ and concave over the support $[A^{low} = .8, A^{high} = 1.06]$.[24]

The model does a good job in matching in-sample features of the data. Table 4 reports the model-implied median and 90% credible sets for the standard deviations of the observable variables and their data counterparts. The model matches the absolute volatility of the quarterly growth rate of real GDP, investment, consumption and wages, as well as the standard deviation of the risk-free rate the natural logarithm of per-capita hours worked and the financing gap share. The model estimates overstate the standard deviations of quarterly inflation, probably in an attempt to fit the relatively low volatility of post-1989 observed inflation and the higher volatility implied by the 1954 to 1988 pre-sample priors in table 3.

Table 5 reports the model-implied median and 90% credible sets for the autocorrelation coefficients of order one of the observable variables, compared to their data counterparts. The model is able to reproduce significant positive autocorrelations for all the observables, in line with data evidence. The estimates match the autocorrelation coefficients for the rate of growth of real GDP, investment and consumption, as well as for the nominal interest rate and the financing gap share.

[23] Government-backed liquid assets include checkable deposits and currency, Treasury securities, and Agency and GSE-backed securities from table L.102 in the Flow of Funds for the corporate non-financial sector.

[24] The estimates also reject the assumption that idiosyncratic capital accumulation technologies are uniformly distributed ($b \neq c \neq 0$), an assumption that was made in a previous version of this paper.

The inflation and the real wage growth processes in the data are slightly less persistent than their estimated model counterparts, while the data series for log-hours is slightly more persistent than estimated in the model. The persistence of the corporate spread in the model is estimated to be lower than in the data, with an autocorrelation coefficient of order one ranging from 0.21 to 0.73, compared to a sample estimate of 0.85. The variance decomposition exercise in section 4.3 suggests that the dynamics of the corporate spread, Sp_t, and the financing gap share, FGS_t, are mostly driven by financial intermediation shocks. The model estimation tries to jointly fit the different persistence of the observables, but while matching the lower autocorrelation coefficient of the financing gap share, FGS_t, it misses the relatively higher persistence of the corporate spread.

Figures 4 and 5 show the corporate spread and the financing gap share series used as observables (solid black lines), respectively, in direct comparison with their model-implied counterparts, obtained as a combination of the smoothed fundamental shocks at the model posterior mode (dashed red lines), net of the realized measurement errors. The estimated corporate spread in figure 4 accurately matches the level and volatility of the data. When plotted against NBER recessions, the model corporate spread series shows a marked countercyclical pattern that tracks the sample data fairly closely, with a moderate positive phase-shift with respect to the sample data. This feature of the estimation seems to arise from the tension between the cyclical phases of the corporate spreads and the rest of the observables in the sample, including the financing gap share in figure 5. The estimation tries to explain their cyclical movements by means of sequences of financial intermediation shocks. As documented by Gilchrist and Zakrajsek (2011) and confirmed by the data plotted in the figures, corporate spreads tend to rise in anticipation of an economic downturn and they do so earlier in the data than in the model. In contrast, the financing gap share (as well as all the other macro variables used for the estimation) starts declining with the recession episodes. The estimation seems to favor a more synchronous cycle across the observables at the expense of a closer fit of the timing of movements in corporate spreads.

The model-implied financing gap shares (red dashed line) describes a low-frequency and less volatile series than its sample data counterpart (black solid line) in figure 5, attributing most of the high-frequency movement to measurement error. Nonetheless, the smoothed series matches the average and the range of values of the data relatively well, together with its marked procyclical pattern of long booms followed by rapid contractions.

4.2 Impulse Responses to a Financial Intermediation Shock

Figure 6 shows the impulse responses to a one-standard-deviation positive financial shock (i.e., an increase in the financial intermediation costs), evaluated at the estimated parameter mode. The plots also report the 90% credible sets for the impulse response functions.[25]

[25] Figures 10 to 15 in the appendix report the set of estimated impulse responses for the standard Smets and Wouters (2003) shocks.

When financial intermediation costs rise, the spread between the entrepreneurs' cost of raising external financial resources and the risk-free rate goes up by around 100 basis points on an annual basis. Contemporaneously, quarterly investment growth drops by 2% on impact. The financing gap share drops by 2%, signaling that entrepreneurs react to increased borrowing costs by reducing their reliance on outside funding by more than the decrease in investment. Inflation drops by around 0.5% on an annual basis, while the central bank lowers the nominal risk-free rate (FFR) slowly by 0.6% over the course of 2 years. 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 6 of figure 7 and discussed further in section 4.5). Higher real rates discourage consumption today so that consumption growth drops, together with investment, by around 0.05%, and the quarterly growth rate of output falls by 0.4%. The drop in the growth rate of real wages is modest (0.04% on impact), since nominal wages and prices are estimated to be sticky. With limited downward adjustment in real wages, hours worked drop persistently by more than 1% over the course of a year in response to lower aggregate demand.

4.3 Variance Decomposition

This section quantifies the relative importance of the fundamental shocks in the model in driving business cycle fluctuations. Table 6 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).

The fourth column of table 6 suggests that the financial intermediation shock is the most important source of business cycle fluctuations, explaining around 40% of the unconditional variance of GDP growth and around 60% of the volatility of investment. The shock is also able to explain around 33% of cyclical movements in inflation and 35% of the variance 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.[26]

Column 1 of table 6 shows how, according to the model estimates, neutral technology shocks explain around 16% of the variance of GDP growth in the sample period. Intertemporal preference shocks in column 5 of table 6 also play a big role in the model and explain around 25% of variations in real GDP growth, by driving more than 85% of fluctuations in consumption growth and around 23% of fluctuations in hours worked. This result confirms the suggestive evidence of previous work in the empirical macro literature that reports a decrease in the importance of TFP shocks as drivers of business cycle fluctuations in favor of demand shocks.[27]

[26] Christiano, Motto, and Rostagno. (2012) find that financial (risk) shocks in a Bernanke, Gertler, and Gilchrist (1999) framework can account for around 60% of output fluctuations in the United States. Christiano, Trabandt, and Walentin (2011b) find that the same shock explains 25% of output growth and 75% of investment growth in a small open economy like Sweden.

[27] For estimations on a similar sample period, see Christiano, Motto, and Rostagno. (2012). In support of a reduced

The financial intermediation wedge, τ_t^q, affects the relative price of external funding for entrepreneurs and their investment and financial decisions in the model. As a result, the estimation procedure attributes around 45% of cyclical fluctuations of the observed corporate spread, Sp_t, and 64% of the financing gap share, FGS_t, to the financial intermediation shock.[28]

Appendix E reports variance decomposition results for model estimations performed on the same macro variables but on different financial observables than the baseline estimation in table 6. 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.

Table 11 shows results for the model estimated on a financing gap share series that does not consider dividend payments as unavoidable commitments of corporations, as described in section 1.[29] If dividend payments are not considered to be an unavoidable commitment to shareholders, then the average degree of dependence of corporate firms on the financial system is lower. Accordingly, the average financing gap share in the sample drops to around 25%, compared to 35% in the baseline calculations in equation (2) and (4) (see table 1). The estimation on the financing gap measure that excludes dividends confirms the main result from table 6: financial intermediation shocks account for a large fraction of business cycle fluctuations in output and investment growth. In both cases the importance of financial shocks in explaining output growth fluctuations is moderately reduced with respect to the baseline (30% compared to 40% reported in table 6). Under a more conservative definition of the financing gap share, corporate investment is less dependent on the financial system and the transmission of financial intermediation shocks to real activity is partially dampened.

In table 13 in the appendix, I report the variance decomposition results of the estimation of the model, performed substituting the BBB corporate spread series with the EBP from Gilchrist and Zakrajsek (2011) in the set of observables.[30] Data on corporate yields and corporate spreads (like the BBB series used in the baseline estimation of the model) respond both to changes in the expected compensation for default losses on corporate debt as well as to the evolution of aggregate financial conditions. Gilchrist and Zakrajsek (2011) empirically separate the excess bond premium (EBP) from the default compensation using firm-level corporate yield data and show that the economy-wide EBP is related to measures of financial system distress. The variance decomposition results obtained by estimating the model on the EBP supports the main result from table 6: financial intermediation shocks account for 25% of business cycle fluctuations in output growth and 40% in investment growth. By construction the dynamics of the EBP do not account for one source of variation of

role for technology shocks in recent history, Shimer (2010) finds no evidence in the last 20 years of U.S. data that labor productivity and real wages are procyclical.

[28]The measurement errors on the corporate spread and the financing gap share explain around 30% of the variation of the two variables. As discussed in section 4.1, the fit of the corporate spread series and of the financing gap share suffers from the imperfect lead-lag structure of the variables in the model with respect to the data. Moreover, the estimation seems to attribute most of the high-frequency variation in the financing gap share to measurement error.

[29]The estimation is performed using the FGS_{EXDIV} plotted in figure 1 as a blue dashed line, instead of the FGS black solid line in the baseline case. The relative parameter estimates are reported in table 10.

[30]The parameter estimates are reported in table 12.

corporate spreads, namely the time-variation in the compensation for expected default losses on corporate obligations. As a result, the estimation of the model on the EBP shows a moderately lower, yet still prominent, role of financial intermediation shocks in explaining U.S. business cycle fluctuations.[31]

4.4 Smoothed Shocks and Historical Decomposition of GDP growth

In this section I present the historical decomposition of GDP growth in the smoothed fundamental shocks that buffet the model at the posterior mode. I describe the historical contribution of the different shocks and evaluate their role in shaping the dynamics of the Great Recession.

Figure 8 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 color legend on the right-hand side of the graph. Shocks to total factor productivity, ε_t^z, (TFP, in dark green) 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, 2007-2009).[32] Positive financial intermediation shocks $\varepsilon_t^{\tau q}$ (in red) 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 TFP shocks. The decomposition also suggests that negative financial intermediation shocks contributed to shape all three recessions in the sample, most notably the Great Recession. Negative financial shocks preceded the NBER start dates both in the 1990-1991 and in the 2007-2009 recessions. 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 pre-dated the drop in aggregate GDP.

Monetary policy shocks, ε_t^{mp} in dark blue, have acted as countercyclical drivers of output growth, sustaining growth 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. Nonetheless traditional monetary policy interventions became mildly contractionary or ineffective at best once the nominal short term interest rate reached the zero lower bound at the end of 2008. Government spending shocks (in grey) have

[31] As an additional robustness check and to verify the empirical results included in a previous version of this paper, I have also estimated the model on speculative grade B-rated corporate spreads instead of using the BBB spread series used in the baseline exercise and in the literature. Since lower-rated securities are subject to higher expected default losses, the use of speculative grade corporate spreads exacerbates the mismatch between the data and the model, in which financing spreads move in response to financial intermediation disturbances and not due to default risk. Variance decomposition results for the estimation on B-rated corporate bond spreads are in line with the other sets of estimates reported here. The full set of results is available upon request.

[32] 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 9. In comparison with Fernald's estimates, my model estimates produce a slightly more volatile process for smoothed TFP growth and suggest a more prominent role of negative TFP growth realizations in shaping the 2007-2009 recession.

non-Ricardian 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 policy experiments in KM, Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) and Guerrieri and Lorenzoni (2011). The estimation suggests that the contribution of the government spending shocks to GDP growth fluctuations during the sample period was modest. In the case of the Great Recession, the decomposition suggests that increased government spending reduced the drop in output growth by around 1% cumulatively over the course of the contraction, while restrictive fiscal policy after 2009 negatively affected the recovery.[33]

4.5 Why are Financial Shocks Important?

In this section, I explore the role of nominal rigidities in generating the positive co-movement of aggregate consumption, investment and hours worked in the wake of a financial intermediation shock.

4.5.1 Nominal Rigidities and Positive Co-movement of Investment, Consumption and Hours Worked

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 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.[34]

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.[35]

[33] Research by Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) suggests that unconventional monetary policy (e.g., in the model, public supply of liquid assets, B_t in exchange for illiquid ones, N_t) can play an important role in sustaining economic activity after a negative shock to the liquidity of traded assets, especially when the zero lower bound is binding. Christiano, Eichenbaum, and Rebelo (2011) also find that the government spending multiplier is large when the zero lower bound for the nominal interest rate binds. For estimation purposes, I abstract from imposing the zero lower bound on the nominal interest rate but nonetheless estimate a countercyclical (yet small) effect of government spending due to the presence in the model of non-Ricardian government debt.

[34] 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).

[35] Financial intermediation shocks in my model may look similar to liquidity shocks described by KM and Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010), as they both hit the intertemporal Euler equation for equity holdings and

In this section, I confirm the importance of nominal rigidities in the amplification of financial intermediation shocks and in generating the positive co-movement between macro aggregates. In particular, by comparing impulse responses of the model estimated under the assumptions of sticky and flexible wages, I find that wage rigidities are central in amplifying the response of hours worked and output that allows consumption to fall after a negative financial intermediation shock.

Figure 7 shows the impulse responses for aggregate output, investment and consumption growth, real wages growth, hours worked, together with the equilibrium real interest rate to a one-standard deviation negative financial shock for different versions of the model. The impulse response in the black dashed lines are computed at the posterior mode parameters in table 2, as in figure 6, for the benchmark model estimated under the assumption of price and wage rigidities. The figure also reports impulse responses for the model estimated under the alternative assumption of flexible wages (blue dashed lines, posterior mode parameters in table 14). Finally, the plots include impulse response functions for the estimated flexible-wage model in which the Calvo price-setting parameter is set to 0.01 (magenta dotted lines) so as to mimic the behavior of a model with flexible prices and wages.

When the intermediation cost, τ_t^q, rises, sellers with a good investment opportunities observe an increase in their financing spreads and can rely on a reduced amount of external funding for each new unit of new capital they want to install. As a consequence, investment, I_t, plunges. In the absence of nominal rigidities, prices and wages can adjust freely to clear markets. In particular the real rate of interest would drop to induce consumption to rise and pick up the slack in the market of final goods instantaneously, in line with the argument in Barro and King (1984). The impulse responses for the model without nominal rigidities in figure 7 (magenta dotted lines) highlight the negative co-movement between investment and consumption, in line with the intuition inBarro and King (1984) and with the findings in KM in the case of liquidity shocks.

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,

affect the trading margin between sellers and buyers of equity. Shi (2011) shows that liquidity shock in models without nominal rigidities generate a negative co-movement between output and asset prices. In appendix C.1, I confirm this finding and show that financial intermediation shocks instead are immune to Shi (2011)'s critique in models without price and wage rigidities. In appendix C.2, I also show that Shi (2011)'s critique of liquidity shocks extends to models with nominal rigidities in which the degree of inertia in the central bank's nominal interest rate rule is low. Finally, in appendix C.3 I verify that the asset market dynamics implied by my estimated model with financial intermediation shocks share important properties with U.S. financial market data, other than the corporate bond spreads.

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 6).

In the next section I will discuss evidence that suggests that the negative correlation of output and consumption is robust to changes in the degree of inertia of the monetary policy rule. Here I will highlight instead the role played by wage rigidities in amplifying the effect of the shock through the changes in aggregate hours worked. To do so, I re-estimate the model under the assumption that prices are sticky.[36]

Table 14 in the appendix reports the parameter estimates of the model with flexible wages. Compared with the baseline model estimates in table 2, the model with flexible wages features an increased degree of price stickiness, with an estimated median Calvo re-optimization parameter ξ_p equal to 0.98, implying that firms can re-optimize their prices once every 50 quarters on average. This is in contrast to a value for ξ_p of 0.86 in the baseline estimation, implying that firms can re-optimize their prices every 6 quarters on average. Moreover, the median estimate for the Taylor rule inertial parameter, ρ_i, increases from 0.87 in the model with sticky wages to 0.98 in the model with flexible wages. The estimation of the model with flexible wages favors high price-stickiness and high Taylor-rule persistence in substitution of wage rigidities, so as to allow the real interest rate to rise and consumption to drop in response to a financial intermediation shock and to explain the joint dynamics of the macro variables and corporate spreads in the observed U.S. data.

Figure 7 allows a direct comparison of the impulse responses of the model estimated with and without wage rigidities. The impulse responses reveal that after a negative financial intermediation shock the real rate does increase on impact in the flexible wage model, but less than in the baseline model.[37] As a result, consumption growth shows less of a marked decline and a non-monotone response to a financial intermediation shock and hours worked and output decrease by less than in the baseline model.

This intuition is confirmed by comparing the variance decomposition exercises for the model

[36] In the model with flexible wages, the wage mark-up shock is substituted with a labor disutility shock affecting the parameter χ_0 in the utility function. I re-estimate the model to find the set of parameter values (and the historical shocks) that maximize the posterior and thus best fit the data and prior evidence under the new assumption.

[37] The higher estimated degrees of persistence in nominal interest rate and in inflation translates into a more persistent response in the real rate in the model with flexible wages than in the baseline model.

estimated under the assumption of sticky and flexible wages. I report results for the two cases respectively in tables 6 and 7. The estimation of the model under flexible wages shows that the importance of the financial intermediation shock in explaining business cycle fluctuations drops significantly with respect to the sticky wages model: financial intermediation shocks explain around 18% of GDP growth business cycle volatility compared to 40% in the benchmark model. [38]

5 Conclusions

In this paper I have addressed the question of how important financial intermediation shocks are in driving the business cycle. The main finding of this research is that the contribution of financial intermediation shocks to cyclical fluctuations is large and accounts for around 40% of output and 60% of investment volatility, when estimated on the last 20 years of US macro data.

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 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 wage rigidities allow the shock to generate the positive co-movement of investment, consumption and hours worked that is observed in the data along the business cycles. Assuming flexible wages and re-estimating the model on the same data series along the same sample period delivers very different results: the financial intermediation shock is only able to explain around 18% of output growth.

This paper focuses on the the degree of firms' financial dependence that arises from the investment in fixed capital. I document in the empirical analysis of Compustat data, that working capital financing needs represent a non-trivial fraction of the total financial dependence of U.S. corporations. I leave the analysis of the business cycle properties of working capital needs, their financing and their role in amplifying financial intermediation shocks to future research.

[38] Interestingly, TFP shocks gain importance in explaining business cycle fluctuations (from 16% in the baseline model to 37% of GDP growth volatility explained at business cycle frequencies) as they are able to generate the positive co-movement between output, consumption and investment observed in the U.S. data. Labor disutility shocks also become more important in explaining output fluctuations, as they can help offset the countercyclical behavior of labor supply induced by TFP shocks in a model with no nominal rigidities and reconcile the dynamics of hours worked observed in the data with a TFP-driven business cycle (see figure 10).

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Tables and Figures

Table 1: Compustat Evidence on Corporate Investment Financing

Variable V_t	Mean(V_t)	StdDev(V_t)
${FGS_t}^1$	**35.20%**	**4.72%**
${FGS_t}^2$ - Excluding Dividends	24.91%	4.67%
${WKS_t}^3$	31.44%	4.93%
–		
${LIQS_t}^4$	24.95%	22.14%
${CASHS_t}^5$	21.96%	15.10%

Mean and standard deviations of variables across sample Period 1989:Q1 - 2012:Q4, if not otherwise specified. Source: Compustat.

1. Financing gap share of capital expenditure defined in equation (4), total of U.S. corporations in Compustat.
2. Financing sap share, excluding dividend payments, total of U.S. corporations.
3. Share of total financing gap due to working capital needs. U.S. corporations.
4. Share of financing gap funded by portfolio liquidations. U.S. corporations
5. Share of financing gap funded by variations in cash reserves. U.S. corporations

Baseline Model - Estimation Results

Table 2: Baseline Model with Sticky Wages: Calibrated Values, Priors and Posterior Estimates for the Model Parameters

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
A_l	Entr. Tech. Distr. (level)	Calibrated	0.800	[	–	–	–	]
d_A	Entr. Tech. Distr. (width)	Calibrated	0.225	[	–	–	–	]
a	Entr. Tech. Distr. (norm.)	Calibrated	3.748	[	–	–	–	]
b	Entr. Tech. Distr. (slope)	$N(0.200, 1.000)$	1.052	[	1.017	–	1.088	]
c	Entr. Tech. Distr. (curv.)	$N(0.000, 1.000)$	-0.173	[	-0.176	–	-0.171	]
γ	SS Output Growth	$N(0.500, 0.050)$	0.425	[	0.353	–	0.497	]
$(\beta^{-1} - 1) \times 100$	Discount Factor	Calibrated	0.750	[	–	–	–	]
δ	Capital Depreciation	Calibrated	0.025	[	–	–	–	]
ν	Inverse Frisch	$\Gamma(2.000, 0.750)$	1.831	[	1.084	–	2.790	]
h	Habit	$B(0.500, 0.200)$	0.945	[	0.927	–	0.960	]
η	Capital Share	$B(0.300, 0.050)$	0.733	[	0.715	–	0.750	]
λ_p	Price Mark-up	$N(0.150, 0.050)$	0.072	[	0.047	–	0.104	]
ξ_p	Calvo Prices	$B(0.660, 0.100)$	0.882	[	0.862	–	0.901	]
ι_p	Index Prices	$B(0.500, 0.150)$	0.106	[	0.064	–	0.166	]
ξ_w	Calvo Wages	$B(0.660, 0.100)$	0.941	[	0.929	–	0.950	]
λ_w	Wage Mark-up	$N(0.150, 0.050)$	0.150	[	0.083	–	0.218	]
ι_w	Index Wages	$B(0.500, 0.150)$	0.214	[	0.111	–	0.309	]
$\phi_{ss} \times 100$	Liquidity Constr.	$\Gamma(5.000, 3.000)$	0.167	[	0.095	–	0.236	]
θ	Borrowing Constr.	$B(0.300, 0.150)$	0.198	[	0.187	–	0.210	]
$\tau_{q_{ss}} \times 100$	SS Spread	$\Gamma(1.000, 0.200)$	0.775	[	0.608	–	0.993	]
BoY	Liquidity over GDP	$B(0.300, 0.100)$	0.022	[	0.020	–	0.025	]
gs_{ss}	Govt over GDP	Calibrated	0.170	[	–	–	–	]
τ_k	Capital Tax Rate	Calibrated	0.184	[	–	–	–	]
τ_l	Labor Tax Rate	Calibrated	0.223	[	–	–	–	]
t_B	Fiscal Rule - Debt	$\Gamma(1.000, 0.500)$	1.366	[	0.803	–	2.302	]
t_Y	Fiscal Rule - GDP Growth	$\Gamma(1.000, 0.500)$	0.852	[	0.352	–	1.409	]

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
θ_I	IAC	$\Gamma(2.000, 0.125)$	1.933	[	1.751	–	2.131	]
π_{ss}	SS inflation	$N(0.500, 0.100)$	0.200	[	0.123	–	0.290	]
ρ_i	Taylor Rule inert.	$B(0.600, 0.200)$	0.869	[	0.841	–	0.894	]
ϕ_π	Taylor Rule infl.	$N(1.700, 0.200)$	2.141	[	1.888	–	2.387	]
ϕ_{DY}	Taylor Rule growth	$N(0.125, 0.050)$	0.157	[	0.103	–	0.212	]
θ_π	Inflation MA	Calibrated	0.750	[	–	–	–	]
θ_{DY}	GDP Growth MA	Calibrated	0.750	[	–	–	–	]
ρ_z	AR(1) TFP gr. shock	$B(0.600, 0.200)$	0.483	[	0.365	–	0.584	]
ρ_g	AR(1) G shock	$B(0.600, 0.200)$	0.973	[	0.970	–	0.979	]
ρ_β	AR(1) Beta shock	$B(0.600, 0.200)$	0.608	[	0.505	–	0.703	]
ρ_p	AR(1) P Mark-up shock	$B(0.600, 0.200)$	0.705	[	0.587	–	0.788	]
ρ_w	AR(1) W Mark-up shock	$B(0.600, 0.200)$	0.132	[	0.065	–	0.183	]
ρ_τ	AR(1) Fin. shock	$B(0.600, 0.200)$	0.959	[	0.953	–	0.965	]
θ_p	MA(1) P shock	$B(0.500, 0.200)$	0.235	[	0.111	–	0.351	]
θ_w	MA(1) W shock	$B(0.500, 0.200)$	0.131	[	0.106	–	0.148	]
σ_z	Stdev TFP Growth Shock	Inv. $\Gamma(0.500, 1.000)$	0.693	[	0.623	–	0.777	]
σ_g	Stdev G Shock	Inv. $\Gamma(0.500, 1.000)$	0.169	[	0.152	–	0.192	]
σ_i	Stdev MP Shock	Inv. $\Gamma(0.100, 1.000)$	0.119	[	0.105	–	0.136	]
σ_τ	Stdev Fin. Shock	Inv. $\Gamma(2.000, 1.000)$	1.310	[	1.011	–	1.690	]
σ_β	Stdev Beta Shock	Inv. $\Gamma(0.100, 1.000)$	7.616	[	5.827	–	10.398	]
σ_p	Stdev P Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.067	[	0.056	–	0.081	]
σ_w	Stdev W Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.292	[	0.263	–	0.326	]
$\sigma_{ME_{sp}}$	Stdev ME Spread	Inv. $\Gamma(0.200, 0.500)$	0.386	[	0.340	–	0.440	]
$\sigma_{ME_{fgs}}$	Stdev ME FGS	Inv. $\Gamma(2.000, 0.500)$	4.742	[	4.214	–	5.386	]

Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model.
1 N stands for Normal, B Beta, Γ Gamma and Inv. Γ Inverse-Gamma1 distribution.
2 Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm.
Acceptance rate 24%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 3: Priors on Theoretical Moments

Moment	Prior Type	Prior Mean	Prior Std
$\text{Var}(\Delta \log X_t)$	N	1.28	0.77
$\text{Var}(\Delta \log I_t)$	N	16.31	10.11
$\text{Var}(\Delta \log C_t)$	N	0.27	0.16
$\text{Var}(\Delta \log w_t)$	N	0.21	0.13
$\text{Var}(\pi_t)$	N	0.42	0.24
$\text{Var}(R_t^B)$	N	0.83	0.51
$\text{Var}(\log L)$	N	11.55	5.22
$\text{Var}(Sp_t)$	-	-	-
$\text{E}[LIQS_t]$	B	0.25	0.02
$\text{E}[CASH_t]$	B	0.20	0.02

Prior distributions on the variances of observables are the Normal asymptotic distributions of the GMM variance estimators, computed on a pre-sample that spans from 1954:Q3 to 1988:Q4. The prior standard deviations reflect the weight assigned to the pre-sample in computing the posterior. The numbers reported correspond to a weight of 1/20. Results are robust to the choice of the weight, although higher weights deliver tighter significance bands for impulse response estimates. Source: Haver Analytics. Prior distributions on steady-state level of asset liquidation share ($LIQS_{ss}$) and cash reserve shares ($CASH_t$), informed by Compustat sample averages over the sample 1989:Q1 - 2012:Q4. Source: Compustat.

Table 4: Model Fit : Standard Deviations

Observables	Data	Model Median	[	5%	-	95%	]
Stdev($\Delta \log GDP_t$)	0.78	0.81	[	0.67	–	1.00	]
Stdev($\Delta \log I_t$)	2.55	2.97	[	2.37	–	3.73	]
Stdev($\Delta \log C_t$)	0.53	0.57	[	0.46	–	0.70	]
Stdev($\Delta \log w_t$)	0.75	0.80	[	0.68	–	0.93	]
Stdev(π_t)	0.25	0.49	[	0.37	–	0.68	]
Stdev(R_t^B)	0.64	0.66	[	0.39	–	1.09	]
Stdev($\log L_t$)	4.28	4.16	[	2.77	–	6.09	]
Stdev(Sp_t)	0.91	1.06	[	0.43	–	2.88	]
Stdev(FGS_t)	0.05	0.07	[	0.05	–	0.09	]

Standard deviations of observable variables. Model implied vs. Data and implied prior distribution mean from Table 3. Source: Haver Analytics. Sample period: 1989:Q1 - 2012:Q4. Pre-sample for priors: 1954:Q3 - 1988:Q4. Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 24%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 5: Model Fit : Autocorrelations of Order 1

Observables	Data	Model Median	[	5%	-	95%	]
AC(1)($\Delta \log GDP_t$)	0.65	0.64	[	0.49	–	0.76	]
AC(1)($\Delta \log I_t$)	0.61	0.71	[	0.58	–	0.81	]
AC(1)($\Delta \log C_t$)	0.53	0.60	[	0.42	–	0.74	]
AC(1)($\Delta \log w_t$)	0.06	0.34	[	0.17	–	0.51	]
AC(1)(π_t)	0.55	0.82	[	0.70	–	0.90	]
AC(1)(R_t^B)	0.95	0.96	[	0.90	–	0.98	]
AC(1)($\log L_t$)	0.98	0.95	[	0.90	–	0.97	]
AC(1)(Sp_t)	0.85	0.50	[	0.21	–	0.73	]
AC(1)(FGS_t)	0.66	0.45	[	0.17	–	0.70	]

Autocorrelation of Order 1 of Observable Variables. Model implied vs. Data Data source: Haver Analytics, Sample period 1989:Q1 - 2012:Q4. Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 24%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 6: Baseline Model with Sticky Wages: Posterior Variance Decomposition

	TFP	**Gov't**	**MP**	**Financial**	**Preference**	**Price Mark up**	**Wage Mark up**	**ME Spread**	**ME FGS**
$\Delta \log GDP_t$	**15.7**	**1.2**	**3.1**	**40.7**	**25**	**10**	**3.1**	**0**	**0**
	[9 - 25.2]	[0.8 - 1.6]	[2.1 - 4.4]	[32.2 - 50.1]	[18.8 - 32.1]	[6.7 - 14.5]	[1.9 - 4.8]	[0 - 0]	[0 - 0]
$\Delta \log I_t$	**11.3**	**0**	**4.7**	**62.2**	**1.3**	**15.6**	**3.9**	**0**	**0**
	[6 - 19]	[0 - 0.1]	[3.3 - 6.8]	[51.4 - 72.3]	[0.7 - 2.6]	[10.5 - 22.2]	[2.3 - 6.1]	[0 - 0]	[0 - 0]
$\Delta \log C_t$	**8.7**	**0.1**	**0.1**	**1.8**	**88.5**	**0.3**	**0.4**	**0**	**0**
	[4.8 - 15.1]	[0 - 0.1]	[0.1 - 0.3]	[1 - 3.1]	[81.2 - 93.2]	[0.1 - 0.6]	[0.2 - 0.7]	[0 - 0]	[0 - 0]
$\Delta \log w_t$	**24.5**	**0**	**0.2**	**2.4**	**1.2**	**20.5**	**49.9**	**0**	**0**
	[15.4 - 36.1]	[0 - 0]	[0.1 - 0.4]	[0.9 - 5.4]	[0.4 - 2.9]	[14.3 - 28.9]	[40.5 - 58.9]	[0 - 0]	[0 - 0]
π_t	**11**	**0.1**	**0.7**	**33.3**	**6.8**	**41.4**	**5.6**	**0**	**0**
	[6.7 - 16.9]	[0 - 0.1]	[0.3 - 1.2]	[25.7 - 41.6]	[4.2 - 11]	[31.8 - 52.3]	[3.7 - 8.3]	[0 - 0]	[0 - 0]
R_t^B	**6.8**	**0.1**	**17.9**	**35.9**	**7.6**	**26.5**	**3.9**	**0**	**0**
	[4 - 10.8]	[0 - 0.2]	[12.7 - 25.2]	[28.5 - 43.8]	[4.7 - 12.4]	[19.5 - 34.8]	[2.5 - 5.8]	[0 - 0]	[0 - 0]
$\log L_t$	**14**	**0.9**	**3.1**	**42.9**	**22.6**	**11.5**	**3.8**	**0**	**0**
	[10.5 - 18.7]	[0.6 - 1.2]	[2.2 - 4.5]	[35.9 - 50.7]	[16.7 - 29.6]	[7.4 - 17.3]	[2.3 - 6.2]	[0 - 0]	[0 - 0]
Sp_t	**3**	**0**	**2.5**	**44.4**	**0.9**	**15**	**1.3**	**31.9**	**0**
	[1.9 - 4.7]	[0 - 0]	[1.5 - 4.2]	[33.6 - 55.2]	[0.5 - 1.7]	[10.4 - 21.4]	[0.8 - 2]	[24.1 - 41.1]	[0 - 0]
FGS_t	**0.4**	**0.3**	**0.2**	**63.5**	**0.2**	**0.3**	**0.1**	**0**	**34.9**
	[0.2 - 1]	[0.1 - 0.6]	[0.1 - 0.2]	[54.9 - 71.1]	[0.1 - 0.5]	[0.2 - 0.5]	[0 - 0.3]	[0 - 0]	[27.6 - 43.4]

Variance Decomposition of the observables, periodic component with cycles between 6 and 32 quarters. Median values and 90% confidence intervals reported. Posterior percentiles obtained from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 24%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Values are percentages. Rows may not sum up to 100% due to rounding error. Computed used parameter estimates in table 2.

Table 7: Model with Flexible Wages: Posterior Variance Decomposition

	TFP	**Gov't**	**MP**	**Financial**	**Preference**	**Price Mark up**	**Wage Mark up**	**ME Spread**	**ME FGS**
$\Delta \log GDP_t$	**37.6**	**1.8**	**3.2**	**18.3**	**25.8**	**0.1**	**12.7**	**0**	**0**
	[28.7 - 46.8]	[1.1 - 2.8]	[2.4 - 4.2]	[14.8 - 22.3]	[18.8 - 34.1]	[0 - 0.2]	[9.4 - 16.4]	[0 - 0]	[0 - 0]
$\Delta \log I_t$	**11.7**	**2.8**	**6.2**	**67.7**	**4.8**	**0.1**	**6.3**	**0**	**0**
	[8.6 - 15.6]	[1.7 - 4]	[4.7 - 8.2]	[60.9 - 74.3]	[3.1 - 7.1]	[0 - 0.2]	[4.4 - 8.7]	[0 - 0]	[0 - 0]
$\Delta \log C_t$	**26.2**	**2.7**	**0.1**	**2.3**	**61.7**	**0**	**6.4**	**0**	**0**
	[18 - 34.8]	[1.4 - 4.8]	[0 - 0.2]	[0.6 - 6.7]	[47.2 - 74.5]	[0 - 0.1]	[3.8 - 9.5]	[0 - 0]	[0 - 0]
$\Delta \log w_t$	**11.3**	**0.7**	**8.4**	**30.4**	**22.6**	**0.7**	**25.4**	**0**	**0**
	[8.9 - 14]	[0.4 - 1.3]	[6.3 - 11]	[25.4 - 35.9]	[17.7 - 27.7]	[0.3 - 1.2]	[19.6 - 32]	[0 - 0]	[0 - 0]
π_t	**0**	**2.9**	**1.2**	**16**	**0.1**	**79.5**	**0.1**	**0**	**0**
	[0 - 0.1]	[0.8 - 6.3]	[0.5 - 2.3]	[6.9 - 25.8]	[0 - 0.1]	[66.4 - 91.5]	[0 - 0.1]	[0 - 0]	[0 - 0]
R_t^B	**0**	**0**	**98.9**	**0.2**	**0**	**0.7**	**0**	**0**	**0**
	[0 - 0]	[0 - 0.1]	[97.6 - 99.7]	[0.1 - 0.7]	[0 - 0]	[0.2 - 1.6]	[0 - 0]	[0 - 0]	[0 - 0]
$\log L_t$	**5.7**	**3.1**	**5**	**30.9**	**33.1**	**0.1**	**21.4**	**0**	**0**
	[3.4 - 9.3]	[2.1 - 4.4]	[3.7 - 6.7]	[25.4 - 37]	[25.6 - 41]	[0 - 0.2]	[15.2 - 28.2]	[0 - 0]	[0 - 0]
Sp_t	**0.6**	**0.5**	**12**	**10.1**	**1.6**	**0.1**	**0.6**	**74**	**0**
	[0.4 - 1]	[0.2 - 1.1]	[8.6 - 16.5]	[6.7 - 14.6]	[1.1 - 2.3]	[0 - 0.2]	[0.4 - 0.9]	[67.5 - 79.7]	[0 - 0]
FGS_t	**1.5**	**2.9**	**2.3**	**54.4**	**6.5**	**0.1**	**1.4**	**0**	**30.5**
	[0.9 - 2.7]	[2.1 - 3.9]	[1.6 - 3.2]	[48.3 - 60.3]	[4.1 - 9.1]	[0 - 0.1]	[0.8 - 2.3]	[0 - 0]	[24.8 - 37]

Variance Decomposition of the observables, periodic component with cycles between 6 and 32 quarters. Median values and 90% confidence intervals reported. Posterior percentiles obtained from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 26%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Values are percentages. Rows may not sum up to 100% due to rounding error. Computed used parameter estimates in table 8.

Table 8: Compustat and Flow of Funds data on Capital Expenditures and Investment

Moment	$CAPX_t$	$FoF\ CAPX_t$	$FoF\ I_t$
$E[\frac{CAPX_t}{V_t}]$	1	58.28%	31.62%
$E[\Sigma_{s=0}^{3}\frac{\Delta\log V_{t-s}}{4}]$	1.20%	1.19%	1.01%
$\text{Stdev}[\Sigma_{s=0}^{3}100\frac{\Delta\log V_{t-s}}{4}]$	2.98%	2.80%	2.28%
$\text{Corr}[\Sigma_{s=0}^{3}100\frac{\Delta\log V_{t-s}}{4}, \Sigma_{s=0}^{3}100\frac{\Delta\log CAPX_{t-s}}{4}]$	1	0.64	0.53

Variables V_t in columns are: $CAPX_t$: Compustat aggregate capital expenditure; $FoF\ CAPX_t$: Flow of Funds Corporate capital expenditure; $FoF\ I_t$: Flow of Funds Aggregate Investment.
The table reports:
1. $E[\frac{CAPX_t}{V_t}]$: the average fraction that $CAPX_t$ represents of each variable V_t;
2. $E[\Sigma_{s=0}^{3}100\frac{\Delta\log V_{t-s}}{4}]$: the four-quarter trailing average of the growth rate of V_t;
3. $\text{Stdev}[\Sigma_{s=0}^{3}100\frac{\Delta\log V_{t-s}}{4}]$: the standard deviation of the four-quarter trailing average of the growth rate of V_t;
4. $\text{Corr}[\Sigma_{s=0}^{3}100\frac{\Delta\log V_{t-s}}{4}, \Sigma_{s=0}^{3}100\frac{\Delta\log CAPX_{t-s}}{4}]$: the correlation of the four-quarter trailing averages of the growth rate of V_t and $CAPX_t$.
All series are seasonally adjusted using the Census X-12 procedure. Source: Compustat and Flow of Funds Tables. Sample Period 1989:Q1 - 2012:Q4.

Table 9: Stock Market Growth Moments - Estimated Model vs. Data

Moment	Data	Model (Theoretical)	Model (Smoothed)
Mean	0.81	0.43	0.45
Standard Deviation	4.70	0.72	0.62
AC(1)	0.81	0.73	0.77
Corr. with GDP Growth	0.64	0.70	0.75
Corr. with SMG data	1	–	0.55

The table reports the first and (selected) second moments for the 4-quarter trailing average of Stock Market Growth (SMG) in the data and in the model (theoretical and of the smoothed series at the posterior mode). Sample period: 1989:Q1 to 2012:Q4). The SMG rate in the data refers to the S&P 500 index divided by the GDP deflator and the growth rate the of the U.S. population for consistency with the model. All moments are significantly different from zero at a 5% or lower level. Data source: FRED

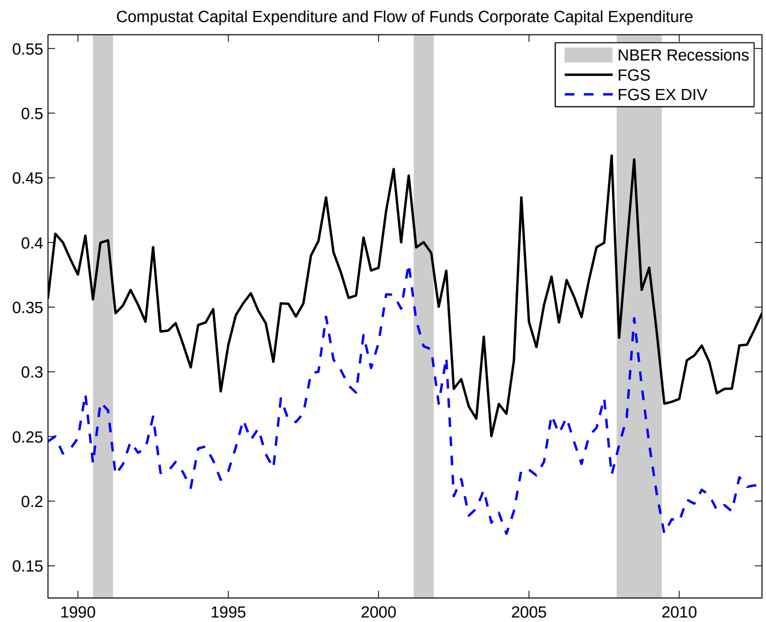

Figure 1: Financing gap share, as computed in equation (5) (black solid line) for the aggregate of U.S. corporations. The series is compared to results obtained by not considering dividends as unavoidable commitments of the firms and hence not accounting dividend payments as contributing to the financing gap (blue dashed line). Source: Compustat. Sample period 1989:Q1 - 2012:Q4.

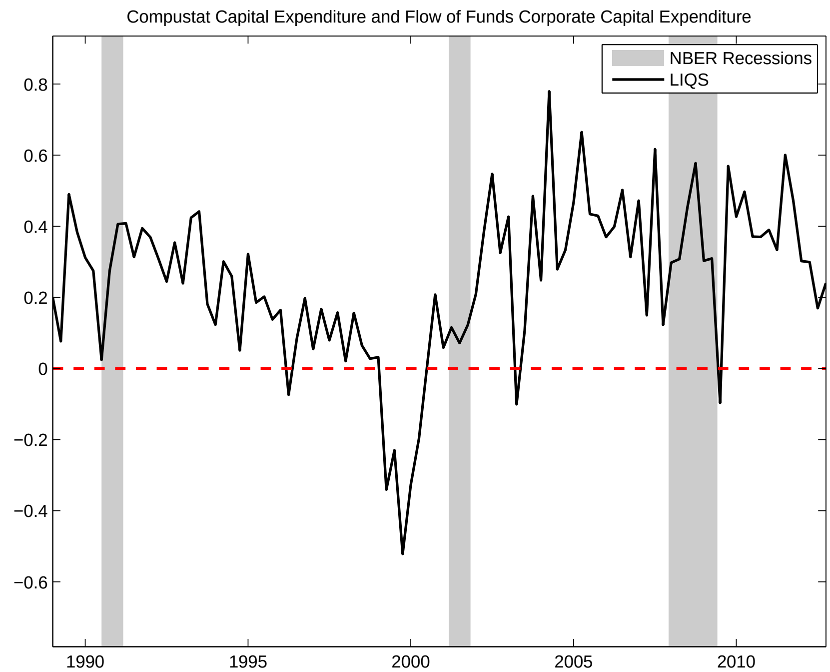

Figure 2: LIQS$_t$: Share of financing gap funded through portfolio liquidations and changes in cash reserves. Panel A (top) reports the raw data (blue dashed line) against the seasonally-adjusted series (black solid line). Panel B shows the raw data (blue dashed line) against the extracted trend (black solid line). Seasonal adjustment and trend extraction performed using the Census X12 procedure. Source: Compustat. Sample period 1989:Q1 - 2012:Q4.

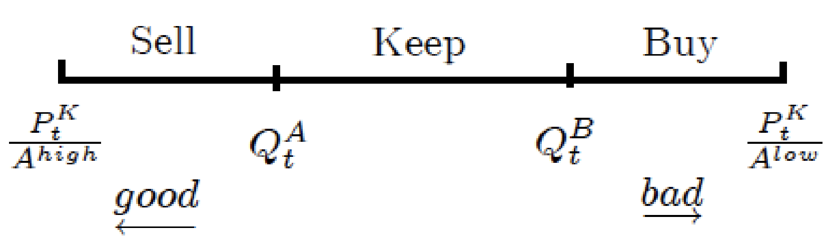

Figure 3: Distribution of Relative Price of Investment Technologies across Entrepreneurs

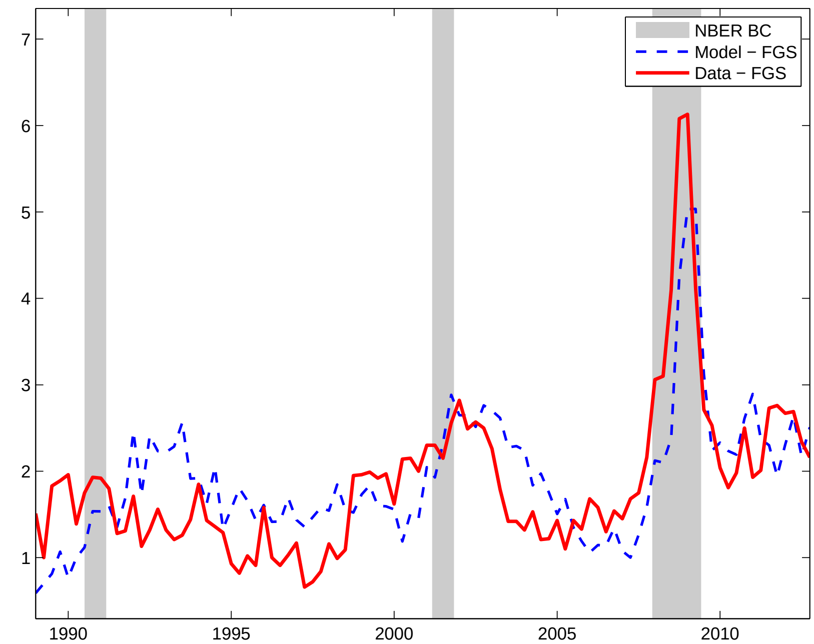

Figure 4: Corporate Bond Spreads - Data vs. Model, in percentage points. Source for Spread data: Moody's and FRB. Sample period 1989:Q1 - 2012:Q4.

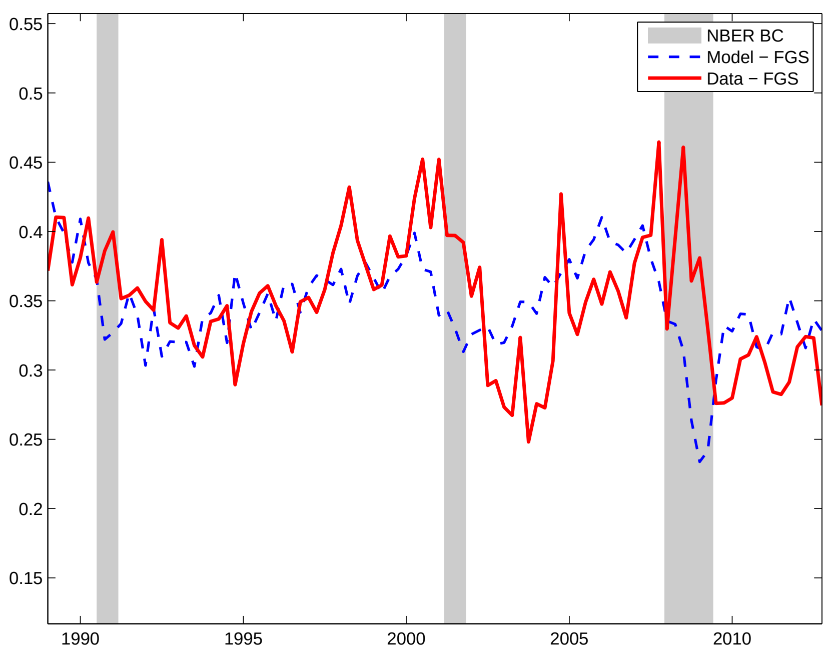

Figure 5: Financing gap share in the data (black solid line) and in the model (red dashed line), net of measurement error. Source for data: Moody's and FRB. Sample period 1989:Q1 - 2012:Q4.

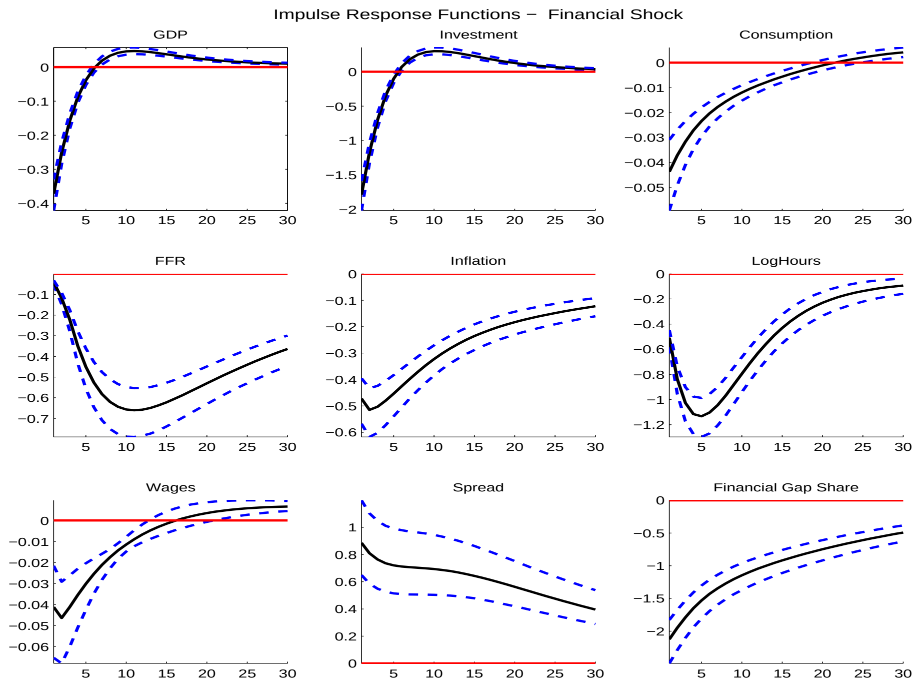

Figure 6: Impulse responses to a one standard deviation financial shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

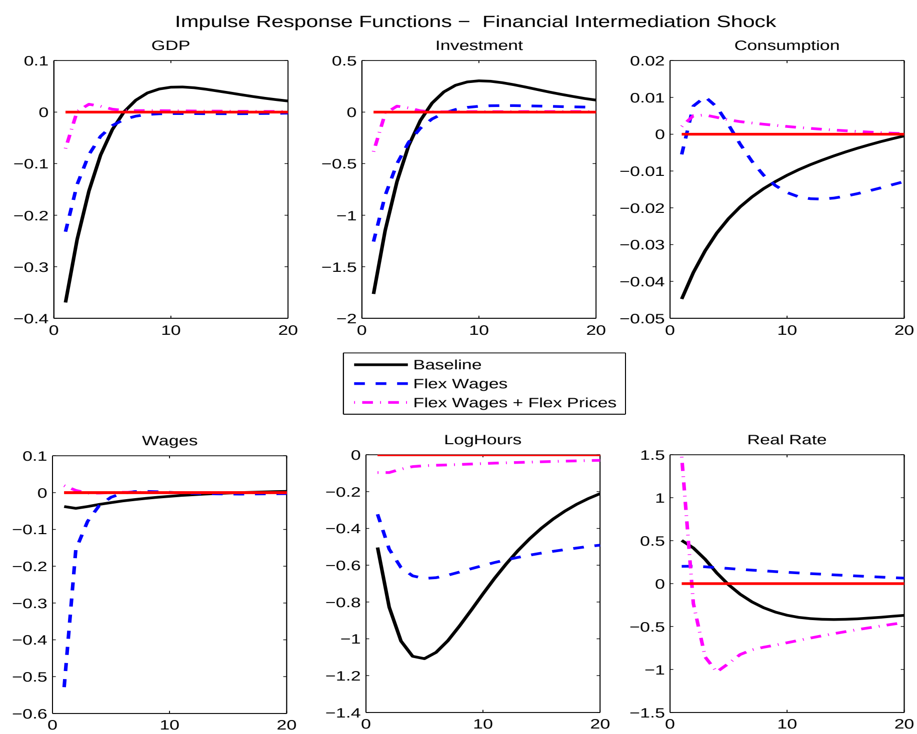

Figure 7: Impulse response functions to a one standard deviation financial shock. Comparison between baseline model (black solid line), flexible wages (blue dashed line) and flexible wages and prices (magenta dotted line).

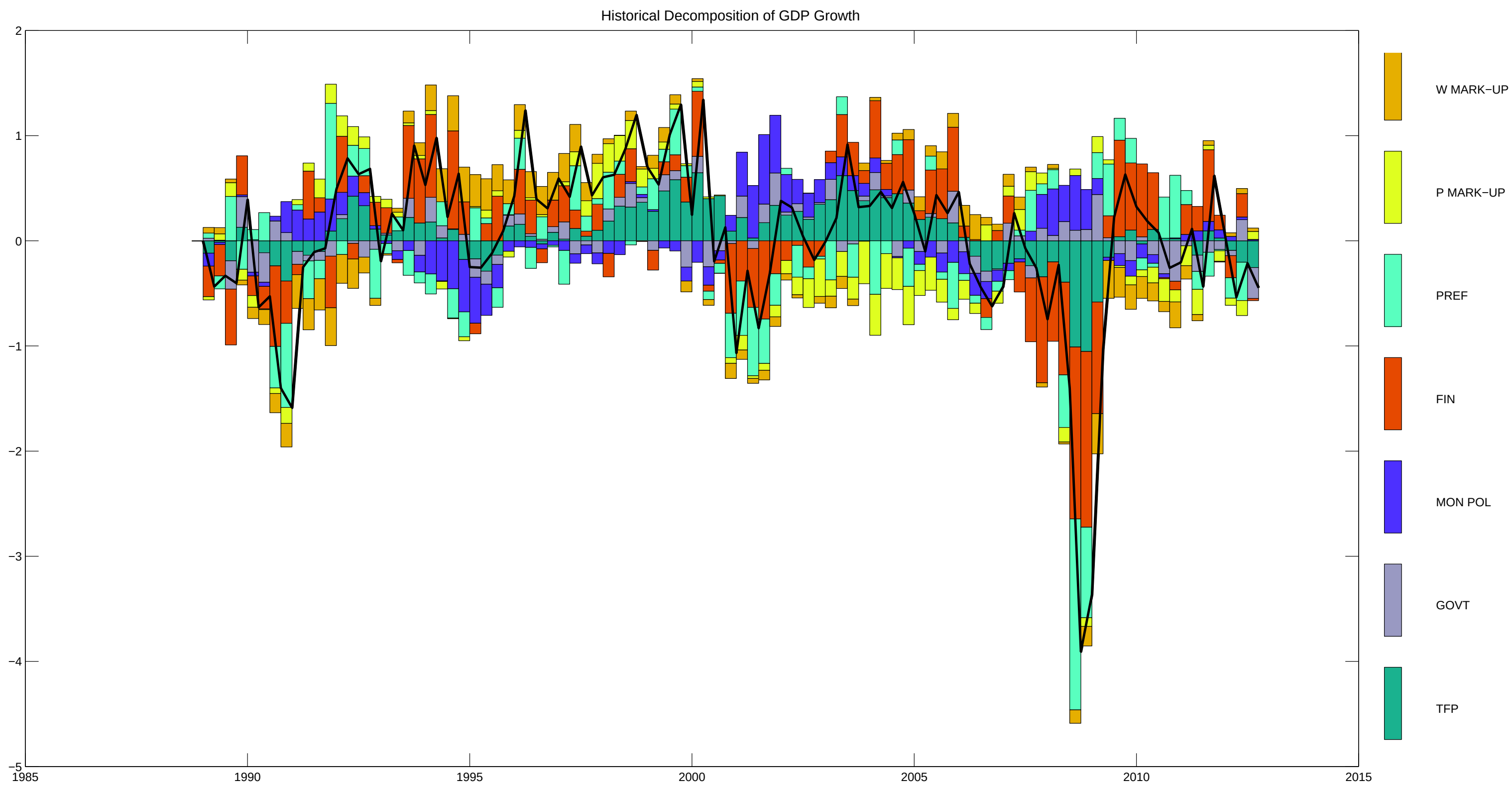

Figure 8: Quarterly de-trended GDP growth in the data (black line) decomposed into contributions of each structural shock through Kalman smoothing at the posterior mode. Source for GDP data: Haver Analytics.

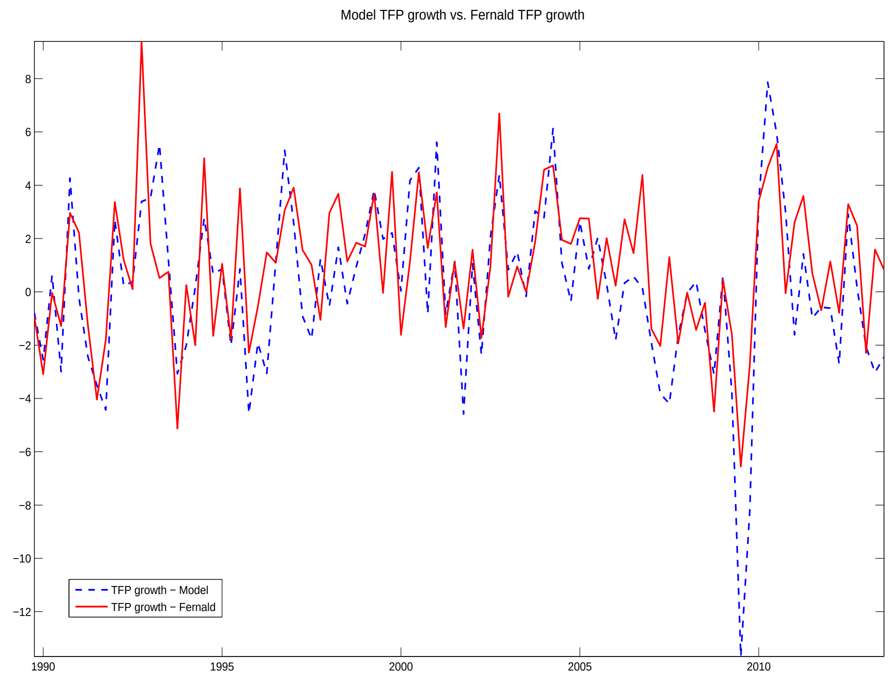

Figure 9: Smoothed TFP growth at posterior mode compared to estimated TFP growth not adjusted for capital utilization from Fernald (2012). Source: www.frbsf.org/economic-research/total-factor-productivity-tfp .

Online Appendix

A Flow of Funds and Compustat Corporate Cash Flow Data

Figure 16 and Table 8 compare dynamic properties of level and growth rates of capital expenditures in Compustat, $CAPX_t$ with those of aggregate corporate capital expenditures from the Flow of Funds table, $FoF\ CAPX_t$ and of aggregate investment, I_t. Capital expenditures for the aggregate of U.S. Compustat corporations account for around 60% of quarterly Flow of Funds U.S. corporate capital expenditure and 32% of aggregate investment from 1989:Q1 to 2012:Q4.

I find that capital expenditures growth in Compustat correlates well with aggregate capital expenditures growth from the Flow of Funds table for corporations (F.102). The two series show similar averages and standard deviations of their annual trailing growth rates. The Compustat series in the graph was seasonally adjusted using the Census X12 procedure.

The same Flow of Funds table for corporations (F.102) reports a measure of financial dependence of the whole corporate sector on transfer of resources from other actors in the economy (e.g., households) defined as the financing gap. This variable is computed as the difference between internal funds generated by business operations in the United States for the aggregate of firms, U.S. Internal Funds_t, U.S. internal funds in a given quarter t are computed as corporate profits net of taxes, dividend payments and capital depreciation:

$$\text{U.S. Internal Funds}_t = \text{Profits}_t - \text{Tax}_t - \text{Dividends}_t + \text{K Depreciation}_t$$

and total investment (or expenditure) on fixed capital, $CAPX_t$:

$$\text{Financing Gap}_t = FG_t = \text{U.S. Internal Funds}_t - CAPX_t. \tag{A.1}$$

In a given quarter FG_t is positive when the aggregate of U.S. corporations generate cash flows from their business operations large enough to cover their capital expenditures and lend resources to the rest of the economy. On the other hand, in a quarter when FG_t is negative, the firms draw resources from the rest of the economy to finance a fraction of their capital expenditures. This aggregate measure, however, is not informative of the degree of dependence of single corporations on financial markets. Firms in deficit are aggregated with firms in surplus and positive values for the aggregate financing gap can coexist with corporations with large deficits at the micro-level. In Flow of Funds data from 1952 to 2012, the average share of the financing gap out of total capital expenditures for U.S. corporations amounts to +8%, showing that the corporate sector has on average been a net supplier of savings to the rest of the economy.

B Mapping Compustat's Financing Gap into the Model

I interpret the aggregate of entrepreneurs in the model as the universe of corporations in Compustat and derive the equivalent of the financing gap share series, FGS_t, from their flow of funds constraints. Entrepreneurs earn operating cash flows from their capital stock and use them to finance new capital expenditures. They also access financial markets to either raise external financing or to liquidate part of their assets. Starting from the accounting cash flow identity (2) in section 1, I can map its components to the flow of funds constraint of an entrepreneur that is willing to buy and install new capital goods in my model in section 2:

$$\underbrace{PC_{e,t}}_{DIV_{e,t}}+\underbrace{P_t^K i_{e,t}}_{CAPX_{e,t}}-\left[\underbrace{Q_t^A\phi\left(1-\delta\right)N_{e,t-1}}_{NFI_{e,t}}+\underbrace{\left(R_{t-1}^B B_{e,t-1}-B_{e,t}\right)}_{\Delta CASH_{e,t}}\right]-\underbrace{\theta Q_t^A A_{e,t} i_{e,t}}_{\left(CF_{e,t}^D+CF_{e,t}^{EO}\right)}=\underbrace{R_t^K N_{e,t-1}}_{CF_{e,t}^O} \tag{B.1}$$

The returns on the equity holdings, $R_t^K N_{e,t-1}$, correspond to the operating cash flows, $CF_{e,t}^O$. Entrepreneur's nominal consumption, $P_t\mathrm{C}_{e,t}$, can be identified with dividends paid to equity holders, $DIV_{e,t}$, and the purchase of new capital goods, $P_t^K i_{e,t}$, with capital expenditures, $CAPX_{e,t}$. Net financial operations in Compustat, $NFI_{e,t}$, are mapped into net sales of old equity claims, $Q_t^A\phi\left(1-\delta\right)N_{e,t-1}$, while variations in the amount of liquidity, $\Delta\mathrm{CASH}_{e,t}$, correspond in the model to net acquisitions of government bonds, $\left(R_{t-1}^B B_{t-1}-B_t\right)$. Finally transfers from debt and equity holders, $\mathrm{CF}_{e,t}^D+\mathrm{CF}_{e,t}^{EO}$, correspond to issuances of equity claims on the new capital goods installed, $\theta Q_t^A A_{e,t} i_{e,t}$.

From (B.1), it is easy to derive the model equivalent of the financing gap share defined in (4). Entrepreneurs with the best technology to install capital goods (sellers) are willing to borrow resources and to utilize their liquid assets to carry on their investment. The aggregate Financing Gap over the $\chi_{s,t}$ measure of sellers, $S=\left[\frac{P_t^K}{Q_t^A},A_t^{high}\right]$, can be written as:

$$\begin{aligned}
FG_t &= \int_S\left[\underbrace{R_t^K N_{s,t-1}}_{CF_{s,t}^O}-\underbrace{PC_{s,t}}_{DIV_{s,t}}-\underbrace{P_t^K i_{s,t}}_{CAPX_{s,t}}\right]f(A_{s,t})ds\\
&= \int_S\left[\underbrace{Q_t^A\phi\left(1-\delta\right)N_{s,t-1}}_{NFI_{s,t}}+\underbrace{\left(R_{t-1}^B B_{s,t-1}-B_{s,t}\right)}_{\Delta CASH_{s,t}}-\underbrace{\theta Q_t^A A_{s,t} i_{s,t}}_{\left(CF_{s,t}^D+CF_{s,t}^{EO}\right)}\right]f(A_{s,t})ds\\
&= Q_t^A\left(\phi\left(1-\delta\right)\chi_{s,t}N_{t-1}+\int_S\theta A_{s,t} i_{s,t} f(A_{s,t})ds\right)+R_{t-1}^B\chi_{s,t}B_{s,t-1}.
\end{aligned}$$

so that the financing gap share is equal to the ratio of the market value of the resources raised by external finance, $Q_t^A\theta A_{s,t} i_{e,t}$, those raised by liquidation of selling illiquid securities, $Q_t^A\phi\left(1-\delta\right)\chi_{s,t}N_{t-1}$, and from the liquid assets that come to maturity, $R_{t-1}^B\chi_{s,t}B_{t-1}$, over aggregate investment, I_t in each quarter:

$$FGS_t = \frac{Q_t^A \left(\phi\left(1-\delta\right)\chi_{s,t}N_t + \int_S \theta A_{s,t} i_{s,t} f(A_{s,t})ds\right) + R_{t-1}^B \chi_{s,t} B_t}{I_t}.$$

. Following the definitions introduced in section 1, I compute the model equivalent for the Liquidation Share, $LIQS_t$, as the fraction of sellers' financing gap, FG_t, that is funded by the liquidation of financial claims and liquid assets:

$$LIQS_t = \frac{Q_t^A \left(\phi\left(1-\delta\right)\chi_{s,t}N_t\right) + R_{t-1}^B \chi_{s,t} B_{s,t-1}}{FG_t}. \tag{B.2}$$

and the Cash Share as the fraction of sellers' financing gap funded by the return on liquid assets:

$$CASHS_t = \frac{R_{t-1}^B \chi_{s,t} B_{s,t-1}}{FG_t}. \tag{B.3}$$

C Financial Intermediation and Liquidity Shocks

This section provides a comparison of the effects of *financial intermediation* shocks and *liquidity* shocks à la KM on asset prices under different model assumptions.

Following KM original contribution, I define a liquidity shock in the model as an exogenous change in the share of resalable assets in the economy, ϕ. In particular, I assume that $\phi = \phi_t$ follows an AR(1):

$$\phi_t = (1 - \rho_\phi)\phi + \rho_\phi \phi_{t-1} + \varepsilon_t^\phi,$$

with $\varepsilon_t^\phi \sim \text{N}(0, \sigma_\phi^2)$, i.i.d.

Below I compare impulse responses of the economy to financial intermediation shocks and to liquidity shocks with and without nominal rigidities and for different degrees of inertia in the central bank's nominal interest rate rule.

C.1 Nominal Rigidities and The Dynamics of Asset Prices

As noted by Shi (2011), under plausible calibrations of the KM model, a negative liquidity shocks generates a recession while on financial markets the contraction in asset supply pushes up the price of financial claims.[39] In contrast, Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) emphasize that liquidity shocks can produce positive co-movement between output and asset prices in a calibrated variation of the original KM model when the economy features a certain degree of nominal rigidities and when the nominal interest rate in the economy is at the zero lower bound.

Figures 17 and 18 compare the impulse responses of the model to a negative liquidity shock and financial intermediation respectively, under different model parameterizations. The impulse responses are computed at the posterior mode of the model (black solid lines), under the assumption that prices and wages are nearly flexible to replicate an economy similar to KM and Shi (2011) ($\xi_p = \xi_w = 0.01$, magenta dotted line) and finally under the assumption of (nearly) flexible prices and wages and lower persistence of the shock ($\xi_p = \xi_w = 0.01$ and $\rho_\tau = \rho_\phi = 0.5$ compared to 0.96 in the baseline).[40]

The magenta lines in figure 17 confirm that a negative liquidity shock in a model without nominal rigidities is accompanied by a marked and prolonged drop in the real interest rate. Both the real purchase and resale prices of equity claims, q_t^B and q_t^A, rise to maintain the no-arbitrage equilibrium on equity and bond markets. The countercyclical responses of asset prices are more pronounced when the liquidity shock is less persistent.[41]

[39] Nezafat and Slavik (2013) show how shocks to the share of pledgeable units of capital θ in a model similar to KM also generate countercyclical asset price movements.

[40] All impulse responses are normalized so that the drop in aggregate GDP on impact is of the same magnitude as under the estimated baseline financial intermediation shock (figure 18, panel 1). The persistence of the baseline liquidity shock is set equal to that of the estimated financial intermediation shock, $\rho_\phi = \rho_\tau = 0.96$.

[41] If liquidity shocks are highly persistent, then the household considers equity claims to be more risky: they cannot be sold easily for longer periods of time once a negative liquidity shock hits. The demand for illiquid assets drops more

In contrast, in the presence of nominal rigidities and inertial nominal interest rates, liquidity shocks induce equity prices to drop on impact. As described in section 4.5.1, nominal rigidities and inertial nominal rates prevent the real rate to drop on impact after the shock hits. The black solid lines in figure 17 show that real rate rises on impact, while buyers' real purchase price of financial claims from intermediaries, q_t^B, drops to equate the expected returns on equity claims and bonds. The downward pressure on q_t^B translates one-to-one on the resale price of equity q_t^A, by means of the zero-profit conditions of the banking sector.

Figure 18, instead, shows the impulse responses of the model after a financial intermediation shock. Financial intermediation shocks captures an increase in intermediation costs in the banking sectors that drives down the resale price of equity, q_t^A, raising the borrowing costs of entrepreneurs, with negative effects on capital accumulation. The third panel in figure 18 reveals that a negative financial intermediation shock robustly generates a drop in the real resale price of equity claims, q_t^A, in models with and without nominal rigidities and a lower degree of persistence of the shock.

The evidence in this section corroborates the findings of the literature that point at a shortcoming of the original KM formulation of liquidity shocks as producing countercyclical asset price movements in models with flexible prices and wages. Financial intermediation shocks can instead deliver procyclical predictions for asset price dynamics that are robust to the absence of nominal rigidities.

In such models, the policy rule plays an important role on the dynamic adjustment of the economy. The next section explores this in more detail.

C.2 Monetary Policy Inertia and The Dynamics of Asset Prices

In this section, I offer a discussion on the role of nominal interest rate inertia in the transmission of liquidity and financial intermediation shocks in my New Keynesian model with nominal rigidities. Figures 19 and 20 compare the impulse responses of the model to a negative liquidity shock and financial intermediation shock, respectively. Each plot shows impulse responses of GDP, consumption, the real interest rate, and the real resale prices of equity, q_t^A, computed at the posterior mode (black solid lines), under a degree of interest rate inertia that is half of the one estimated in the baseline, $\rho_i = 0.43$ (magenta dotted lines) and under the extreme assumption of no interest rate smoothing, $\rho_i = 0$, (blue dashed lines).[42]

Figure 19 shows that the ability of liquidity shocks to produce a procyclical response of asset prices depends on the degree of inertia of the central bank's interest rate rule. In contrast fig-

after more persistent liquidity shocks. The drop in demand offsets the reduction in the supply of traded assets at first and delivers an initial drop in the resale price of equity, q_t^A. Nonetheless, after a short-lived reduction in the price of equity, the supply effect dominates and translates in a marked increase of the resale price of equity.

[42] All impulse responses are normalized so that the drop in aggregate GDP on impact is of the same magnitude as under the estimated baseline financial intermediation shock (figure 20, panel 1) The persistence of the baseline liquidity shock is set equal to that of the estimated financial intermediation shock, $\rho_\phi = \rho_\tau = 0.96$.

ure 20 shows that the positive co-movement between asset prices and GDP induced by financial intermediation shocks is robust to changes in the nominal interest rate inertia parameter.

Under the estimated degree of inertia for the nominal interest rate $\rho_i = 0.86$, both liquidity shocks and financial intermediation shocks deliver positive comovement of asset prices and output in the baseline model. Financial intermediation shocks however generate more volatile responses in asset prices than liquidity shocks for a given change in output. If the Taylor rule features a high degree of interest rate inertia and prices and wages are sticky, after a shock hits, agents expect the real interest rate to rise on impact and adjust downward slowly. In the case of liquidity shocks, the rise in the real interest rate commands a drop of -0.8% in the real price of financial claims, q_t^A, to equate the expected return on equity to the real interest rate in a non-arbitrage equilibrium. After the initial drop, equity prices rise above their steady state level in around 7 quarters and stay persistently above it. In the case of financial intermediation shocks the resale price of equity, q_t^A, drops more, by -2% on impact in the baseline model. After the initial drop, equity prices stay persistently below their steady state level.[43]

When I reduce the interest rate inertia parameter to half its estimated value, $\rho_i = 0.43$ (magenta dotted lines), and then to zero (dashed blue lines), negative liquidity shocks generate a recession in which asset prices drop initially but quickly reverse and stay above their steady-state level. Figure 19 shows that this reversal is faster and more pronounced than in the baseline model (solid black lines), weakening the positive co-movement between asset prices and GDP. In contrast the impulse responses to a negative financial intermediation shocks in figure 20 show patterns that are in line with those in the baseline model, with a strong positive correlation between asset prices and GDP.

It is important to note that changes in the degree of Taylor rule inertia do not have as stark as an effect on the cyclical properties of consumption in the model, while the presence or the absence of nominal rigidities do (see section 4.5.1): the impulse responses in figures 19 and 20 suggest that a lower degree of inertia of the interest rate rule does not change the procyclical behavior of consumption in response to both liquidity and financial intermediation shocks.

In conclusion, the degree of inertia of the central bank's interest rate rule proves crucial in generating a strong positive co-movement between output and asset prices in response to liquidity shocks in a model with nominal rigidities. In contrast, financial intermediation shocks deliver a robust positive co-movement between asset prices and output, regardless of the degree of inertia of the Taylor rule.

C.3 Model Fit and Stock Market Growth

My model with financial intermediation shocks is estimated by fitting data on credit spreads for corporate bonds of BBB rating. I discussed the properties of the estimated model in fitting the

[43] The purchase price of equity claims, q_t^B, (not shown) also drops persistently below its steady state value. The purchase price, q_t^B, is however less volatile than the resale value q_t^A and its initial drop amounts to -1.2%.

observable corporate spread series in section 4.1. It is interesting, as a source of external validation of the model fit and in light of the procyclical responses of asset prices to financial intermediation shocks, to check how the estimated model performs in replicating the dynamics of stock market prices in the United States.

Table 9 compares first and selected second moments of per-capita real stock market growth in the data (per-capita SP 500 index normalized by the GDP deflator) and its model equivalent:[44]

$$SMG_t = \frac{\frac{Q_t^A N_t}{P_t}}{\frac{Q_{t-1}^A N_{t-1}}{P_{t-1}}} = \frac{q_t^A N_t}{q_{t-1}^A N_{t-1}}$$

The average historical realized returns on lower-medium grade corporate bonds (on which the model is estimated) are not as sizable as realized average equity returns and bond prices are not as volatile as equity prices in the data. Row 1 in table 9 shows that the average growth rate of the stock market in the data is higher than the one estimated in the model.[45] Moreover, row 2 highlights that the stock market growth data series features a higher standard deviation than its theoretical counterpart in the model computed at the posterior mode (4.7% vs. 0.72%). Consistently the standard deviation of the data series is also higher than the standard deviation of the smoothed stock market growth series computed at the posterior mode (4.7% vs. 0.62%).

Interestingly, however, stock market growth in the data and in the model show similar autocorrelation of order one (0.81 in the data, compared to a theoretical moment of 0.73 and a realized moment for the smoothed series of 0.77). Notably, in light of the discussion in section C.2, stock market growth correlates highly with GDP growth in the data (coefficient of 0.64) and in the model (theoretical estimate of 0.70 and smoothed estimate of .75). Most importantly, the stock market growth data series is positively correlated with its smoothed model equivalent with a correlation coefficient equal to 0.55.

[44]The reference price used to compute the market value in the model is q_t^A: the resale price of equity shares, also defined as the highest price that competitive intermediaries are willing to spend to acquire one unit of financial claims from sellers. Moments computed using the household purchase price q_t^B do not differ significantly from those reported in table 9 and an available upon request.

[45]In the model the average growth rate of stock market growth coincides with the average growth rate of the economy γ.

D Model Equilibrium Conditions

Intermediate Firms

The production function for a generic intermediate firm i takes the form:

$$Y_t(i) = A_t^{1-\alpha} K_{t-1}(i)^{\alpha} L_t(i)^{1-\alpha} - A_t F\,,$$

where:

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

and $\varepsilon_t^z \sim N(0, \sigma_z)$. Firms minimize total costs by solving:

$$\min_{K_{t-1}(i), L_t(i)} W_t L_t(i) + R_t^K K_{t-1}(i)$$

subject to (D). The first order conditions are:

$$MC_t(i) A_t^{1-\alpha} \left(\frac{L_t(i)}{K_{t-1}(i)}\right)^{-\alpha} = \frac{W_t}{P_t}$$

$$MC_t(i) A_t^{1-\alpha} \left(\frac{L_t(i)}{K_{t-1}(i)}\right)^{1-\alpha} = \frac{R_t^k}{P_t}\,,$$

where $MC_t(i)$ is the marginal cost for firm i. Taking the ratio of the two expressions above I obtain:

$$\frac{K_{t-1}(i)}{L_t(i)} = \frac{K_{t-1}}{L_t} = \frac{W_t}{R_t^k}\frac{\alpha}{(1-\alpha)}\,, \tag{D.2}$$

which pins down a common value for the marginal cost across different firms:

$$MC_t = \frac{1}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} R_t^{K\alpha} \left(\frac{W_t}{A_t}\right)^{1-\alpha}\,. \tag{D.3}$$

Firms' profits at time t are defined as the difference between revenues and total costs incurred producing output $Y_t(i)$. Those monopolistic intermediate firms that can re-optimize their price at time t maximize their future expected profits:

$$\max_{P_t(i)} E_t \left\{ \sum_{s=0}^{\infty} \xi_p^s \frac{\beta^s \mu_{t+s}^{\Sigma C}}{\mu_{t+s}^{\Sigma C}} \left[\left(P_t(i) \prod_{k=1}^{s} (\pi_{t+k-1}^{\iota_p} \pi^{1-\iota_p}) - MC_{t+s} \right) Y_{t+s}(i) \right] \right\}$$

subject to the demand for intermediate inputs from final producers:

$$Y_{t+s}(i) = \left(\frac{P_t(i) \prod_{k=1}^{s} (\pi_{t+k-1}^{\iota_p} \pi^{1-\iota_p})}{P_{t+s}} \right)^{\left(-\frac{1+\lambda_{p,t+s}}{\lambda_{p,t+s}}\right)} Y_{t+s}$$

where marginal costs MC_t in (D.3) are equal to average costs given the structure of the production function in (D) and:

$$\log\left(1+\lambda_{p,t}\right)=\left(1-\rho_p\right)\log\left(1+\lambda_p\right)+\rho_p\log\left(1+\lambda_{p,t-1}\right)+\varepsilon_t^p+\theta_p\varepsilon_{t-1}^p \tag{D.4}$$

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

Profits are discounted at the marginal rate of intertemporal substitution of the household, $\left(\beta^s b_{t+s}\frac{\mu_{t+s}^{\Sigma C}}{\mu_{t+s}^{\Sigma C}}\right)$, the shareholder of intermediate firms. The maximization is subject to the demand for intermediate product i, coming from final good producers. The optimality condition is then:

$$E_t\left\{\sum_{s=0}^{\infty}\xi_p^s\beta^s b_{t+s}\mu_{t+s}^{\Sigma C}\tilde{Y}_{t+s}\left[\tilde{P}_t\prod_{k=1}^{s}(\pi_{t+k-1}^{\iota_p}\pi^{1-\iota_p})-(1+\lambda_{p,t+s})MC_{t+s}\right]\right\}=0\,, \tag{D.5}$$

where $\tilde{P}$ is the optimal price chosen and $\tilde{Y}=Y_{t+s}(i)$ is the corresponding optimal demand. Note that the optimal price depends on present and future marginal costs and mark-ups, MC_{t+s} and $\lambda_{p,t+s}$ and is therefore common to all re-optimizing firms. Aggregate prices at time t will be a combination of prevalent aggregate prices at time $t-1$, P_{t-1}, and the new optimal prices, $\tilde{P}_t$:

$$P_t=\left[(1-\xi_p)\tilde{P}_t^{\frac{1}{\lambda_{p,t}}}+\xi_p(\pi_{t-1}^{\iota_p}\pi^{1-\iota_p}P_{t-1})^{\frac{1}{\lambda_{p,t}}}\right]^{\lambda_{p,t}}\,. \tag{D.6}$$

Capital Producers

Capital good producers operate in regime of perfect competition and on a national market. Producers purchase consumption goods from the final goods market, Y_t^I at a price P_t , transform them into investment goods, I_t, by means of a linear technology:

$$I_t=Y_t^I.$$

Producers then have access to a capital production technology to produce i_t units of capital goods for an amount I_t of investment goods:

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

where $S\left(\cdot\right)$ is a convex function in $\frac{I_t}{I_{t-1}}$, with $S=0$ and $S'=0$ and $S''>0$ in steady state. Producers sell capital goods to the entrepreneurs on a competitive market at a price P_t^K.

In every period capital producers will choose the optimal amount of inputs, I_t as to maximize their expected discounted profits:

$$\max_{I_{t+s}}E_t\sum_{s=0}^{\infty}\beta^s b_{t+s}E_{t+s}\left\{\mu_{t+s}^{\Sigma C}\left[P_{t+s}^K i_{t+s}-P_{t+s}I_{t+s}\right]\right\}$$

s.t.

$$i_{t+s} = \left[1 - S\left(\frac{I_{t+s}}{I_{t+s-1}}\right)\right] I_{t+s}. \tag{D.7}$$

The first order condition for a generic time t will then be:

$$\frac{P_t^K}{P_t}\left[\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) - \frac{I_t}{I_{t-1}}S'\left(\frac{I_t}{I_{t-1}}\right)\right] - 1 = E_t\left\{(\beta b_t)\frac{\mu_{t+1}^{\Sigma C}}{\mu_t^{\Sigma C}}\frac{P_{t+1}}{P_t}\left[\frac{P_{t+1}^K}{P_{t+1}}\left(\frac{I_{t+1}^2}{I_t^2}\right)S'\left(\frac{I_{t+1}}{I_t}\right)\right]\right\}. \tag{D.8}$$

Household

The head of the household maximizes the aggregate lifetime utility of the household:

$$\max_{\substack{C_{t+s},\,\iota_{t+s},\,\Delta N_{t+s}^{+},\,\Delta N_{t+s}^{-},\,N_{t+s},\,B_{t+s},\\ C_{i,t+s},\,W_{i,t+s},\,\iota_{i,t+s},\,\Delta N_{i,t+s}^{+},\,\Delta N_{i,t+s}^{-},\,N_{i,t+s},\,B_{i,t+s}}} \sum_{s=0}^{\infty}(\beta)^{t+s}b_{t+s}E_t\left[log(C_{t+s} - hC_{t+s-1}) - \chi_0\chi_{b,t}\frac{L_{t+s}^{(1+\nu)}}{(1+\nu)}\right]$$

subject to the individual flow of funds constraints (7), the individual equity accumulation equation (8), the individual borrowing constraint (12) the aggregate equity accumulation equation (11) together with the definition of aggregate consumption and aggregate bond holdings (10) and non-negativity constraints (2.1). The discount factor is subject to random shocks and follows a process:

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b \tag{D.9}$$

where $\varepsilon_t^b \sim$ i.i.d. $\mathrm{N}(0, \sigma_b^2)$. Nominal transfers of profits of intermediate firms and banking costs are lumped into D_t defined as:

$$P_tD_t = \left(P_tY_t - R_t^KK_{t-1} - W_tL_t\right) + \left(P_t^K\left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right)I_t - I_t\right) + \left(Q_t^B - Q_t^A\right)\Delta N_t \tag{D.10}$$

The first order conditions of the maximization problems are:

$$
\begin{aligned}
&C_t : \frac{1}{(C_t - hC_{t-1})} - \beta b_t h E_t \left[\frac{1}{(C_{t+1} - hC_t)} \right] = \mu_t^{\Sigma C} \\
&N_t : \mu_t^N = \beta b_t E_t \left\{ E_{A_{i,t+1}} \left[\lambda_{i,t+1}(1-\tau_k) R_{t+1}^K + (1-\phi_{t+1}) \mu_{i,t+1}^N (1-\delta) + \phi_{t+1}(\mu_{i,t+1}^N + \mu_{i,t+1}^L)(1-\delta) \right] \right\} \\
&B_t : \mu_t^{\Sigma B} = \beta b_t E_t \left\{ E_{A_{i,t+1}} \left[\lambda_{i,t+1} R_t^B \right] \right\} \\
&C_{i,t} : \lambda_{i,t} P_t = \mu_t^{\Sigma C} + \mu_{i,t}^{C+} \\
&\iota_{i,t} : \lambda_{i,t} P_t^K = \mu_{i,t}^N A_{i,t} + \mu_t^L \theta A_{i,t} + \mu_{i,t}^{\iota+} \\
&\Delta N_{i,t}^+ : \lambda_{i,t} Q_t^B = \mu_{i,t}^N + \mu_{i,t}^{\Delta++} \\
&\Delta N_{i,t}^- : \lambda_{i,t} Q_t^A = \mu_{i,t}^N + \mu_{i,t}^L - \mu_{i,t}^{\Delta-+} \\
&N_{i,t} : \mu_{i,t}^N = \mu_t^N \\
&B_{i,t} : \lambda_{i,t} - \mu_{i,t}^{B+} = \mu_t^{\Sigma B}
\end{aligned}
$$

together with constraints holding with equality (7), (8), (11), (10) and complementary slackness conditions:

$$
\begin{aligned}
&\mu_{i,t}^{C+} C_{i,t} = 0 \\
&\mu_{i,t}^{\iota+} \iota_{i,t} = 0 \\
&\mu_{i,t}^{\Delta++} \Delta N_{i,t}^+ = 0 \\
&\mu_{i,t}^{\Delta-+} \Delta N_{i,t}^- = 0 \\
&\mu_{i,t}^L(-\Delta N_{s,t}^- + \theta A_{s,t} \iota_{s,t} + \phi \left(1-\delta\right) N_{t-1}) \\
&\mu_{i,t}^{B+} B_{i,t} = 0
\end{aligned}
$$

Conditional on their draw of the level of capital installation technology $A_{i,t}$ household members are optimally sorted into three categories: buyers, keepers and sellers. If $Q_t^B > Q_t^A$ their optimal contingencies plans are as follows:

Buyers receive instructions to set aside their relatively inefficient capital accumulation technology, not purchase capital goods $\iota_{b,t}$ and instead use their income to purchase consumption goods $C_{b,t}$, equity claims $\Delta N_{b,t}^{+}$ and liquid assets $B_{b,t} > 0$:

$$
\begin{aligned}
&C_{b,t} > 0,\ \mu_{b,t}^{C+} = 0 \\
&\iota_{b,t} = 0,\ \mu_{i,t}^{\iota+} > 0 \\
&\Delta N_{b,t}^{+} > 0,\ \mu_{b,t}^{\Delta++} = 0 \\
&\Delta N_{b,t}^{-} = 0,\ \mu_{b,t}^{\Delta-+} > 0 \\
&\Delta N_{b,t}^{-} < \theta A_{b,t}\iota_{b,t} + \phi\left(1-\delta\right)N_{t-1},\ \mu_{b,t}^{L} = 0 \\
&B_{b,t} > 0,\ \mu_{b,t}^{B+} > 0
\end{aligned}
$$

Keepers receive instructions to use their capital accumulation technology and use their income to purchase capital goods $\iota_{k,t}$, while forgoing purchase of consumption goods $C_{k,t} = 0$, equity claims $\Delta N_{k,t}^{+} = 0$ and liquid assets $B_{k,t} = 0$:

$$
\begin{aligned}
&C_{k,t} = 0,\ \mu_{k,t}^{C+} > 0 \\
&\iota_{k,t} > 0,\ \mu_{k,t}^{\iota+} = 0 \\
&\Delta N_{k,t}^{+} = 0,\ \mu_{k,t}^{\Delta++} > 0 \\
&\Delta N_{k,t}^{-} = 0,\ \mu_{k,t}^{\Delta-+} > 0 \\
&\Delta N_{k,t}^{-} < \theta A_{k,t}\iota_{k,t} + \phi\left(1-\delta\right)N_{t-1},\ \mu_{k,t}^{L} = 0 \\
&B_{k,t} = 0,\ \mu_{k,t}^{B+} > 0
\end{aligned}
$$

Sellers receive instructions to use their efficient capital accumulation technology and use their income and resources raised by selling equity on financial markets, $\Delta N_{s,t}^{-} > 0$, to purchase capital goods $\iota_{s,t}$, while forgoing purchase of consumption goods $C_{s,t} = 0$, equity claims $\Delta N_{s,t}^{+} = 0$ and liquid assets $B_{s,t} = 0$:

$$
\begin{aligned}
&C_{s,t} = 0,\ \mu_{s,t}^{C+} > 0 \\
&\iota_{s,t} > 0,\ \mu_{s,t}^{\iota+} = 0 \\
&\Delta N_{s,t}^{+} = 0,\ \mu_{s,t}^{\Delta++} > 0 \\
&\Delta N_{s,t}^{-} > 0,\ \mu_{s,t}^{\Delta-+} = 0 \\
&\Delta N_{s,t}^{-} = \theta A_{s,t}\iota_{s,t} + \phi\left(1-\delta\right)N_{t-1},\ \mu_{s,t}^{L} > 0 \\
&B_{k,t} = 0,\ \mu_{k,t}^{B+} > 0
\end{aligned}
$$

To verify that this is an equilibrium, I check that the first order conditions of the maximization problems hold once I substitute in the guessed solution for buyers, keepers and sellers.

Sellers:

$$
\begin{aligned}
&C_{s,t} : \lambda_{s,t} P_t = \mu_t^{\Sigma C} + \mu_{s,t}^{C+} \\
&\iota_{s,t} : \frac{\frac{p_t^K}{A_{s,t}} - \theta q_t^A}{1-\theta} = \frac{\mu_{s,t}^N}{P_t \lambda_{s,t}} = \tilde{q}_t^A \\
&\Delta N_{s,t}^+ : q_t^B = \frac{\mu_{s,t}^N}{P_t \lambda_{s,t}} + \frac{\mu_{s,t}^{\Delta++}}{P_t \lambda_{s,t}} \\
&\Delta N_{s,t}^- : q_t^A = \frac{\mu_{s,t}^N}{P_t \lambda_{s,t}} + \frac{\mu_{s,t}^L}{P_t \lambda_{k,t}} \\
&N_{s,t} : \mu_{s,t}^N = \mu_t^N \\
&B_{s,t} : \lambda_{s,t} - \mu_{s,t}^{B+} = \mu_t^{\Sigma B}
\end{aligned}
$$

Since $q_t^B > q_t^A > \frac{p_t^K}{A_{s,t}}$ then $\mu_{s,t}^{\iota+} = 0$, $\mu_{s,t}^{\Delta++} > 0$, $\mu_{s,t}^{\Delta-+} = 0$, $\mu_{s,t}^L = 0$, confirming the initial guess that sellers indeed sell equity claims up to their borrowing constraint to purchases capital goods $\iota_{s,t} > 0$ but they do not purchase equity claims, $\Delta N_{b,t}^+ = 0$.

Keepers:

$$
\begin{aligned}
&C_{k,t} : \lambda_{k,t} P_t = \mu_t^{\Sigma C} + \mu_{k,t}^{C+} \\
&\iota_{i,t} : \frac{p_t^K}{A_{k,t}} = \frac{\mu_{k,t}^N}{P_t \lambda_{k,t}} \\
&\Delta N_{k,t}^+ : q_t^B = \frac{\mu_{k,t}^N}{P_t \lambda_{k,t}} + \frac{\mu_{k,t}^{\Delta++}}{P_t \lambda_{k,t}} \\
&\Delta N_{k,t}^- : q_t^A = \frac{\mu_{k,t}^N}{P_t \lambda_{k,t}} - \frac{\mu_{k,t}^{\Delta-+}}{P_t \lambda_{k,t}} \\
&N_{k,t} : \mu_{k,t}^N = \mu_t^N \\
&B_{k,t} : \lambda_{k,t} - \mu_{k,t}^{B+} = \mu_t^{\Sigma B}
\end{aligned}
$$

Since $q_t^B > \frac{p_t^K}{A_{k,t}} > q_t^A$ then $\mu_{k,t}^{\iota+} = 0$, $\mu_{k,t}^{\Delta++} > 0$ and $\mu_{k,t}^{\Delta-+} > 0$, confirming the initial guess. Buyers purchases capital goods $\iota_{k,t} > 0$ but they do not purchase nor sell equity claims, $\Delta N_{b,t}^+ = 0$ $\Delta N_{b,t}^- = 0$.

Buyers:

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

$$\iota_{b,t} : \frac{p_t^K}{A_{b,t}} - q_t^B = \frac{\mu_{i,t}^{\iota+}}{\mu_t^{\Sigma C}} > 0$$

$$\Delta N_{b,t}^{+} : q_t^B = \frac{\mu_{b,t}^N}{\mu_t^{\Sigma C}}$$

$$\Delta N_{b,t}^{-} : q_t^B - q_t^A = \frac{\mu_{b,t}^{\Delta-+}}{\mu_t^{\Sigma C}} > 0$$

$$N_{b,t} : \frac{\mu_{b,t}^N}{\mu_t^{\Sigma C}} = \frac{\mu_t^N}{\mu_t^{\Sigma C}} = q_t^B$$

$$B_{b,t} : \lambda_{b,t} = \mu_t^{\Sigma B}$$

Since $\frac{p_t^K}{A_{b,t}} > q_t^B > q_t^A$ then $\mu_{b,t}^{\iota+} > 0$ and $\mu_{b,t}^{\Delta-+} > 0$, confirming the initial guess. Buyers do not purchases capital goods $\iota_{b,t} = 0$ nor they sell equity claims, $\Delta N_{b,t}^{-} = 0$.

Dividing the first order conditions with respect to $\iota_{s,t}$ by the first order condition with respect to $\iota_{b,t}$, I obtain:

$$\frac{\lambda_{s,t}}{\lambda_{b,t}} = \frac{\lambda_{s,t}}{\mu_t^{\Sigma C}} = \frac{q_t^B}{\tilde{q}_{s,t}^A}$$

and similarly using the first order condition with respect to $\iota_{k,t}$ I obtain:

$$\frac{\lambda_{k,t}}{\lambda_{b,t}} = \frac{\lambda_{k,t}}{\mu_t^{\Sigma C}} = \frac{q_t^B}{\frac{p_t^K}{A_{k,t}}}$$

These equalities, combined with the first order conditions with respect to consumption and bond holdings for sellers and keepers, imply that:

$$\mu_{s,t}^{C+} = \mu_{s,t}^{B+} = \frac{q_t^B}{\tilde{q}_{s,t}^A} - 1 > 0$$

and

$$\mu_{k,t}^{C+} = \mu_{k,t}^{B+} = \frac{q_t^B}{\frac{p_t^K}{A_{k,t}}} - 1 > 0$$

confirming that in equilibrium sellers and keepers do not purchase consumption goods $C_{i,t}$, nor liquid assets $B_{i,t}$ for $i = \{s, k\}$.

To conclude, the solution implies the following optimal choices for sellers, keepers and buyers:

- Sellers

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

$$\Delta N^{-}_{s,t} = \theta A_{s,t} I_{s,t} + \phi \left(1-\delta\right) N_{t-1}$$

$$\Delta N^{+}_{s,t} = 0.$$

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 to solve for the optimal level of capital goods purchased by seller s:

$$\iota_{s,t} = \frac{1}{(P^K_t - Q^A_t \theta A_{s,t})}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t + Q^A_t \phi(1-\delta)N_{t-1}]$$

and for the seller's optimal equity stock:

$$N_{s,t} = \frac{1}{\tilde{Q}^A_{s,t}}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t + Q^A_t \phi(1-\delta)N_{t-1} + \tilde{Q}^A_{s,t}(1-\phi)(1-\delta)N_{t-1}].$$

where $\tilde{Q}^A_{s,t}$ is the replacement cost of one unit of internal capital:

$$\tilde{Q}^A_{s,t} = \frac{(P^K_t - Q^A_t \theta A_{s,t})}{1-\theta}$$

The fraction of sellers can be computed using the CDF of $A_{i,t}$:

$$\chi_s = Pr\left(A_{i,t} \geq \frac{Q^A_t}{P^K_t}\right) = 1 - F\left(\frac{Q^A_t}{P^K_t}\right)$$

- Keepers

$$C_{k,t} = 0, \quad B_{k,t} = 0.$$

$$\iota_{k,t} = \frac{1}{P^K_t}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t]$$

$$\Delta N^{-}_{k,t} = 0, \quad \Delta N^{+}_{k,t} = 0$$

$$N_{k,t} = \frac{A_{k,t}}{P^K_t}[(1-\tau_k)R^K_t N_{t-1} + R^B_{t-1}B_{t-1} + P_t D_t + P_t T_t + \frac{P^K_t}{A_{k,t}}(1-\delta)N_{t-1}].$$

The measure of keepers in the economy is:

$$\chi_{k,t} = \Pr\left(Q^A_t \leq \frac{P^K_t}{A_{e,t}} \leq Q^B_t\right) = F\left(\frac{Q^B_t}{P^K_t}\right) - F\left(\frac{Q^A_t}{P^K_t}\right)$$

- Buyers

Buyers' intertemporal Euler equations for equity and bond holdings coincide with those of the household in its entirety:

$$C_t : \frac{1}{(C_t - hC_{t-1})} - \beta b_t h E_t \left[\frac{1}{(C_{t+1} - hC_t)}\right] = \mu_t^{\Sigma C} = P_t \lambda_{b,t} \tag{D.11}$$

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

Substituting the values of the ratios $\frac{\lambda_{s,t}}{\lambda_{b,t}}$ and $\frac{\lambda_{s,t}}{\lambda_{b,t}}$ computed above, I obtain the Euler equation for equity holdings:

$$\begin{aligned}
N_t : Q_t^B = \ & \beta b_t E_t \left\{ \frac{\mu_{t+1}^{\Sigma C}}{\mu_t^{\Sigma C}} \times \right. \\
& \times \left[\chi_{s,t+1} E_{A_{i,t+1}} \left(\frac{Q_{t+1}^B}{\tilde{Q}_{i,t+1}^A} \left((1-\tau_k) R_{t+1}^K + (1-\phi_{t+1}) \tilde{Q}_{i,t+1}^A (1-\delta) + \phi_{t+1} Q_{t+1}^A (1-\delta) \right) \middle| \frac{P_t^K}{A_{i,t}} \leq Q_t^A \right) + \right. \\
& + \chi_{k,t+1} E_{A_{i,t+1}} \left(\frac{Q_{t+1}^B}{\frac{P_{t+1}^K}{A_{i,t+1}}} \left((1-\tau_k) R_{t+1}^K + \frac{P_{t+1}^K}{A_{i,t+1}} (1-\delta) \right) \middle| Q_{t+1}^A \leq \frac{P_{t+1}^K}{A_{i,t+1}} \leq Q_{t+1}^B \right) + \\
& \left. \left. + \ \chi_{b,t+1} E_{A_{i,t+1}} \left((1-\tau_k) R_{t+1}^K + Q_{t+1}^B (1-\delta) \middle| \frac{P_{t+1}^K}{A_{i,t+1}} \geq Q_{t+1}^B \right) \right] \right\}
\end{aligned} \tag{D.12}$$

where the payoff expectations across members are computed as:

$$\chi_{s,t+1}E_{A_{i,t+1}}\left[\frac{Q^B_{t+1}}{\tilde{Q}^A_{i,t+1}}\Big((1-\tau_k)R^K_{t+1}+(1-\phi_{t+1})\tilde{Q}^A_{i,t+1}(1-\delta)+\phi_{t+1}Q^A_{t+1}(1-\delta)\Big)\Bigg|\frac{P^K_t}{A_{i,t}}\leq Q^A_t\right]=$$
$$=Q^B_{t+1}\left[\frac{(1-\theta)}{2(\theta Q^A_t)^3}\left[2\log(\theta Q^A_t A_{s,t}-P^K_t)(\theta Q^A_t(aQ^A_t+bP^K_t)+cP^{K2}_t)+\theta Q^A_t A_{s,t}\times\right.\right.$$
$$\left.\left.\times\left(2b\theta Q^A_t+2cP^K_t+c\theta Q^A_t A_{s,t}\right)\right]\right]^{A^{high}}_{\frac{P^K_t}{Q^A_t}}\left((1-\tau_k)R^K_{t+1}+\phi_{t+1}Q^A_{t+1}(1-\delta)\right)+\chi_{s,t+1}(1-\phi_{t+1})(1-\delta)$$

$$\chi_{k,t+1}\left[\frac{Q^B_{t+1}}{\frac{P^K_{t+1}}{A_{i,t+1}}}\left((1-\tau_k)R^K_{t+1}+\frac{P^K_{t+1}}{A_{i,t+1}}(1-\delta)\right)\Bigg|Q^A_{t+1}\leq\frac{P^K_{t+1}}{A_{i,t+1}}\leq Q^B_{t+1}\right]=$$
$$=Q^B_{t+1}\left[\frac{A^2_{k,t}(6a+(4b+3cA_{k,t}))}{12P^K_t}\right]^{\frac{P^K_t}{Q^A_t}}_{\frac{P^K_t}{Q^B_t}}\left((1-\tau_k)R^K_{t+1}\right)+\chi_{k,t+1}(1-\delta)$$

$$\chi_{b,t+1}E_{A_{i,t+1}}\left((1-\tau_k)R^K_{t+1}+Q^B_{t+1}(1-\delta)\Bigg|\frac{P^K_{t+1}}{A_{i,t+1}}\geq Q^B_{t+1}\right)=$$
$$=\chi_{b,t+1}\left((1-\tau_k)R^K_{t+1}+Q^B_{t+1}(1-\delta)\right)$$

I can also write the Euler equation for bond holdings as:

$$\begin{aligned}B_t:1=\beta b_t E_t\Bigg\{&\frac{\mu^{\Sigma C}_{t+1}}{\mu^{\Sigma C}_t}\frac{1}{\pi_{t+1}}\times\left[\chi_{s,t+1}\;E_{A_{i,t+1}}\left(\frac{Q^B_{t+1}}{\tilde{Q}^A_{i,t+1}}\Bigg|\frac{P^K_t}{A_{i,t}}\leq Q^A_t\right)+\right.\\&+\chi_{k,t+1}E_{A_{i,t+1}}\left(\frac{Q^B_{t+1}}{\frac{P^K_{t+1}}{A_{i,t+1}}}\Bigg|Q^A_{t+1}\leq\frac{P^K_{t+1}}{A_{i,t+1}}\leq Q^B_{t+1}\right)+\\&\left.+\;\chi_{b,t+1}E_{A_{i,t+1}}\left(1\Bigg|\frac{P^K_{t+1}}{A_{i,t+1}}\geq Q^B_{t+1}\right)\right]R^B_t\Bigg\}\end{aligned}\tag{D.13}$$

where the payoff expectations across members are computed as:

$$\chi_{s,t+1}E_{A_{i,t+1}}\left(\frac{Q^B_{t+1}}{\tilde{Q}^A_{i,t+1}}\middle|\frac{P^K_t}{A_{i,t}}\leq Q^A_t\right)=$$
$$=Q^B_{t+1}\left[\frac{(1-\theta)}{2(\theta Q^A_t)^3}\left[2\log(\theta Q^A_t A_{s,t}-P^K_t)(\theta Q^A_t(aQ^A_t+bP^K_t)+cP^{K2}_t)+\theta Q^A_t A_{s,t}\times\right.\right.$$
$$\left.\left.\times\left(2b\theta Q^A_t+2cP^K_t+c\theta Q^A_t A_{s,t})\right]\right]^{A^{high}}_{\frac{P^K_t}{Q^A_t}}$$
$$\chi_{k,t+1}E_{A_{i,t+1}}\left(\frac{Q^B_{t+1}}{\frac{P^K_{t+1}}{A_{i,t+1}}}\middle|Q^A_{t+1}\leq\frac{P^K_{t+1}}{A_{i,t+1}}\leq Q^B_{t+1}\right)=$$
$$=Q^B_{t+1}\left[\frac{A^2_{k,t}(6a+(4b+3cA_{k,t}))}{12P^K_t}\right]^{\frac{P^K_t}{Q^A_t}}_{\frac{P^K_t}{Q^B_t}}$$
$$\chi_{b,t+1}E_{A_{i,t+1}}\left(1\middle|\frac{P^K_{t+1}}{A_{i,t+1}}\geq Q^B_{t+1}\right)=$$
$$=\chi_{b,t+1}.$$

With the optimal plans for each household member in hand, I can aggregate their decision rules to compute the household-level purchase of capital goods, ι_t as well as asset positions:

$$\iota_t=\int^{A^{high}}_{\frac{P^K_t}{Q^A_t}}\iota_{s,t}dF(A_{s,t})+\int^{\frac{P^K_t}{Q^B_t}}_{\frac{P^K_t}{Q^B_t}}\iota_{k,t}dF(A_{k,t})$$
$$=\int^{A^{high}}_{\frac{P_t}{Q^A_t}}\frac{1}{(P^K_t-Q^A_t\theta A_{s,t})}[(1-\tau_k)R^K_tN_{t-1}+R^B_{t-1}B_{t-1}+P_tD_t+P_tT_t+Q^A_t\phi(1-\delta)N_{t-1}]dF(A_{s,t})$$
$$+\int^{\frac{P^K_t}{Q^A_t}}_{\frac{P^K_t}{Q^B_t}}\frac{1}{P^K_t}[(1-\tau_k)R^K_tN_{t-1}+R^B_{t-1}B_{t-1}+P_tD_t+P_tT_t]dF(A_{k,t})$$
$$=\left[-\frac{1}{2(\theta Q^A_t)^3}\left(2\log(\theta Q^A_t A_{s,t}-P^K_t\right)\left(\theta Q^A_t(a\theta Q^A_t+bP^K_t)+cP^{K2}_t\right)+\theta Q^A_t A_{s,t}(2b\theta Q^A_t+\right.$$
$$\left.+2cP^K_t+c\theta Q^A_t A_{s,t})\right)\Big]^{A^{high}}_{\frac{P^K_t}{Q^A_t}}[(1-\tau_k)R^K_tN_{t-1}+R^B_{t-1}B_{t-1}+P_tD_t+P_tT_t+Q^A_t\phi(1-\delta)N_{t-1}]+$$
$$+\left[aA_{k,t}+b\frac{A^2_{k,t}}{2}+3\frac{A^3_{k,t}}{3}\right]^{\frac{P^K_t}{Q^A_t}}_{\frac{P^K_t}{Q^B_t}}\frac{1}{P^K_t}[(1-\tau_k)R^K_tN_{t-1}+R^B_{t-1}B_{t-1}+P_tD_t+P_tT_t]\tag{D.14}$$

$$N_t = \int_{\frac{P_t^K}{Q_t^A}}^{A^{high}} N_{s,t} dF(A_{s,t}) + \int_{\frac{P_t^K}{Q_t^B}}^{\frac{P_t^K}{Q_t^B}} N_{k,t} dF(A_{k,t})$$

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

$$+ \int_{\frac{P_t^K}{Q_t^B}}^{\frac{P_t^K}{Q_t^B}} \frac{A_{k,t}}{P_t^K}[(1-\tau_k)R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t + P_t T_t + \frac{P_t^K}{A_{k,t}}(1-\delta)N_{t-1}]dF(A_{k,t})$$

$$= \Bigg[\frac{(1-\theta)}{2(\theta Q_t^A)^3} \left[2\log(\theta Q_t^A A_{s,t} - P_t^K)(\theta Q_t^A(aQ_t^A + bP_t^K) + cP_t^{K2}) + \right.$$

$$\left. + \theta Q_t^A A_{s,t}(2b\theta Q_t^A + 2cP_t^K + c\theta Q_t^A A_{s,t}) \right] \Bigg]_{\frac{P_t^K}{Q_t^A}} [(1-\tau_k)R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t + P_t T_t + Q_t^A \phi(1-\delta)N_{t-1}]$$

$$+ \left[aA_{i,t} + b\frac{A_{i,t}^2}{2} + 3\frac{A_{i,t}^3}{3} \right]_{\frac{P_t^K}{Q_t^B}}^{A^{high}} (1-\phi)(1-\delta)N_{t-1} +$$

$$+ \left[\frac{A_{k,t}^2(6a + (4b + 3cA_{k,t}))}{12P_t^K} \right]_{\frac{P_t^K}{Q_t^B}}^{\frac{P_t^K}{Q_t^A}} [(1-\tau_k)R_t^K N_{t-1} + R_{t-1}^B B_{t-1} + P_t D_t + P_t T_t] \tag{D.15}$$

A_t^{high} and the parameter $a = a_t$ of the distribution adjust in every period so that the average productivity of investment technology in use is always equal to 1:

$$\int_{\frac{P_t^K}{Q_t^B}}^{A_t^{high}} A_{i,t} dF(A_{i,t}) = 1 \tag{D.16}$$

and that the cdf of $F(A_{i,t}) = 1$ for $A_{i,t} = A_t^{high}$:

$$F(A_t^{high}) = \int_{A^{low}}^{A_t^{high}} dF(A_{i,t}) = 1 \tag{D.17}$$

- Wage Setting Decision

The first order conditions of the households' wage setting decision is:

$$E_t \left\{ \sum_{s=0}^{\infty} {\xi_w}^s \beta^s \frac{\mu_{t+s}^{\Sigma C}}{P_{t+s}} \tilde{L}_{t+s} \left[\frac{\tilde{W}_{b,t}}{\chi_{b,t+s}} \Pi_{t,t+s}^w - (1 + \lambda_{w,t+s})\omega \frac{\tilde{L}_{t+s}^{\nu}}{\mu_{t+s}^{\Sigma C}} \right] \right\} = 0 \tag{D.18}$$

where:

$$\Pi_{t,t+s}^w = \prod_{k=1}^{s} \left[(\pi e^{\gamma})^{1-\iota_w} (\pi_{t+k-1} e^{z_{t+k-1}})^{\iota_w} \right]$$

and:

$$\log\left(1+\lambda_{w,t}\right)=\left(1-\rho_w\right)\log\left(1+\lambda_w\right)+\rho_w\log\left(1+\lambda_{w,t-1}\right)+\varepsilon_t^w+\theta_p\varepsilon_{t-1}^w \tag{D.19}$$

with $\varepsilon_t^w \sim N\left(0,\sigma^2_{\lambda_w}\right)$. Aggregate wages evolve as:

$$\begin{aligned} W_t &= \chi_{b,t}\left\{\left(1-\xi_w\right)\left(\frac{\tilde{W}_{b,t}}{\chi_{b,t}}\right)^{\frac{1}{\lambda_w}}+\xi_w\left[\left(\pi e^{\gamma}\right)^{(1-\iota_w)}\left(\pi_{t-1}e^{z_{t-1}}\right)^{(\iota_w)}\frac{W_{t-1}}{\chi_{b,t}}\right]^{\frac{1}{\lambda_w}}\right\}^{\lambda_w} \\ &= \left\{\left(1-\xi_w\right)\left(\tilde{W}_{b,t}\right)^{\frac{1}{\lambda_w}}+\xi_w\left[\left(\pi e^{\gamma}\right)^{(1-\iota_w)}\left(\pi_{t-1}e^{z_{t-1}}\right)^{(\iota_w)}W_{t-1}\right]^{\frac{1}{\lambda_w}}\right\}^{\lambda_w}. \end{aligned} \tag{D.20}$$

Financial Intermediaries

In each period, bank i maximizes its nominal profits:

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

s.t.

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

where:

$$\log\left(1+\tau_t^q\right)=\left(1-\rho_\tau\right)\log\left(1+\tau^q\right)+\rho_\tau\log\left(1+\tau_{t-1}^q\right)+\varepsilon_t^\tau \tag{D.21}$$

where $\varepsilon_t^\tau \sim N\left(0,\sigma_\tau^2\right)$. Perfect competition among intermediaries implies that their profits are equal to zero in equilibrium so that:

$$Q_t^B=\left(1+\tau_t^q\right)Q_t^A \tag{D.22}$$

Monetary Authority

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

$$\frac{R_t^B}{R^B}=\left(\frac{R_{t-1}^B}{R^B}\right)^{\rho_R}\left[\left(\frac{\bar{\pi}_t}{\pi}\right)^{\phi_\pi}\right]^{1-\rho_R}\left(\frac{\Delta\overline{X}_{t-s}}{\gamma}\right)^{\phi_Y}\eta_{mp,t} \tag{D.23}$$

where:

$$\log\eta_{mp,t}=\varepsilon_{mp,t} \tag{D.24}$$

and $\varepsilon_{mp,t}$ is iid $N\left(0,\sigma^2_{mp}\right)$.

Fiscal Authority

The government runs a balanced budget in every period:

$$B_t+\tau^k R_t^K K_{t-1}+\tau^l W_t L_t=R_{t-1}^B B_{t-1}+G_t+T_t\,. \tag{D.25}$$

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

$$G_t = \left(1 - \frac{1}{g_t}\right) Y_t \,, \tag{D.26}$$

where:

$$\log g_t = (1 - \rho^g)\, g_{ss} + \rho^g \log g_{t-1} + \varepsilon_t^g \tag{D.27}$$

and $\varepsilon_t^g \sim iidN\left(0, \sigma^{g2}\right)$. I assume the share of transfers over total output, T_t/Y_t, evolve according to:

$$\frac{T_t/Y_t}{ToY} = \left(\frac{\Delta log(Y_t)}{\gamma}\right)^{-\varphi_Y} \left(\frac{B_t/Y_t}{BoY}\right)^{-\varphi_B} \,. \tag{D.28}$$

Equilibrium

An equilibrium in this economy is defined as a sequence of prices and rates of return:

$$\{P_t^K, Q_t^A, Q_t^B, W_t, R_t^K, R_t^B\}$$

such that for a given realization of aggregate shocks:

- final goods producers choose inputs $\mathrm{Y}_t(i)$ and output $\{Y_t\}$ levels to maximize their profits subject the available technology;
- intermediate goods producers set their prices $\tilde{P}_t(i)$ to maximize their monopolistic profits subject to the demand from final producers (22) and their production function (23);
- capital producers choose the optimal level of input and output $\left\{Y_t^I, i_t\right\}$ that maximize their profits (D) under their technological constraint (D.7);
- household members choose optimal consumption, capital goods purchases, equity sales and purchases as well as asset holdings and their relative wage rate:

  $$\left\{C_{i,t}, \iota_{i,t}, \Delta N_{i,t}^{+}, \Delta N_{i,t}^{-}, N_{i,t}, B_{i,t}, \tilde{W}_{i,t}\right\}$$

  that maximize their lifetime utility (6), under their flow of funds constraint (7), and the law of accumulation of equity (8), while satisfying the liquidity constraint (12) and the non-negativity conditions (2.1) and the demand for hours worked of employment agencies 17;
- banks maximize their profits (D), to intermediate an amount of equity claims $\Delta N_{i,t}^{+} = \Delta N_{i,t}^{-}$ between savers and buyers;
- employment agencies maximize their profits by choosing the optimal supply of homogeneous labor, L_t, and their demand for households' specialized labor, $L_{b,t}$;

- Markets clear:

$$
\begin{aligned}
Y_t &= \int_0^1 Y_t(i)di &\text{(D.29)}\\
Y_t &= \int_{A^{low}}^{A_t^{high}} C_{i,t}dF(A_{i,t}) + I_t + G_t &\text{(D.30)}\\
\Delta N_t &= \int_{A^{low}}^{A_t^{high}} \left[\Delta N_{i,t}^{+}\right] dF(A_{i,t}) = \int_{A^{low}}^{A_t^{high}} \left[\Delta N_{i,t}^{-}\right] dF(A_{i,t}) &\text{(D.31)}\\
i_t &= \int_{A^{low}}^{A_t^{high}} \iota_{i,t}dF(A_{i,t}) &\text{(D.32)}\\
N_t &= K_t &\text{(D.33)}
\end{aligned}
$$

The 26 equations and 7 exogenous processes (D.1)-(D.33) summarize the set of non-linear equilibrium conditions of the rational expectation model in the 33 variables:

$$
\begin{bmatrix}
K_t, L_t, MC_t, R_t^K, \tilde{W}_t, W_t, P_t, \tilde{P}_t, P_t^K, R_t^B, Q_t^A, Q_t^B \\
Y_t, C_t, I_t, i_t, \iota_t, G_t, B_t, N_t, T_t, D_t, \Delta N_t, \mu_t^{\Sigma C}, A_t^{high}, a_t, A_t, \lambda_{p,t}, \lambda_{w,t}, b_t, \tau_t^q, \eta_{mp,t}, g_t
\end{bmatrix}
$$

Productivity A_t follows a non-stationary process. The price level is also non-stationary. The model variables can be scaled so that all equations are expressed in terms of stationary real variables:

$$\begin{aligned}
k_t &= \frac{K_t}{A_t} \\
n_t &= \frac{N_t}{A_t} \\
y_t &= \frac{Y_t}{A_t} \\
\hat{I}_t &= \frac{I_t}{A_t} \\
\hat{i}_t &= \frac{i_t}{A_t} \\
\hat{\iota}_t &= \frac{\iota_t}{A_t} \\
c_t &= \frac{C_t}{A_t} \\
\hat{G}_t &= \frac{G_t}{A_t} \\
\hat{B}_t &= \frac{B_t}{A_t} \\
t_t &= \frac{T_t}{A_t} \\
d_t &= \frac{D_t}{A_t} \\
\Delta n_t &= \frac{\Delta N_t}{A_t} \\
r_t^K &= \frac{R_t^K}{P_t} \\
w_t &= \frac{W_t}{P_t A_t} \\
\tilde{w}_{b,t} &= \frac{\tilde{W}_t}{P_t A_t} \\
mc_t &= \frac{MC_t}{P_t} \\
p_t^K &= \frac{P_t^K}{P_t} \\
q_t^A &= \frac{Q_t^A}{P_t} \\
\tilde{q}_{s,t}^A &= \frac{\tilde{Q}_{s,t}^A}{P_t} \\
q_t^B &= \frac{Q_t^B}{P_t} \\
\hat{\mu}_t^{\Sigma C} &= \frac{\mu_t^{\Sigma C}}{A_t} \\
\pi_t &= \frac{P_t}{P_{t-1}} \\
\tilde{p}_t &= \frac{\tilde{P}_t}{P_t}
\end{aligned}$$

The system of stationary equations is composed of the:

$$\log\left(z_t\right) = \left(1-\rho_z\right)\log\left(\gamma\right) + \rho_z \log\left(z_{t-1}\right) + \varepsilon_t^z \tag{D.34}$$

$$\log\left(1+\lambda_{p,t}\right) = \left(1-\rho_p\right)\log\left(1+\lambda_p\right) + \rho_p \log\left(1+\lambda_{p,t-1}\right) + \varepsilon_t^p + \theta_p \varepsilon_{t-1}^p \tag{D.35}$$

$$\log\left(1+\lambda_{w,t}\right) = \left(1-\rho_w\right)\log\left(1+\lambda_w\right) + \rho_w \log\left(1+\lambda_{w,t-1}\right) + \varepsilon_t^w + \theta_p \varepsilon_{t-1}^w \tag{D.36}$$

$$\log b_t = \rho_b \log b_{t-1} + \varepsilon_t^b \tag{D.37}$$

$$\log\left(1+\tau_t^q\right) = \left(1-\rho_\tau\right)\log\left(1+\tau^q\right) + \rho_\tau \log\left(1+\tau_{t-1}^q\right) + \varepsilon_t^\tau \tag{D.38}$$

$$\log \eta_{mp,t} = \varepsilon_{mp,t} \tag{D.39}$$

$$\log g_t = \left(1-\rho^g\right) g_{ss} + \rho^g \log g_{t-1} + \varepsilon_t^g \tag{D.40}$$

$$\frac{k_{t-1}\exp(z_t)^{-1}}{L_t(i)} = \frac{w_t}{r_t^k}\frac{\alpha}{(1-\alpha)} \tag{D.41}$$

$$MC_t = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} r_t^{K\alpha}\left(w_t\right)^{1-\alpha} \text{(D.42)}$$

$$E_t\left\{\sum_{s=0}^{\infty} \xi_p^s \beta^s b_{t+s}\hat{\mu}_{t+s}^{\Sigma C}\tilde{y}_{t+s}\left[\tilde{p}_t \prod_{k=1}^{s}(\pi_{t+k-1}^{\iota_p}\pi^{1-\iota_p}\pi_{t+k}^{-1}) - (1+\lambda_{p,t+s})mc_{t+s}\right]\right\} = 0 \tag{D.43}$$

$$1 = \left[(1-\xi_p)\tilde{p}_t^{\frac{1}{\lambda_{p,t}}} + \xi_p(\pi_{t-1}^{\iota_p}\pi^{1-\iota_p}\pi_t^{-1})^{\frac{1}{\lambda_{p,t}}}\right]^{\lambda_{p,t}} \tag{D.44}$$

$$\hat{i}_t = \left[1 - S\left(\frac{\hat{I}_t \exp z_t}{\hat{I}_{t-1}}\right)\right]\hat{I}_t. \tag{D.45}$$

$$\begin{aligned} p_t^K\left[\left(1 - S\left(\frac{\hat{I}_t\exp(z_t)}{\hat{I}_{t-1}}\right)\right) - \frac{\hat{I}_t\exp(z_t)}{\hat{I}_{t-1}}S'\left(\frac{\hat{I}_t\exp(z_t)}{\hat{I}_{t-1}}\right)\right] - 1 \quad &= \\ E_t\left\{(\beta b_t)\frac{\hat{\mu}_{t+1}^{\Sigma C}}{\hat{\mu}_t^{\Sigma C}}\left[p_{t+1}^K\left(\frac{\hat{I}_{t+1}^2\exp(z_{t+1})^2}{\hat{I}_t^2}\right)S'\left(\frac{\hat{I}_{t+1}\exp(z_{t+1})}{\hat{I}_t}\right)\right]\right\} & \end{aligned} \tag{D.46}$$

$$\frac{1}{(c_t - hc_{t-1}\exp(z_t)^{-1})} - \beta b_t h E_t\left[\frac{1}{(c_{t+1}\exp(z_t) - hc_t)}\right] = P_t\hat{\mu}_t^{\Sigma C} \tag{D.47}$$

$$q_t^B = \beta b_t E_t \left\{ \frac{\hat{\mu}_{t+1}^{\Sigma C}}{\hat{\mu}_t^{\Sigma C}} \exp(z_{t+1}) \times \right.$$
$$\times \left[\chi_{s,t+1} E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\tilde{q}_{i,t+1}^A} \left((1-\tau_k) r_{t+1}^K + (1-\phi_{t+1}) \tilde{q}_{i,t+1}^A (1-\delta) + \phi_{t+1} q_{t+1}^A (1-\delta) \right) \middle| \frac{p_t^K}{A_{i,t}} \le q_t^A \right) + \right.$$
$$+ \chi_{k,t+1} E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\frac{p_{t+1}^K}{A_{i,t+1}}} \left((1-\tau_k) r_{t+1}^K + \frac{p_{t+1}^K}{A_{i,t+1}} (1-\delta) \right) \middle| q_{t+1}^A \le \frac{p_{t+1}^K}{A_{i,t+1}} \le q_{t+1}^B \right) +$$
$$\left. \left. + \ \chi_{b,t+1} E_{A_{i,t+1}} \left((1-\tau_k) r_{t+1}^K + q_{t+1}^B (1-\delta) \middle| \frac{p_{t+1}^K}{A_{i,t+1}} \ge q_{t+1}^B \right) \right] \right\} \tag{D.48}$$

$$1 = \beta b_t E_t \left\{ \frac{\hat{\mu}_{t+1}^{\Sigma C}}{\hat{\mu}_t^{\Sigma C}} \frac{\exp(z_{t+1})}{\pi_{t+1}} \times \left[\chi_{s,t+1} \ E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\tilde{q}_{i,t+1}^A} \middle| \frac{p_t^K}{A_{i,t}} \le q_t^A \right) + \right. \right.$$
$$+ \chi_{k,t+1} E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\frac{p_{t+1}^K}{A_{i,t+1}}} \middle| q_{t+1}^A \le \frac{p_{t+1}^K}{A_{i,t+1}} \le q_{t+1}^B \right) +$$
$$\left. \left. + \ \chi_{b,t+1} E_{A_{i,t+1}} \left(1 \middle| \frac{p_{t+1}^K}{A_{i,t+1}} \ge q_{t+1}^B \right) \right] R_t^B \right\} \tag{D.49}$$

$$1 \quad = \beta b_t E_t \left\{ \frac{\hat{\mu}_{t+1}^{\Sigma C}}{\hat{\mu}_t^{\Sigma C}} \exp(z_{t+1}) \times \left[\chi_{s,t+1} \ E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\tilde{q}_{i,t+1}^A} \middle| \frac{p_t^K}{A_{i,t}} \le q_t^A \right) + \right. \right.$$
$$+ \chi_{k,t+1} E_{A_{i,t+1}} \left(\frac{q_{t+1}^B}{\frac{p_{t+1}^K}{A_{i,t+1}}} \middle| q_{t+1}^A \le \frac{p_{t+1}^K}{A_{i,t+1}} \le q_{t+1}^B \right) +$$
$$\left. \left. + \ \chi_{b,t+1} E_{A_{i,t+1}} \left(1 \middle| \frac{p_{t+1}^K}{A_{i,t+1}} \ge q_{t+1}^B \right) \right] r_t^B \right\} \tag{D.50}$$

$$\hat{\imath}_t = \left[-\frac{1}{2(\theta q_t^A)^3} \left(2 \log(\theta q_t^A A_{s,t} - p_t^K \right) \left(\theta q_t^A (a \theta q_t^A + b p_t^K) + c p_t^{K2} \right) + \theta q_t^A A_{s,t} (2 b \theta q_t^A \ + \ 2 c p_t^K + c \theta q_t^A A_{s,t})) \right]_{\frac{p_t^K}{q_t^A}}^{A^{high}} \times$$
$$\times \left[(1-\tau_k) r_t^K n_{t-1} \exp(z_t)^{-1} + r_{t-1}^b \hat{B}_{t-1} \exp(z_t)^{-1} + d_t + t_t + q_t^A \phi (1-\delta) n_{t-1} \exp(z_t)^{-1} \right] +$$
$$+ \left[a A_{k,t} + b \frac{A_{k,t}^2}{2} + 3 \frac{A_{k,t}^3}{3} \right]_{\frac{p_t^K}{q_t^B}}^{\frac{p_t^K}{q_t^A}} \frac{1}{p_t^K} \left[(1-\tau_k) r_t^K n_{t-1} \exp(z_t)^{-1} + r_{t-1}^B \hat{B}_{t-1} \exp(z_t)^{-1} + d_t + t_t \right]$$
$$\tag{D.51}$$

$$N_t = \left[\frac{(1-\theta)}{2(\theta q_t^A)^3}\left[2\log(\theta q_t^A A_{s,t} - p_t^K)(\theta q_t^A(a q_t^A + b p_t^K) + c p_t^{K2}) + \theta q_t^A A_{s,t}(2b\theta q_t^A + 2c p_t^K + c\theta q_t^A A_{s,t})\right]\right]_{\frac{p_t^K}{q_t^A}}^{A^{high}} \times$$

$$\times\left[(1-\tau_k) r_t^K n_{t-1}\exp(z_t)^{-1} + r_{t-1}^B \hat{B}_{t-1}\exp(z_t)^{-1} + d_t + t_t + q_t^A \phi(1-\delta) n_{t-1}\exp(z_t)^{-1}\right] +$$

$$+\left[a A_{i,t} + b\frac{A_{i,t}^2}{2} + 3\frac{A_{i,t}^3}{3}\right]_{\frac{p_t^K}{q_t^B}}^{A^{high}} (1-\phi)(1-\delta) n_{t-1}\exp(z_t)^{-1} +$$

$$+\left[\frac{A_{k,t}^2(6a + (4b + 3cA_{k,t}))}{12 p_t^K}\right]_{\frac{p_t^K}{q_t^B}}^{\frac{p_t^K}{q_t^A}} \left[(1-\tau_k) r_t^K n_{t-1}\exp(z_t)^{-1} + r_{t-1}^B \hat{B}_{t-1}\exp(z_t)^{-1} + d_t + t_t\right] \tag{D.52}$$

$$\int_{\frac{p_t^K}{q_t^B}}^{A_t^{high}} A_{i,t} dF(A_{i,t}) = 1 \tag{D.53}$$

$$F(A_t^{high}) = \int_{A^{low}}^{A_t^{high}} dF(A_{i,t}) = 1 \tag{D.54}$$

$$E_t\left\{\sum_{s=0}^{\infty} \xi_w{}^s \beta^s \hat{\mu}_{t+s}^{\Sigma C} \tilde{L}_{t+s}\left[\frac{\tilde{w}_{b,t}}{\chi_{b,t+s}}\prod_{k=1}^{s}(\pi_{t+k}^{-1}\exp(z_{t+k})^{-1})\Pi_{t,t+s}^w - (1+\lambda_{w,t+s})\omega\frac{\tilde{L}_{t+s}^{\nu}}{\hat{\mu}_{t+s}^{\Sigma C}}\right]\right\} = 0 \tag{D.55}$$

$$w_t = \left\{(1-\xi_w)\left(\tilde{w}_{b,t}\right)^{\frac{1}{\lambda_w}} + \xi_w\left[\left(\pi e^{\gamma}\right)^{(1-\iota_w)}\left(\pi_{t-1} e^{z_{t-1}}\right)^{(\iota_w)} w_{t-1}\exp(\pi_t z_t)^{-1}\right]^{\frac{1}{\lambda_w}}\right\}^{\lambda_w} \tag{D.56}$$

$$q_t^B = \left(1 + \tau_t^q\right) q_t^A \tag{D.57}$$

$$\frac{R_t^B}{R^B} = \left(\frac{R_{t-1}^B}{R^B}\right)^{\rho_R}\left[\left(\frac{\bar{\pi}_t}{\pi}\right)^{\phi_\pi}\right]^{1-\rho_R}\left(\frac{\Delta \overline{X}_{t-s}}{\gamma}\right)^{\phi_Y} \eta_{mp,t} \tag{D.58}$$

$$\hat{B}_t + \tau^k r_t^K k_{t-1}\exp(z_t)^{-1} + \tau^l w_t L_t = r_{t-1}^B \hat{B}_{t-1} + \hat{G}_t + t_t \tag{D.59}$$

$$\hat{G}_t = \left(1 - \frac{1}{g_t}\right) y_t \tag{D.60}$$

$$\frac{t_t/y_t}{ToY} = \left(\frac{\Delta\log(y_t\exp(z_t))}{\gamma}\right)^{-\varphi_Y}\left(\frac{\hat{B}_t/y_t}{BoY}\right)^{-\varphi_B} \tag{D.61}$$

$$d_t = \left(y_t - r_t^K k_{t-1}\exp(z_t)^{-1} - w_t L_t\right) + \left(p_t^K\left(1 - S\left(\frac{\hat{I}_t\exp(z_t)}{\hat{I}_{t-1}}\right)\right)\hat{I}_t - \hat{I}_t\right) + \left(q_t^B - q_t^A\right)\Delta n_t \tag{D.62}$$

$$y_t = k_t^{\alpha}\exp(z_t)^{-\alpha} L_t^{1-\alpha} \tag{D.63}$$

$$y_t = c_t + \hat{I}_t + \hat{G}_t \tag{D.64}$$

$$\Delta n_t = \theta\int_{A^{low}}^{A_t^{high}} A_{i,t}\hat{\imath}_{i,t} dF(A_{i,t}) + \phi(1-\delta) n_{t-1}\exp(z_t)^{-1} \tag{D.65}$$

$$\hat{i}_t = \hat{\imath}_t \tag{D.66}$$

$$n_t = k_t \tag{D.67}$$

The system is composed of 34 equation, including equation (D.50) to determine the equilibrium real interest rate, r_t^B, and is expressed in 34 stationary variables:

$$[\quad k_t, L_t, mc_t, r_t^K, \tilde{w}_t, w_t, \pi_t, \tilde{p}_t, p_t^K, R_t^B, r_t^B, q_t^A, q_t^B$$
$$y_t, c_t, \hat{I}_t, \hat{i}_t, \hat{\imath}_t, \hat{G}_t, \hat{B}_t, n_t, t_t, d_t, \Delta n_t, \hat{\mu}_t^{\Sigma C}, A_t^{high}, a_t, z_t, \lambda_{p,t}, \lambda_{w,t}, b_t, \tau_t^q, \eta_{mp,t}, g_t \quad]$$

The stationary model has a steady state solution for a given set of parameters and a steady state level of inflation, π_{ss}, and hours worked, L_{ss}.

I derive a log-linear approximation of the stationary equilibrium conditions (D.34)-(D.67) around the steady state equilibrium, using the analytical differentiation routines built into Matlab.[46] For a given parameter vector, I solve for the steady state equilibrium numerically and evaluate the coefficients of the log-linear approximation of the dynamic model's first order conditions. With the numerical approximation of the model at hand, I finally I then solve the system of linear rational expectation equation using the algorithm in Anderson and Moore (1985).

[46] I follow Justiniano, Primiceri, and Tambalotti (2010) to compute the log-linear price and wage Phillips curves analytical from equations (D.3), (D.5), (D.6) and (D.18) - (D.20)

E Additional Tables and Figures

Baseline Model - FGS EX Dividends

Table 10: Calibrated Values, Priors and Posterior Estimates for the Model Parameters

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
A_l	Entr. Tech. Distr. (level)	$\mathrm{N}(0.900, 0.400)$	0.800	[	–	–	–	]
d_A	Entr. Tech. Distr. (width)	Inv. $\Gamma(0.500, 0.200)$	0.225	[	–	–	–	]
a	Entr. Tech. Distr. (norm.)	Calibrated	3.748	[	–	–	–	]
b	Entr. Tech. Distr. (slope)	$\mathrm{N}(0.200, 1.000)$	1.965	[	1.760	–	2.321	]
c	Entr. Tech. Distr. (curv.)	$\mathrm{N}(0.000, 1.000)$	-0.566	[	-0.621	–	-0.519	]
γ	SS Output Growth	$\mathrm{N}(0.500, 0.050)$	0.452	[	0.378	–	0.529	]
$(\beta^{-1} - 1) \times 100$	Discount Factor	$\Gamma(0.250, 0.100)$	0.750	[	–	–	–	]
δ	Capital Depreciation	Calibrated	0.025	[	–	–	–	]
ν	Inverse Frisch	$\Gamma(2.000, 0.750)$	1.505	[	0.741	–	2.669	]
h	Habit	$\mathrm{B}(0.500, 0.200)$	0.868	[	0.832	–	0.896	]
η	Capital Share	$\mathrm{B}(0.300, 0.050)$	0.713	[	0.690	–	0.735	]
λ_p	Price Mark-up	$\mathrm{N}(0.150, 0.050)$	0.207	[	0.152	–	0.265	]
ξ_p	Calvo Prices	$\mathrm{B}(0.660, 0.100)$	0.843	[	0.809	–	0.891	]
ι_p	Index Prices	$\mathrm{B}(0.500, 0.150)$	0.185	[	0.103	–	0.267	]
ξ_w	Calvo Wages	$\mathrm{B}(0.660, 0.100)$	0.923	[	0.889	–	0.942	]
λ_w	Wage Mark-up	$\mathrm{N}(0.150, 0.050)$	0.142	[	0.102	–	0.205	]
ι_w	Index Wages	$\mathrm{B}(0.500, 0.150)$	0.286	[	0.175	–	0.386	]
$\phi_{ss} \times 100$	Liquidity Constr.	$\Gamma(5.000, 3.000)$	0.217	[	0.102	–	0.346	]
θ	Borrowing Constr.	$\mathrm{B}(0.300, 0.150)$	0.251	[	0.213	–	0.281	]
$\tau_{q_{ss}} \times 100$	SS Spread	Inv. $\Gamma(1.000, 0.200)$	0.733	[	0.585	–	0.916	]
Bs_{ss}	Liquidity over GDP	$\mathrm{B}(0.300, 0.100)$	0.036	[	0.027	–	0.041	]
gs_{ss}	Govt over GDP	Calibrated	0.170	[	–	–	–	]
τ_k	Capital Tax Rate	Calibrated	0.184	[	–	–	–	]
τ_l	Labor Tax Rate	Calibrated	0.223	[	–	–	–	]
t_B	Fiscal Rule - Debt	$\Gamma(1.000, 0.500)$	0.970	[	0.641	–	1.749	]
t_Y	Fiscal Rule - GDP Growth	$\Gamma(1.000, 0.500)$	1.089	[	0.344	–	2.321	]

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
θ_I	IAC	$\Gamma(2.000, 0.125)$	1.984	[	1.799	–	2.176	]
π_{ss}	SS inflation	$N(0.500, 0.100)$	0.507	[	0.333	–	0.676	]
ρ_i	Taylor Rule inertia	$B(0.600, 0.200)$	0.852	[	0.822	–	0.877	]
ϕ_π	Taylor Rule inflation	$N(1.700, 0.200)$	1.127	[	1.019	–	1.217	]
ϕ_{DY}	Taylor Rule GDP growth	$N(0.125, 0.050)$	0.085	[	0.047	–	0.106	]
θ_π	Inflation MA	Calibrated	0.750	[	–	–	–	]
θ_{DY}	GDP Growth MA	Calibrated	0.750	[	–	–	–	]
ρ_z	AR(1) TFP growth shock	$B(0.600, 0.200)$	0.486	[	0.379	–	0.586	]
ρ_g	AR(1) G shock	$B(0.600, 0.200)$	0.997	[	0.997	–	0.998	]
ρ_β	AR(1) Beta shock	Inv. $\Gamma(0.600, 0.200)$	0.568	[	0.455	–	0.669	]
ρ_p	AR(1) P Mark-up shock	$B(0.600, 0.200)$	0.804	[	0.658	–	0.877	]
ρ_w	AR(1) W Mark-up shock	$B(0.600, 0.200)$	0.172	[	0.065	–	0.296	]
ρ_τ	AR(1) Fin. shock	$B(0.600, 0.200)$	0.970	[	0.961	–	0.975	]
θ_p	MA(1) P shock	$B(0.500, 0.200)$	0.286	[	0.120	–	0.517	]
θ_w	MA(1) W shock	$B(0.500, 0.200)$	0.153	[	0.066	–	0.246	]
σ_z	Stdev TFP Growth Shock	Inv. $\Gamma(0.500, 1.000)$	0.712	[	0.638	–	0.797	]
σ_g	Stdev G Shock	Inv. $\Gamma(0.500, 1.000)$	0.170	[	0.151	–	0.193	]
σ_i	Stdev MP Shock	Inv. $\Gamma(0.100, 1.000)$	0.125	[	0.110	–	0.144	]
σ_τ	Stdev Fin. Shock	Inv. $\Gamma(2.000, 1.000)$	0.641	[	0.490	–	0.856	]
σ_β	Stdev Beta Shock	Inv. $\Gamma(0.100, 1.000)$	3.205	[	2.564	–	4.121	]
σ_p	Stdev P Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.057	[	0.046	–	0.066	]
σ_w	Stdev W Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.287	[	0.245	–	0.336	]
$\sigma_{ME_{sp}}$	Stdev ME Spread	Inv. $\Gamma(0.200, 0.500)$	0.301	[	0.266	–	0.344	]
$\sigma_{ME_{fgs}}$	Stdev ME FGS	Inv. $\Gamma(2.000, 0.500)$	5.905	[	5.238	–	6.723	]

Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model.
1 N stands for Normal, B Beta, Γ Gamma and Inv. Γ Inverse-Gamma1 distribution.
2 Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm.
Acceptance rate 28%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 11: Posterior Variance Decomposition - Sticky wages - FGS EX Dividends

	TFP	**Gov't**	**MP**	**Financial**	**Preference**	**Price Mark up**	**Wage Mark up**	**ME Spread**	**ME FGS**
$\Delta \log GDP_t$	**26.1**	**2.8**	**5.6**	**30.5**	**16.1**	**12.8**	**4.8**	**0**	**0**
	[17.6 - 36.2]	[1.8 - 4.4]	[3.8 - 8.2]	[23.6 - 39.3]	[11.5 - 22.9]	[7.4 - 17.9]	[2.1 - 7.7]	[0 - 0]	[0 - 0]
$\Delta \log I_t$	**17**	**1.1**	**8.4**	**45.1**	**0.9**	**20.3**	**5.7**	**0**	**0**
	[10.9 - 24.9]	[0.5 - 2.4]	[5.7 - 12.1]	[36 - 58.9]	[0.4 - 1.9]	[12.1 - 27.5]	[2.4 - 9.4]	[0 - 0]	[0 - 0]
$\Delta \log C_t$	**25.9**	**0.2**	**1.1**	**6**	**62.7**	**1.9**	**1.7**	**0**	**0**
	[16.4 - 37.2]	[0.1 - 0.4]	[0.6 - 1.9]	[3.7 - 9.2]	[50.8 - 74.3]	[1 - 3.1]	[0.8 - 2.9]	[0 - 0]	[0 - 0]
$\Delta \log w_t$	**31.5**	**0**	**0.2**	**1**	**0.3**	**22.1**	**43.6**	**0**	**0**
	[20 - 44.5]	[0 - 0.1]	[0 - 0.7]	[0.3 - 4.8]	[0 - 1.6]	[13.5 - 31.4]	[34.1 - 54.3]	[0 - 0]	[0 - 0]
π_t	**4.3**	**2.7**	**2**	**45.5**	**4**	**32.8**	**7.4**	**0**	**0**
	[2.2 - 7.8]	[1.4 - 5]	[0.9 - 3.7]	[36.6 - 54.4]	[2.2 - 7.1]	[24.4 - 43.5]	[4.5 - 11]	[0 - 0]	[0 - 0]
R_t^B	**1.6**	**2.2**	**29.3**	**38.9**	**3.4**	**18.7**	**4.3**	**0**	**0**
	[0.6 - 3.4]	[1.2 - 3.8]	[21 - 40.9]	[29.5 - 48.4]	[1.8 - 6.5]	[13.4 - 26]	[2.5 - 6.7]	[0 - 0]	[0 - 0]
$\log L_t$	**7**	**3.3**	**7**	**38.8**	**17**	**18.7**	**7.2**	**0**	**0**
	[4.8 - 10.1]	[2.1 - 5.1]	[4.8 - 10]	[31.2 - 48.1]	[12.3 - 23.7]	[9.7 - 25.8]	[3 - 11.8]	[0 - 0]	[0 - 0]
Sp_t	**4.6**	**0.4**	**3.8**	**58.4**	**0.2**	**6.2**	**2.5**	**23.3**	**0**
	[3 - 6.8]	[0.1 - 0.9]	[2.2 - 6.4]	[47.9 - 66.9]	[0.1 - 0.5]	[3.4 - 9.6]	[1.4 - 3.9]	[16.7 - 32.3]	[0 - 0]
FGS_t	**1.2**	**1.7**	**0.4**	**35.2**	**0.7**	**2.4**	**1**	**0**	**56.9**
	[0.8 - 1.9]	[1.2 - 2.5]	[0.2 - 0.6]	[25.3 - 45.9]	[0.4 - 1.3]	[1 - 4.3]	[0.6 - 1.7]	[0 - 0]	[46.7 - 66.9]

Variance Decomposition of the observables, periodic component with cycles between 6 and 32 quarters. Median values and 90% confidence intervals reported. Posterior percentiles obtained from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 28%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Values are percentages. Rows may not sum up to 100% due to rounding error. Computed used parameter estimates in table 8.

Baseline Model - Excess Bond Premium

Table 12: Calibrated Values, Priors and Posterior Estimates for the Model Parameters

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
A_l	Entr. Tech. Distr. (level)	N(0.900, 0.400)	0.800	[	–	–	–	]
d_A	Entr. Tech. Distr. (width)	Inv. Γ(0.500, 0.200)	0.225	[	–	–	–	]
a	Entr. Tech. Distr. (norm.)	Calibrated	3.748	[	–	–	–	]
b	Entr. Tech. Distr. (slope)	N(0.200, 1.000)	0.810	[	0.732	–	0.894	]
c	Entr. Tech. Distr. (curv.)	N(0.000, 1.000)	−0.160	[	−0.176	–	−0.146	]
γ	SS Output Growth	N(0.500, 0.050)	0.388	[	0.304	–	0.474	]
$(\beta^{-1}-1)\times 100$	Discount Factor	Γ(0.250, 0.100)	0.750	[	–	–	–	]
δ	Capital Depreciation	Calibrated	0.025	[	–	–	–	]
ν	Inverse Frisch	Γ(2.000, 0.750)	1.329	[	0.675	–	2.418	]
h	Habit	B(0.500, 0.200)	0.874	[	0.833	–	0.906	]
η	Capital Share	B(0.300, 0.050)	0.711	[	0.689	–	0.731	]
λ_p	Price Mark-up	N(0.150, 0.050)	0.146	[	0.097	–	0.207	]
ξ_p	Calvo Prices	B(0.660, 0.100)	0.830	[	0.786	–	0.872	]
ι_p	Index Prices	B(0.500, 0.150)	0.242	[	0.121	–	0.376	]
ξ_w	Calvo Wages	B(0.660, 0.100)	0.925	[	0.898	–	0.946	]
λ_w	Wage Mark-up	N(0.150, 0.050)	0.115	[	0.053	–	0.188	]
ι_w	Index Wages	B(0.500, 0.150)	0.295	[	0.185	–	0.413	]
$\phi_{ss}\times 100$	Liquidity Constr.	Γ(5.000, 3.000)	0.367	[	0.233	–	0.521	]
θ	Borrowing Constr.	B(0.300, 0.150)	0.259	[	0.245	–	0.274	]
$\tau_{q_{ss}}\times 100$	SS Spread	Inv. Γ(1.000, 0.200)	0.620	[	0.502	–	0.770	]
Bs_{ss}	Liquidity over GDP	B(0.300, 0.100)	0.039	[	0.034	–	0.044	]
gs_{ss}	Govt over GDP	Calibrated	0.170	[	–	–	–	]
τ_k	Capital Tax Rate	Calibrated	0.184	[	–	–	–	]
τ_l	Labor Tax Rate	Calibrated	0.223	[	–	–	–	]
t_B	Fiscal Rule - Debt	Γ(1.000, 0.500)	2.027	[	1.263	–	3.193	]
t_Y	Fiscal Rule - GDP Growth	Γ(1.000, 0.500)	0.824	[	0.301	–	1.767	]

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
θ_I	IAC	$\Gamma(2.000, 0.125)$	1.775	[	1.603	–	1.959	]
π_{ss}	SS inflation	$N(0.500, 0.100)$	0.519	[	0.425	–	0.614	]
ρ_i	Taylor Rule inertia	$B(0.600, 0.200)$	0.844	[	0.815	–	0.869	]
ϕ_π	Taylor Rule inflation	$N(1.700, 0.200)$	1.328	[	1.186	–	1.488	]
ϕ_{DY}	Taylor Rule GDP growth	$N(0.125, 0.050)$	0.067	[	0.015	–	0.146	]
θ_π	Inflation MA	Calibrated	0.750	[	–	–	–	]
θ_{DY}	GDP Growth MA	Calibrated	0.750	[	–	–	–	]
ρ_z	AR(1) TFP growth shock	$B(0.600, 0.200)$	0.508	[	0.395	–	0.611	]
ρ_g	AR(1) G shock	$B(0.600, 0.200)$	0.976	[	0.971	–	0.982	]
ρ_β	AR(1) Beta shock	Inv. $\Gamma(0.600, 0.200)$	0.617	[	0.494	–	0.716	]
ρ_p	AR(1) P Mark-up shock	$B(0.600, 0.200)$	0.775	[	0.648	–	0.871	]
ρ_w	AR(1) W Mark-up shock	$B(0.600, 0.200)$	0.147	[	0.049	–	0.329	]
ρ_τ	AR(1) Fin. shock	$B(0.600, 0.200)$	0.984	[	0.981	–	0.987	]
θ_p	MA(1) P shock	$B(0.500, 0.200)$	0.270	[	0.123	–	0.561	]
θ_w	MA(1) W shock	$B(0.500, 0.200)$	0.146	[	0.043	–	0.367	]
σ_z	Stdev TFP Growth Shock	Inv. $\Gamma(0.500, 1.000)$	0.709	[	0.637	–	0.794	]
σ_g	Stdev G Shock	Inv. $\Gamma(0.500, 1.000)$	0.168	[	0.150	–	0.191	]
σ_i	Stdev MP Shock	Inv. $\Gamma(0.100, 1.000)$	0.132	[	0.116	–	0.153	]
σ_τ	Stdev Fin. Shock	Inv. $\Gamma(2.000, 1.000)$	0.900	[	0.690	–	1.162	]
σ_β	Stdev Beta Shock	Inv. $\Gamma(0.100, 1.000)$	3.511	[	2.710	–	4.629	]
σ_p	Stdev P Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.066	[	0.050	–	0.087	]
σ_w	Stdev W Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.293	[	0.251	–	0.338	]
$\sigma_{ME_{sp}}$	Stdev ME Spread	Inv. $\Gamma(0.200, 0.500)$	0.903	[	0.784	–	1.058	]
$\sigma_{ME_{fgs}}$	Stdev ME FGS	Inv. $\Gamma(2.000, 0.500)$	4.784	[	4.229	–	5.457	]

Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model.
1 N stands for Normal, B Beta, Γ Gamma and Inv. Γ Inverse-Gamma1 distribution.
2 Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm.
Acceptance rate 27%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 13: Posterior Variance Decomposition - Sticky wages - Excess Bond Premium

	TFP	**Gov't**	**MP**	**Financial**	**Preference**	**Price Mark up**	**Wage Mark up**	**ME Spread**	**ME FGS**
$\Delta \log GDP_t$	**25.8**	**1**	**4.9**	**25.4**	**18.8**	**16.6**	**6.2**	**0**	**0**
	[17.5 - 36.1]	[0.7 - 1.5]	[3.2 - 7.6]	[19.2 - 32.6]	[13.5 - 25.2]	[11.6 - 22.8]	[3.6 - 9.9]	[0 - 0]	[0 - 0]
$\Delta \log I_t$	**17.4**	**0**	**7.4**	**38.5**	**1.5**	**26.2**	**7.6**	**0**	**0**
	[11.2 - 25.6]	[0 - 0.1]	[4.9 - 11.3]	[29.6 - 48.2]	[0.7 - 3.5]	[19 - 34.3]	[4.3 - 12.3]	[0 - 0]	[0 - 0]
$\Delta \log C_t$	**21.7**	**0.2**	**0.8**	**3.8**	**69.1**	**2**	**1.7**	**0**	**0**
	[13.9 - 32.7]	[0.1 - 0.4]	[0.4 - 1.5]	[2.2 - 6.3]	[57.5 - 79]	[1.1 - 3.5]	[0.9 - 2.9]	[0 - 0]	[0 - 0]
$\Delta \log w_t$	**33.9**	**0**	**0.1**	**0.4**	**0.2**	**22.3**	**42**	**0**	**0**
	[23.3 - 46.1]	[0 - 0]	[0 - 0.3]	[0.1 - 1.5]	[0 - 1.1]	[14.7 - 32.1]	[32.5 - 52.1]	[0 - 0]	[0 - 0]
π_t	**6**	**0.1**	**1.8**	**46.3**	**5.2**	**31.1**	**8.1**	**0**	**0**
	[3.2 - 10.2]	[0 - 0.4]	[0.9 - 3.5]	[38.6 - 54]	[2.7 - 9.3]	[23.1 - 41.1]	[5.3 - 11.8]	[0 - 0]	[0 - 0]
R_t^B	**3.4**	**0.1**	**21**	**43.7**	**4.9**	**19.6**	**5.5**	**0**	**0**
	[1.6 - 6.3]	[0.1 - 0.4]	[14.4 - 30.4]	[35.4 - 52.2]	[2.5 - 9.5]	[13.6 - 27.7]	[3.5 - 8.4]	[0 - 0]	[0 - 0]
$\log L_t$	**9.1**	**0.9**	**5.9**	**31**	**19.5**	**23.1**	**9.3**	**0**	**0**
	[6.3 - 13]	[0.6 - 1.5]	[3.8 - 9.1]	[24.4 - 38.1]	[14.1 - 25.9]	[16.1 - 31.5]	[5.3 - 14.8]	[0 - 0]	[0 - 0]
EBP_t	**7**	**0**	**6.5**	**16.7**	**1.6**	**36.1**	**4.2**	**25.7**	**0**
	[4.2 - 11.2]	[0 - 0.1]	[3.7 - 11.3]	[8.2 - 28.8]	[0.7 - 3.5]	[27 - 46.3]	[2.7 - 6.6]	[18.2 - 34.9]	[0 - 0]
FGS_t	**0.6**	**0.5**	**0.5**	**57.5**	**0.4**	**0.8**	**0.3**	**0**	**39.2**
	[0.3 - 1.1]	[0.2 - 1]	[0.3 - 0.8]	[48.4 - 66]	[0.2 - 0.7]	[0.5 - 1.3]	[0.1 - 0.6]	[0 - 0]	[31.2 - 48]

Variance Decomposition of the observables, periodic component with cycles between 6 and 32 quarters. Median values and 90% confidence intervals reported. Posterior percentiles obtained from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm. Acceptance rate 27%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Values are percentages. Rows may not sum up to 100% due to rounding error. Computed used parameter estimates in table 8.

Flexible Wages Model

Table 14: Calibrated Values, Priors and Posterior Estimates for the Model Parameters

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
A_l	Entr. Tech. Distr. (level)	$\mathrm{N}(0.900, 0.400)$	0.532	[	–	–	–	]
d_A	Entr. Tech. Distr. (width)	Inv. $\Gamma(0.500, 0.200)$	0.496	[	–	–	–	]
a	Entr. Tech. Distr. (norm.)	Calibrated	1.706	[	–	–	–	]
b	Entr. Tech. Distr. (slope)	$\mathrm{N}(0.200, 1.000)$	0.099	[	0.097	–	0.100	]
c	Entr. Tech. Distr. (curv.)	$\mathrm{N}(0.000, 1.000)$	-0.015	[	-0.015	–	-0.015	]
γ	SS Output Growth	$\mathrm{N}(0.500, 0.050)$	0.481	[	0.401	–	0.564	]
$(\beta^{-1} - 1) \times 100$	Discount Factor	$\Gamma(0.250, 0.100)$	0.750	[	–	–	–	]
δ	Capital Depreciation	Calibrated	0.025	[	–	–	–	]
ν	Inverse Frisch	$\Gamma(2.000, 0.750)$	1.568	[	1.298	–	1.913	]
h	Habit	$\mathrm{B}(0.500, 0.200)$	0.633	[	0.512	–	0.749	]
η	Capital Share	$\mathrm{B}(0.300, 0.050)$	0.714	[	0.696	–	0.729	]
λ_p	Price Mark-up	$\mathrm{N}(0.150, 0.050)$	0.150	[	–	–	–	]
ξ_p	Calvo Prices	$\mathrm{B}(0.660, 0.100)$	0.979	[	0.975	–	0.985	]
ι_p	Index Prices	$\mathrm{B}(0.500, 0.150)$	0.200	[	0.095	–	0.324	]
$\phi_{ss} \times 100$	Liquidity Constr.	$\Gamma(5.000, 3.000)$	0.142	[	0.068	–	0.233	]
θ	Borrowing Constr.	$\mathrm{B}(0.300, 0.150)$	0.178	[	0.165	–	0.192	]
$\tau_{q_{ss}} \times 100$	SS Spread	Inv. $\Gamma(1.000, 0.200)$	0.993	[	0.745	–	1.318	]
Bs_{ss}	Liquidity over GDP	$\mathrm{B}(0.300, 0.100)$	0.025	[	0.022	–	0.029	]
gs_{ss}	Govt over GDP	Calibrated	0.170	[	–	–	–	]
τ_k	Capital Tax Rate	Calibrated	0.184	[	–	–	–	]
τ_l	Labor Tax Rate	Calibrated	0.223	[	–	–	–	]
t_B	Fiscal Rule - Debt	$\Gamma(1.000, 0.500)$	0.169	[	0.119	–	0.242	]
t_Y	Fiscal Rule - GDP Growth	$\Gamma(1.000, 0.500)$	0.968	[	0.364	–	2.024	]

Parameter	Description	Prior	Mode	[	5%[2]		95%[2]	]
θ_I	IAC	$\Gamma(2.000, 0.125)$	1.471	[	1.326	–	1.630	]
π_{ss}	SS inflation	$N(0.500, 0.100)$	0.354	[	0.225	–	0.488	]
ρ_i	Taylor Rule inertia	$B(0.600, 0.200)$	0.982	[	0.977	–	0.990	]
ϕ_π	Taylor Rule inflation	$N(1.700, 0.200)$	1.796	[	1.479	–	2.117	]
ϕ_{DY}	Taylor Rule GDP growth	$N(0.125, 0.050)$	0.124	[	0.042	–	0.207	]
θ_π	Inflation MA	Calibrated	0.750	[	–	–	–	]
θ_{DY}	GDP Growth MA	Calibrated	0.750	[	–	–	–	]
ρ_z	AR(1) TFP growth shock	$B(0.600, 0.200)$	0.257	[	0.190	–	0.324	]
ρ_{eta}	AR(1) TFP stat. shock	$B(0.600, 0.200)$	0.980	[	–	–	–	]
ρ_g	AR(1) G shock	$B(0.600, 0.200)$	0.998	[	0.998	–	0.998	]
ρ_β	AR(1) Beta shock	Inv. $\Gamma(0.600, 0.200)$	0.822	[	0.738	–	0.879	]
ρ_p	AR(1) P Mark-up shock	$B(0.600, 0.200)$	0.116	[	0.038	–	0.236	]
ρ_w	AR(1) W Mark-up shock	$B(0.600, 0.200)$	0.961	[	0.939	–	0.975	]
ρ_τ	AR(1) Fin. shock	$B(0.600, 0.200)$	0.994	[	0.994	–	0.995	]
θ_p	MA(1) P shock	$B(0.500, 0.200)$	0.181	[	0.079	–	0.323	]
θ_w	MA(1) W shock	$B(0.500, 0.200)$	0.144	[	0.104	–	0.191	]
σ_z	Stdev TFP Growth Shock	Inv. $\Gamma(0.500, 1.000)$	0.724	[	0.647	–	0.812	]
σ_g	Stdev G Shock	Inv. $\Gamma(0.500, 1.000)$	0.163	[	0.147	–	0.182	]
σ_i	Stdev MP Shock	Inv. $\Gamma(0.100, 1.000)$	0.113	[	0.101	–	0.126	]
σ_τ	Stdev Fin. Shock	Inv. $\Gamma(2.000, 1.000)$	2.790	[	2.073	–	3.800	]
σ_β	Stdev Beta Shock	Inv. $\Gamma(0.100, 1.000)$	1.329	[	1.040	–	1.818	]
σ_p	Stdev P Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	0.127	[	0.108	–	0.151	]
σ_w	Stdev W Mark-up Shock	Inv. $\Gamma(0.100, 1.000)$	1.437	[	1.294	–	1.595	]
$\sigma_{ME_{sp}}$	Stdev ME Spread	Inv. $\Gamma(0.200, 0.500)$	0.334	[	0.296	–	0.380	]
$\sigma_{ME_{fgs}}$	Stdev ME FGS	Inv. $\Gamma(2.000, 0.500)$	5.852	[	5.212	–	6.635	]

Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model.
1 N stands for Normal, B Beta, Γ Gamma and Inv. Γ Inverse-Gamma1 distribution.
2 Posterior percentiles from 3 chains of 100,000 draws generated using a Random Walk Metropolis algorithm.
Acceptance rate 26%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Impulse Responses to Standard Shocks

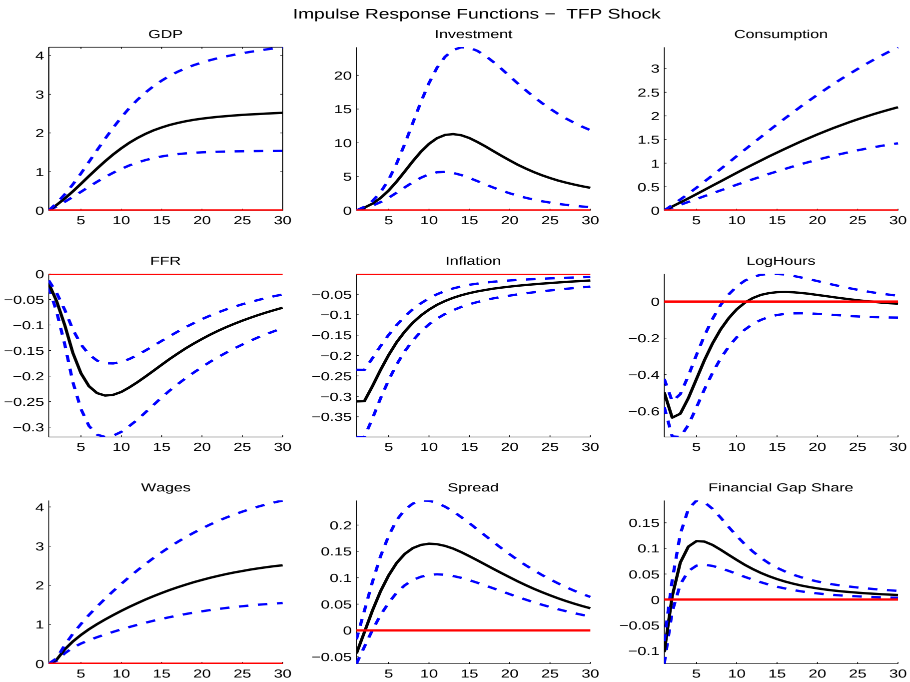

Figure 10: Impulse responses to a one standard deviation TFP shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

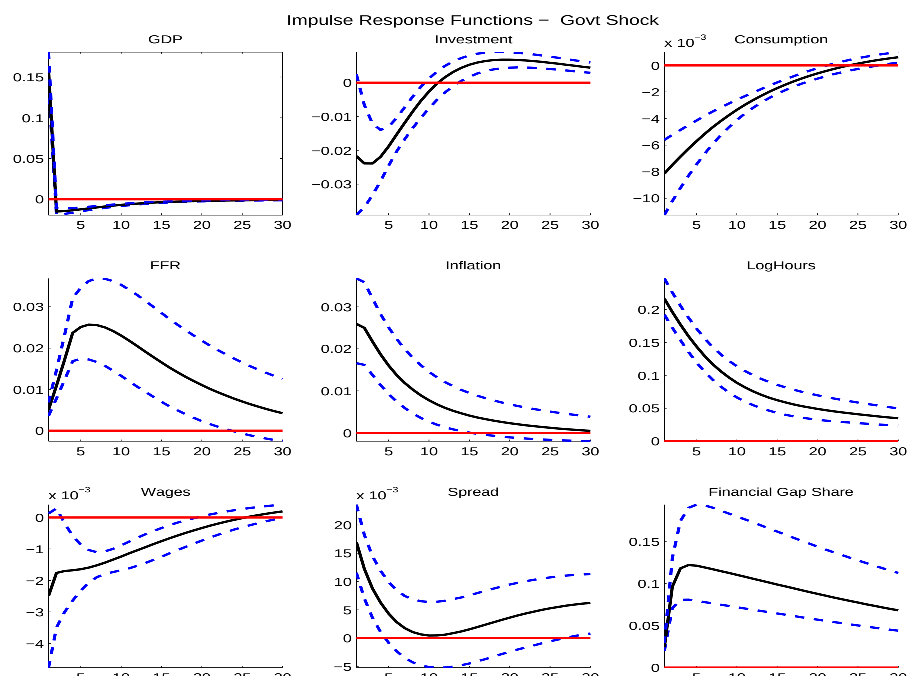

Figure 11: Impulse responses to a one standard deviation government spending shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

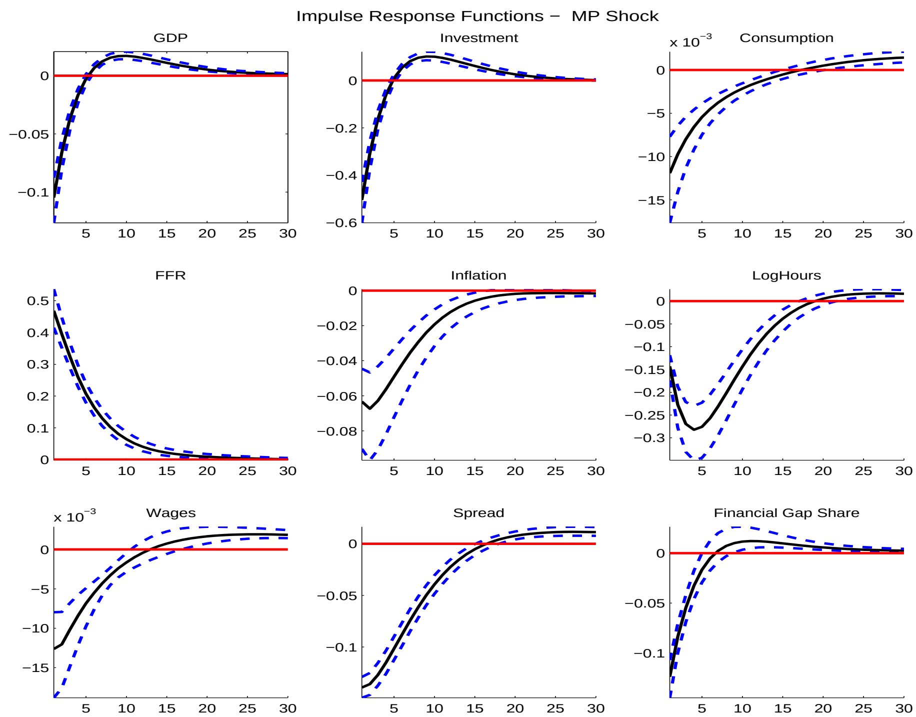

Figure 12: Impulse responses to a one standard deviation monetary policy shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

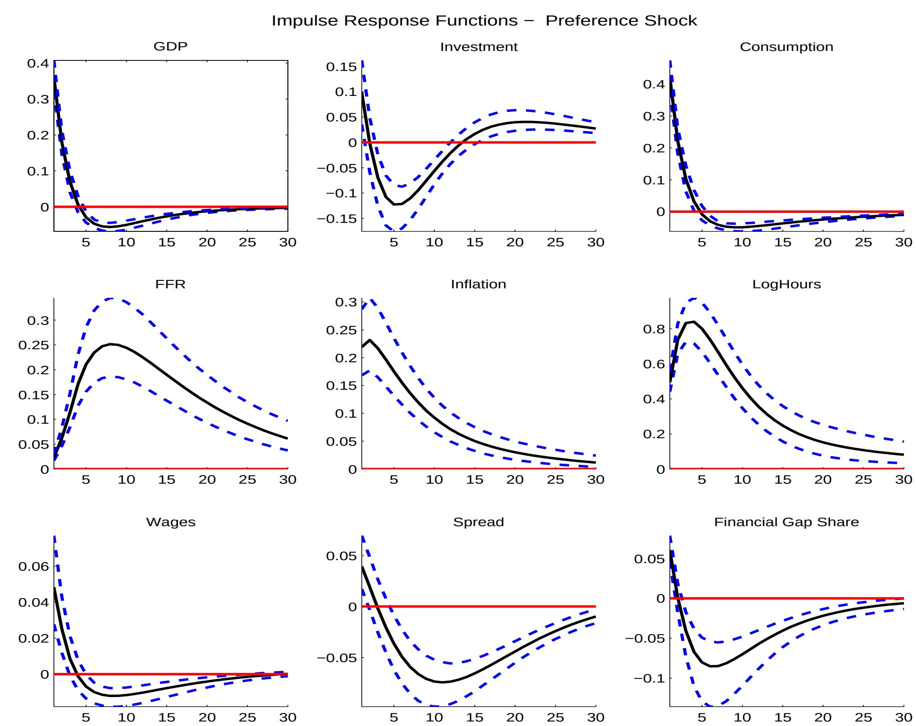

Figure 13: Impulse responses to a one standard deviation time preference shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

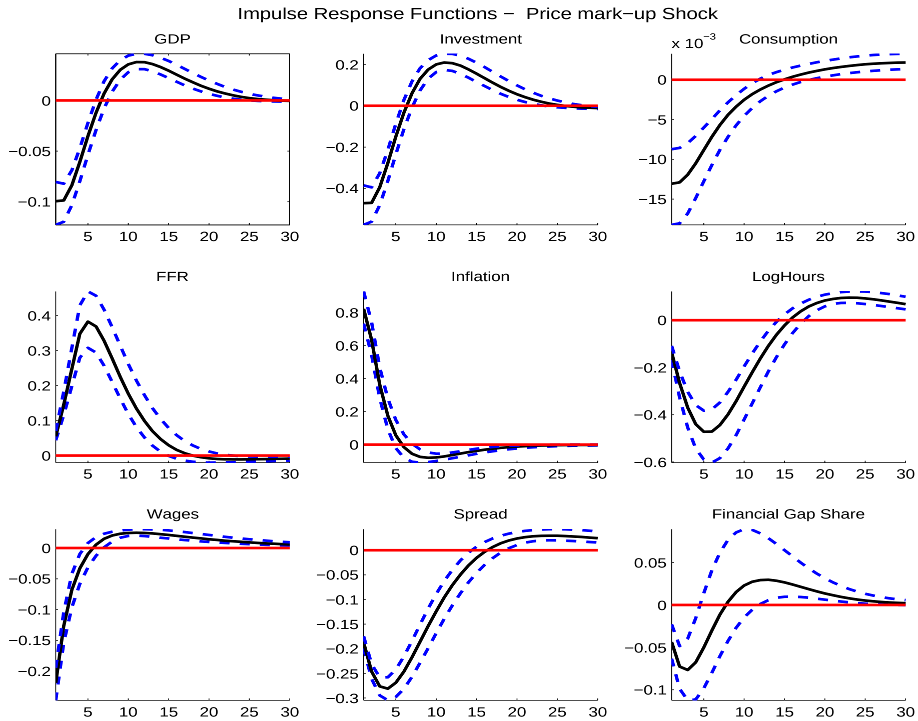

Figure 14: Impulse responses to a one standard deviation price mark-up shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

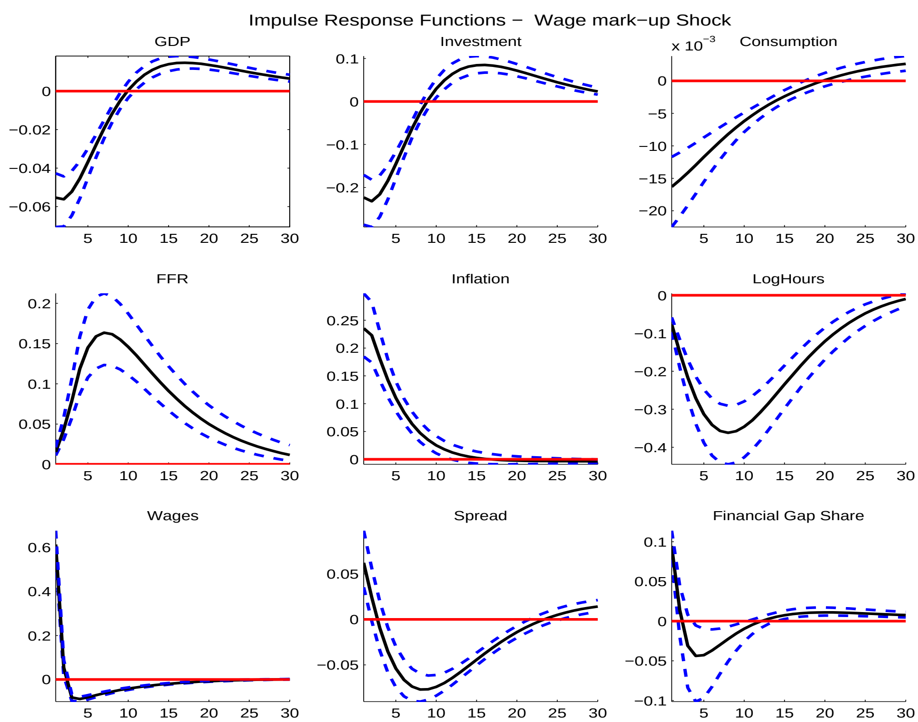

Figure 15: Impulse responses to a one standard deviation wage mark-up shock. The dashed lines represent 90 percent posterior credible sets around the posterior median.

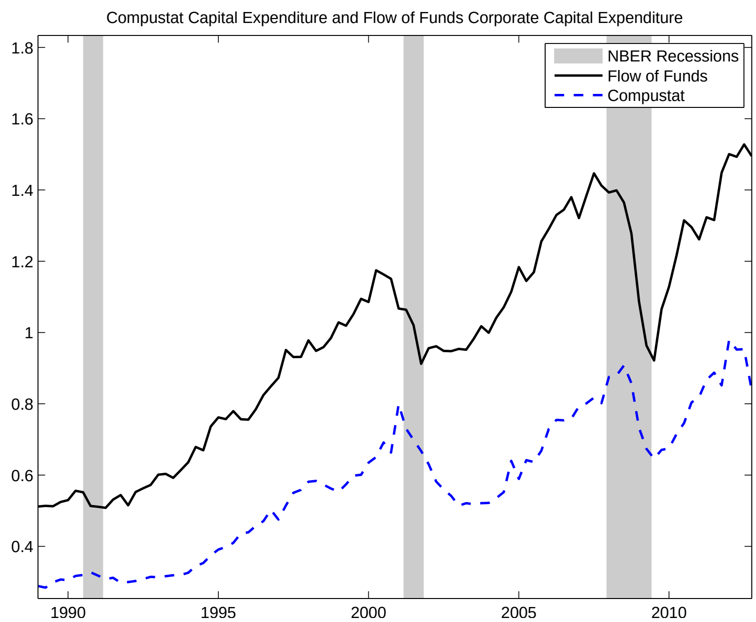

Figure 16: Comparison of capital expenditure of Compustat Firms (blue dashed line) and Non-financial Corporate Sector capital expenditure from the Flow of Funds (black solid line), annualized and seasonally adjusted, in billion of dollars. Sources: Compustat and Flow of Funds Table F.102. Sample period 1989:Q1 - 2012:Q4.

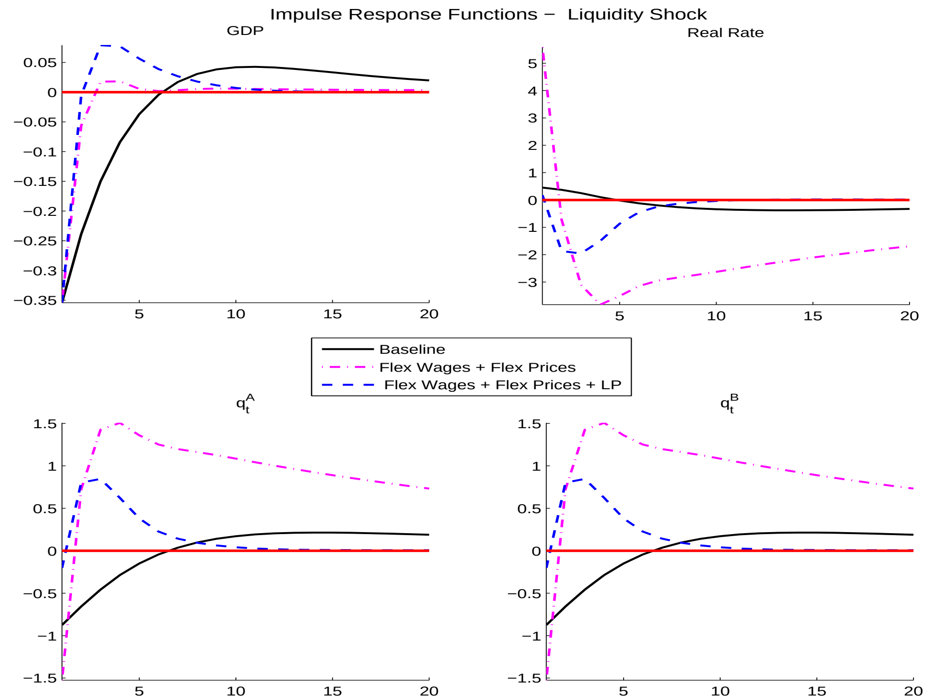

Figure 17: IR Functions to Liquidity Shock: comparison between baseline model with addition of persistent liquidity shock to ϕ(black solid lines), flex prices and wages model (blue dashed lines) and flex price and wage model where the liquidity shock has lower persistence $\rho_\phi = .50$ (dash-dot lines).

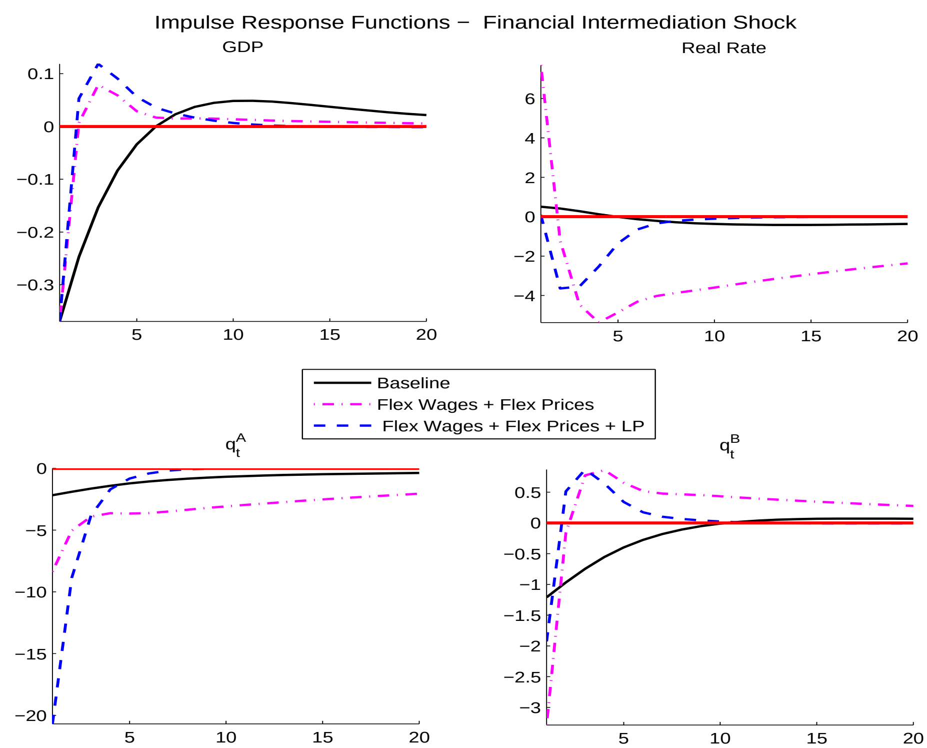

Figure 18: IR Functions to Financial Intermediation Shock: comparison between baseline model (black solid lines), flex prices and wages model (blue dashed lines) and flex price and wage model where the intermediation shock has lower persistence $\rho_\tau = .50$ (dash-dot lines).

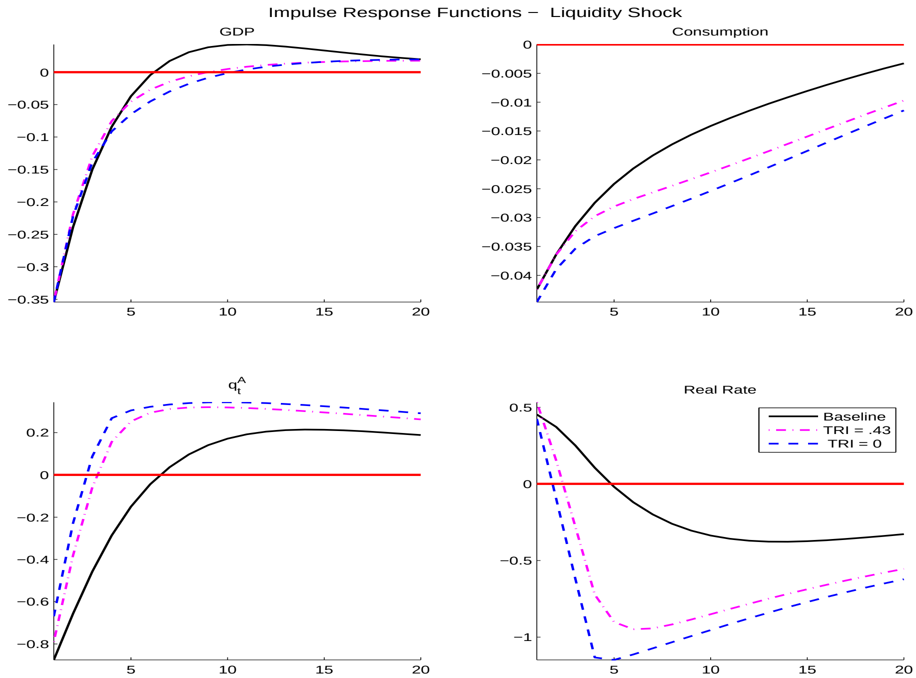

Figure 19: IR Functions to Liquidity Shock: comparison between baseline model (black solid lines), model with $\rho_i = 0.43$ (blue dashed lines) and model with $\rho_i = 0$ (dash-dot lines).

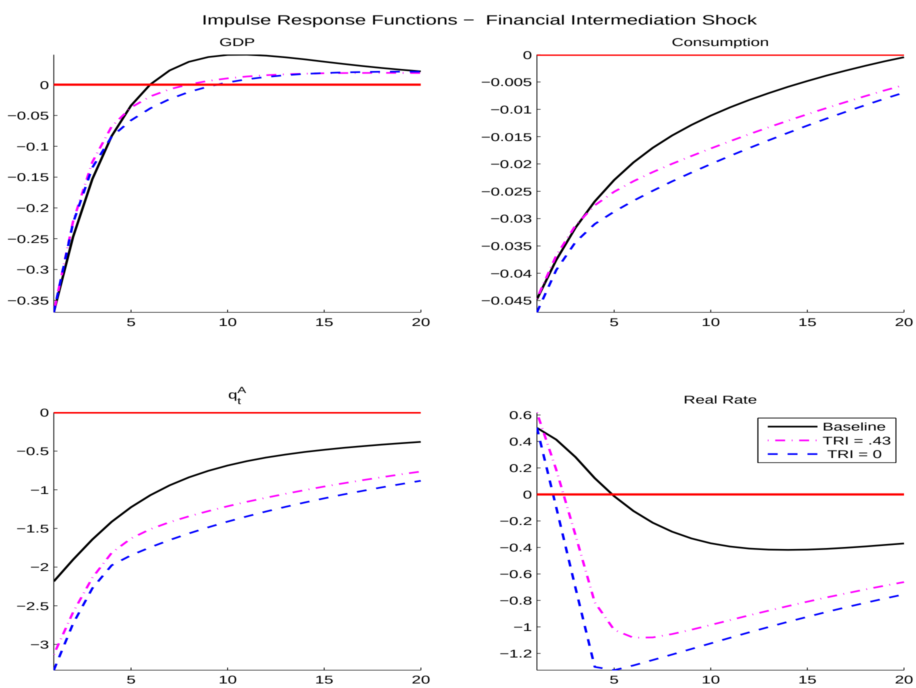

Figure 20: IR Functions to Financial Intermediation Shock: comparison between baseline model (black solid lines), model with $\rho_i = 0.43$ (blue dashed lines) and model with $\rho_i = 0$ (dash-dot lines).