Abstract

How important are financial friction shocks in business cycles fluctuations? To answer this question, I use micro data to quantify key features of US financial markets. I then construct a dynamic equilibrium model that is consistent with these features and fit the model to business cycle data using Bayesian methods. In my micro data analysis, I establish facts that may be of independent interest. For example, I find that a substantial 33% of firm investment is funded using financial markets. The dynamic model introduces price and wage rigidities and a financial intermediation shock into Kiyotaki and Moore (2008). According to the estimated model, the financial intermediation shock explains around 40% of GDP and 70% of investment volatility. The estimation assigns such a large role to the financial shock for two reasons: (i) the shock is closely related to the interest rate spread, and this spread is strongly countercyclical and (ii) according to the model, the response in consumption, investment, employment and asset prices to a financial shock resembles the behavior of these variables over the business cycle.

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1 Introduction

Is the financial sector an important source of business cycle shocks? My model analysis suggests that the answer is ‘yes’. I find that financial sector shocks account for 40% and 70% 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, which may be of independent interest, is a characterization of how important financial markets are for investment. To this end, I analyze the cash flow statements of all the US public non-financial companies included in Compustat. I find that 33% of the capital expenditures of these firms is funded using financial markets. Of this total funding, 75 percent is accomplished by issuing debt and equity and 25 percent is accomplished by liquidating existing assets. My analysis at quarterly frequencies suggests that the financial system is useful to reconcile imbalances between the realization of positive operating cash flows and capital expenditure commitments. Shocks that originate in the financial system and that can promote or halt the transfer of resources to investing firms can have large effects on capital accumulation and productive activity.

To quantify the effects of such shocks on the business cycle, I then build a dynamic general equilibrium model with financial frictions where entrepreneurs, like firms in the Compustat dataset, rely on external finance and trading of financial claims to finance their investments. The model builds on Kiyotaki and Moore (2008), henceforth KM, and modifies their theoretical set-up, introducing price and wage rigidities (Smets and Wouters (2003), Christiano, Eichenbaum, and Evans (2005)), and a financial intermediation shock. Entrepreneurs are endowed with random heterogeneous technologies to accumulate physical capital. Entrepreneurs who receive better technologies optimally decide to raise funds from financial markets 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 follow Chari, Christiano, and Eichenbaum (1995), Goodfriend and McCallum (2007) and Cúrdia and Woodford (2010), and 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 fee to cover their costs. I assume that these intermediation costs vary exogenously over time and interpret these disturbances as financial shocks. When the intermediation fees are higher, the demand for financial assets drops and so does their price. Consequently the cost of borrowing for investing entrepreneurs rises. 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 US macroeconomic time series that spans from 1989 to 2010. I include the high-yield corporate bond spread as one of the observables to identify the financial shock. I choose priors for financial parameters so that the model estimation can be consistent with Compustat evidence on corporate investment financing during the same sample period. The estimation results show that approximately 40% of the variance of output and 70% of the variance of investment can be explained by financial intermediation shocks. The shock is also able to explain the dynamics of the
real variables that shaped the last recession, as well as the 1991 crisis and the boom of the 2000s.

Why is the financial shock able to explain such a large fraction of business cycle dynamics? The reason for this lies in the ability of the model to generate both booms and recessions of a plausible magnitude and the right positive comovement among all of the real variables, including consumption and investment, 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. This is not a trivial result because in a simple frictionless model, a financial intermediation 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 my model there are two classes of agents: entrepreneurs who optimize their intertemporal consumption profile by trading assets on financial markets and building capital, and workers who consume their labor income in every period. On the intertemporal margin, increased financial intermediation costs lower the real rate of return on financial assets, discourage savings and investment and induce entrepreneurs to consume more in the current period. Additionally, the shock induces a drop in aggregate demand that translates into a downward shift in the demand for labor inputs. If workers cannot reoptimize their wages freely, the decrease in labor demand translates into a large drop in the equilibrium amount of hours worked. As a result, the wage bill falls and so does workers’ consumption. The drop in workers’ consumption dominates over the rise in entrepreneurs’ consumption and the reduction in hours amplifies the negative effect of the shock on aggregate output.

My modeling of the financial intermediation wedge is clearly reduced-form, but is inspired by work from Kurlat (2009) on the macroeconomic amplification effects of adverse selection in trading of financial securities. He builds a theoretical model where lemons are traded on financial markets alongside assets of good quality (Akerlof (1970)). If savers have only partial information on the quality of claims they buy, they expect to incur portfolio losses that are larger when the share of lemons traded on the market is big. In his set-up, an aggregate shock that raises asset prices, favors sales of good quality assets and reduces the expected losses for savers induced by the purchase of lemons. In particular, Kurlat (2009) shows that this adverse selection friction maps into a model with homogeneous equity claims where financial transactions are hit by a tax wedge. In my work, I translate this tax wedge into a financial intermediation cost in the spirit of Chari, Christiano, and Eichenbaum (1995), Goodfriend and McCallum (2007) and Cúrdia and Woodford (2010). Moreover I assume the cost to be time-varying and to be subject to exogenous independent shocks over time.

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 imperfection 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, followed by Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999) who first introduced similar frictions in dynamic general equilibrium models. Among research that explores the role of shocks that originate on financial markets as possible drivers of cyclical fluctuations, Christiano, Motto, and Rostagno (2010) estimate a general equilibrium model of the US and Euro Area economies, where 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 30% of fluctuations in aggregate output.

My model is close in its set-up to KM. They focus on financial market transactions and on the aggregate implications of a shock to the degree of liquidity of private assets. The liquidity shock takes the form of a drop in the fraction of assets that can be liquidated to finance new investment projects. Their model, where prices and wages are perfectly flexible, has two unappealing features. First of all, 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. Secondly, the primary impact of the KM 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. To obtain the right comovement of asset prices and output, I introduce random disturbances in the financial intermediation technology.

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)’s focus is on the period of the 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 in the past 20 years.

The paper is structured so to offer an empirical description of corporate investment financing from the Compustat quarterly data in section 2. Section 3 describes the features of the model. Section 4 discusses the estimation strategy, the prior selection on the model parameters and significant moments. Section 5 presents the results and section 6 concludes.

2 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 characterize what fraction of the total investment carried out by firms within a quarter relies on some form of financial market intermediation.

The Flow of Funds table for corporations (table F.102) report a measure of the "Financing Gap" for the aggregate of US corporations. This variable is defined as the difference between internal funds generated by business operations for the aggregate of firms, $CF_t^O$, and total expenditures on physical capital, $CAPX_t$:

\[
\text{Financing Gap} = FG_t = CF_t^O - CAPX_t.
\]
In periods when the financing gap assumes negative values, the aggregate of corporations rely on financial markets and draws resources from the rest of the economy to cover a fraction of capital expenditures. On the other hand, when the variable assumes positive values, firms on average generate enough cash from their business operations to cover their physical investments and lend resources to the rest of the economy. This variable is not informative on the degree of dependence of single corporations on financial markets, to the extent that 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.

To avoid this problem, preliminary work by Chari and Kehoe (2009) looks at annual cash flow data for Compustat firms. In particular, they sum the financing gaps over those firms that do not produce cash flows large enough to cover their investment ($CF^O_t - CAPX_t < 0$). They then 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.

To obtain a similar statistic, I here follow a slightly different methodology than Chari and Kehoe (2009). First of all, I focus on Compustat quarterly cash flow data to quantify the extent of short-term cash-flow imbalances of the firms that are not visible at the annual frequency. I then assume that dividends paid out to equity holders are treated as a non-avoidable commitment for firms, similarly to interests on debt. Finally, I recognize that firms’ negative financing gap may reflect the realization of negative cash flows within a quarter, $CF^O_{e,t} < 0$, rather than a deficit caused by large capital expenditures. Negative operating cash flows reveal that some firms access financial markets to fund their working capital needs.

Quarterly data on cash flow statements are available in Compustat only starting from 1984, while a consistent break-down of quarterly cash flows in their components is only available since 1989. I therefore base my analysis on the sample period that goes from 1989Q1 to 2010Q1 and find that firms rely on financial markets to cover around 33% of their total capital expenditures.

I start my analysis from the observation that for a generic firm $e$, within a period $t$, the variation of liquid assets on its balance sheet ($\Delta CASH_{e,t}$) has to equal the difference between the operating cash flow generated by its business operations ($CF^O_{e,t}$) and net cash receipts delivered to debt and equity holders ($CF^D_{e,t}$, $CF^E_{e,t}$), reduced by the amount of cash used within the period to carry out net financial or physical investments ($CF^I_{e,t}$):

$$\Delta CASH_{e,t} = CF^O_{e,t} - (CF^D_{e,t} + CF^E_{e,t}) - CF^I_{e,t}$$

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 ($CF^{EO}_{e,t}$), so that I can find the firm-level equivalent of the financing gap as:

$$FG_{e,t} = (CF^O_{e,t} - CAPX_{e,t}) = CF^D_{e,t} + (DIV_{e,t} + CF^{EO}_{e,t}) + (NFI_{e,t} + \Delta CASH_{e,t}).$$

If operating cash flows, $CF^O_{e,t}$, are higher than capital expenditures $CAPX_{e,t}$, then firm $e$ reports a financing surplus:
it is able to self-finance its investment in physical capital and to use the extra resources to pay dividends, \(DIV_{e,t}\), buy back shares or pay back its debt obligations \((CF^E_{e,t} + CF^D_{e,t} > 0)\). Alternatively, the firm can use its surplus to increase the stock of financial assets on its balance sheet or its cash reserves \((NFI_{e,t} + \Delta CASH_{e,t} > 0)\).

If instead \((CF^O_{e,t} - CAPX_{e,t})\) is negative, the firm shows a negative financing gap that can be funded by relying on external investors to subscribe new debt or equity securities \((CF^D_{e,t} + CF^E_{e,t} < 0)\), by liquidating assets \((NFI_{e,t} < 0)\) or depleting deposits and cash-reserves \((\Delta CASH_{e,t} < 0)\).

\[
\begin{align*}
\text{Financing Gap Net of Dividends} & = (CF^D_{e,t} + CF^E_{e,t} - \Delta CAPX_{e,t}) + (NFI_{e,t} + \Delta CASH_{e,t}).
\end{align*}
\]  
(2)

To be consistent with the empirical observation from the finance literature that firms tend to smooth out their dividends payouts over time and treat them as a form of unavoidable remuneration to their shareholders (Lintner (1956), Fama and Babiak (1968), Leary and Michaely (2008)), I redefine the financing gap by subtracting dividends from the operating cash flows on the left-hand side of (2). As a result, the financing gap definition that I adopt becomes:

\[
\begin{align*}
\text{Financing Gap Net of Dividends} & = (CF^D_{e,t} + CF^E_{e,t} - \Delta CAPX_{e,t}) - (NFI_{e,t} + \Delta CASH_{e,t}).
\end{align*}
\]  
(3)

In each quarter, I compute the amount in (3) 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 \(t\):

\[
FG_{TOT}^t = \sum_e |FG_{e,t}| \mathbb{1}\{FG_{e,t} < 0\}.
\]  
(4)

I also recognize that a fraction of those firms that report a negative financing gap in each quarter do so because they register a negative operating cash flows. Firms that report \(CF^O_{e,t} < 0\) access financial markets to fund part of their operating expenses. Despite the relevance that working capital financing may have in conditioning production decisions and in driving the demand for financial intermediation of firms, I choose to abstract from it and to concentrate on financial needs that arise in connection to the accumulation of physical capital only. Consequently, I subtract the amount of negative cash-flows reported in every period from the total financing gap in (4) and define the quarterly Financing Gap Share, \(FGS_t\), as the ratio of the financing gap related to physical investment just described and the total capital expenditure across all firms:

\[
FGS_t = \frac{FG_{TOT}^t - \sum_e |CF^O_{e,t}| \mathbb{1}\{FG_{e,t} < 0, CF^O_{e,t} < 0\}}{\sum_e CAPX_{e,t}}.
\]  
(5)

Table 1 in the Appendix shows that from 1989Q1 and 2010Q1, the average of the financing gap share, \(FGS_t\), amounts to 33.15% of total investment, with a standard deviation of 5%:

\[
\overline{FGS} = \frac{\sum_t FGS_t}{T} = 33.15\%.
\]
The share of capital expenditures that relies on financial intermediation is substantial. This result suggests that shocks that can affect financial markets’ ability to transfer new resources to firms in need can potentially have a large impact on capital accumulation.

In the same table I report what fraction of the total financing gap defined in (4) arises due to working capital needs and is excluded from the definition of the Financing Gap Share in (5). I define this ratio as the average over time of the contribution of negative operating cash flows, \( CF_{c,t}^{O} \), to the total financing gap:

\[
WKS = \frac{1}{T} \sum_{t} \left| CF_{c,t}^{O} \right| \frac{1 \{ FG_{c,t} < 0, \; CF_{c,t}^{O} < 0 \}}{FG_{t}^{TOT}} = 26\%
\]

and find that around 26% of firms’ total financial dependence is connected to funding operating expenses.

Moreover, I report the Financing Gap Share statistics computed over annual and quarterly data using Chari and Kehoe (2009)’s definition of financing gap in (2). By direct comparison of their methodology with mine, I can compute and report the share of total financing gap that arises by treating dividends as an unavoidable commitment rather than disposable resources. I find that dividend payouts amount to around 23% of the total financing gap in (4).

Figure 1 shows the evolution of the Financing Gap Share in (5) (black solid line) along the sample period and compares it with an interpolated version of the annual series from Chari and Kehoe (2009) (red dashes line) and with a series computed using their methodology on quarterly data (blue dashed line). The three series are highly correlated, but the average of the quarterly data is, as expected, larger.

What are the cyclical properties of the Financing Gap Share series in figure 1? Reliance on financial markets seems to be growing along periods of economic expansion, especially during the boom of the ’90s and in the 2000s. All three recessions in the sample seem to start with a sudden, but limited, drop in the financing gap share. Overall the dynamics of the series along recessions seems to be driven by large drops in capital expenditures, the denominator of equation (5), rather than by falls in the financing gap at the numerator. During periods of economic contraction, investment seems to drop by more than the amount of resources that firms obtain through external credit and liquidation of assets on their portfolio.

The right-hand-side of equation (3) suggests breaking down the negative financing gaps into the sources of funds that help fund it. In particular the information available in Compustat allows me to determine what fraction of the financing gap is covered by transfers from equity and debt holders and what fraction is instead funded by liquidation of assets on firms’ balance sheets. In particular, I find that debt and equity intakes amount to an average of 73.42% of the total financing gap along the same time frame (see table 1):

\[
\frac{CF^{D} + CF^{EO}}{FG} = 73\%
\]

while the remaining 27% is covered by portfolio liquidations and changes in cash reserves.

Figure 2 reports the evolution of portfolio liquidations as a share of the financing gap over the sample considered. The graph suggests that the relative importance of asset liquidations versus debt and equity intakes is increasing in recessions. Assets illiquidity can be a concern for firms investment capabilities, although recessions seem to be
characterized mostly by a reduced inflow of external finance per unit of investment undertaken (figure 2).

The data in figure 2 shows some important features. Positive realizations of the series represent quarters when firms liquidate assets or deplete cash reserves. Negative realizations instead represent episodes where 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 90s, when the share of corporate mergers and acquisitions had risen to 15% of US GDP in 1999 alone, compared to an average of 4% during the 1980s, (Weston and Weaver (2004)). Another important feature of the data is the difference in the importance that portfolio liquidations acquire in the 2000s, compared to their relative weight in the 90s. Asset liquidations as a sources of financing seem relatively less important in the first half of the sample (average contribution amounts to 19.74% of financing gap), while they receive considerably more weight in the second half (34.27%).

3 The Model

In this section I describe a model that can capture the features of firms’ investment financing in the Compustat quarterly data, where entrepreneurs can borrow external resources or liquidate assets on financial markets to finance new investment opportunities.

The basic economy described in this section consists of a unit measure of entrepreneurs and a unit measure of households, employment agencies that aggregate specialized labor inputs supplied by households, perfectly competitive financial intermediaries (banks), competitive producers of a homogeneous consumption good, intermediate goods producers who act in regime of imperfect competition, and capital producers who transform final goods into ready-to-install capital goods. The government is composed of a monetary authority and a fiscal authority.

Entrepreneurs own the capital stock of the economy and rent it to the intermediate producers in exchange for a competitive rate of return. Each entrepreneur can decide to increase his capital stock by buying capital goods from the capital producers and installing them. Entrepreneurs, however, possess different installation technologies, randomly assigned over their population in every period. These represent investment opportunities of different appeal. In an economy with no financial markets, each entrepreneur is forced to use his own income and his own technology, even when inefficient, if he wants to save over time. If financial markets are perfect, however, the entrepreneurs who possess the best technologies will be able to borrow resources from less efficient ones. They will be able to sell financial claims on their assets that offer a better rate of return on savings to those entrepreneurs who only know of inefficient ways of installing new capital.

In the model I propose here, financial markets are not perfect. Exogenous limits are imposed on the ability of entrepreneurs to raise external sources of financing. As in KM, entrepreneurs can only write a limited number of equity claims on the new investment that they want to undertake. They also can sell only a limited quantity of assets to obtain liquid funds to re-invest in the efficient technology. Moreover, banks are in charge of transferring savings from those entrepreneurs with worse technologies to the more efficient ones. In the spirit of Kurlat (2009), Chari, Christiano, and Eichenbaum (1995) and Cúrdia and Woodford (2010), I introduce a reduced-form cost of intermediation between
the two subsets of agents that can be imagined as a necessary burden paid to overcome some sort of asymmetric information on the quality of traded assets that arises between potential sellers and potential buyers of financial claims.

Households are composed of workers who supply differentiated labor on a monopolistic market, for the production of the final good. Employment agencies aggregate the differentiated labor into homogeneous work hours and supply them to the intermediate producers.

Government finances a stream of exogenous public expenditures and fiscal transfers to the households by levying distortionary taxes on labor income and on the rate of return on capital and by issuing one-period risk-less government bonds. The monetary authority sets the level of the risk-free rate.

### 3.1 Entrepreneurs

As in KM, entrepreneurs own the capital stock of the economy. They can accumulate physical capital if they receive a good technology draw. They can issue claims on their assets to borrow and increase their investment capacity. Last, they can decide to forgo investment opportunities that are not remunerative and instead lend resources to more efficient entrepreneurs, in exchange for the rate of return on the new capital they produce.

At the beginning of the period, a snapshot of each entrepreneur’s balance sheet expressed in terms of units of assets will include his capital stock, \( K_{e,t-1} \), the equity claims acquired in previous periods from other entrepreneurs on the financial market, \( N_{e,t-1}^{\text{others}} \) and interest bearing government bond holdings, \( R_{t-1}B_{e,t-1} \) on the assets side:

\[
\begin{array}{|c|c|}
\hline
A & L \\
\hline
Q_tK_{e,t-1} & Q_tN_{e,t-1}^{\text{sold}} \\
Q_tN_{e,t-1}^{\text{others}} & \\
R_{t-1}B_{e,t-1} & \text{Net Worth} \\
\hline
\end{array}
\]

On the liability side, entrepreneurs regularly sell claims on their capital stock to others, so that part of their \( K_{e,t-1} \) is backed by \( N_{e,t-1}^{\text{sold}} \). Assuming that each unit of homogeneous capital is represented by one unit of equity, so that the two assets share the same expected stream of returns, it is possible to define a unique state variable:

\[
N_{e,t} = K_{e,t} + N_{e,t}^{\text{others}} - N_{e,t}^{\text{sold}}
\]

as the net amount of claims held by entrepreneur \( e \). Entrepreneurs’ net worth is then defined as the difference between assets and liabilities and will be composed of units of equity \( N_{e,t-1} \), evaluated at their nominal market value, \( Q_t \) and bonds \( R_{t-1}B_{e,t-1} \).

At the beginning of each period, entrepreneur \( e \) earns a return on his equity holdings and interest on his government bonds. In every period, entrepreneurs are endowed with a random technology, \( A_{e,t} \sim U[A_{\text{low}}, A_{\text{high}}] \), that they can use to install capital goods and transform them into units of capital inputs. When it comes to the decision to sell or
accumulate assets, any entrepreneur can choose to install new capital units, $K_{e,t}$, or to trade on financial markets to buy or sell equity claims from other entrepreneurs, $N_{e,t}^{other}$, $N_{e,t}^{sold}$. At the start of the period entrepreneur $e$ observes:

1. the price at which he can buy equity claims from the financial intermediaries, $Q_{t}^{B}$
2. the price at which he can sell equity claims to the intermediaries, $Q_{t}^{A}$
3. the relative price at which he can buy and install one new unit of capital goods using his own technology, $A_{e,t}$: $\frac{P_{K,t}}{A_{e,t}}$.

More formally, entrepreneur $e$ maximizes his life-time utility of consumption:

$$\max_{s=0}^{\infty} \sum \beta^{s} b_{t+s} \log(C_{e,t+s})$$ (6)

subject to a flow of funds constraint:

$$P_{t}C_{e,t+s} + P_{t+s}^{K}i_{e,t+s} + Q_{t+s}^{B} \Delta N_{e,t+s}^{+} - Q_{t+s}^{A} \Delta N_{e,t+s}^{-} + P_{t+s}B_{e,t+s} = (1 - \tau^{k}) R_{t+s}^{K} N_{e,t+s-1} + R_{t+s-1}^{R} B_{e,t+s-1}$$ (7)

where $P_{t}$ is the price of the consumption good, $P_{t}^{K}$ is the price of capital goods charged by capital producers, $Q_{t}^{B}$ is the nominal price at which he can buy equity claims, $Q_{t}^{A}$ the one at which he can sell claims, $R_{t}^{k}$ and $R_{t}^{B}$ are respectively the nominal rate of return on capital and on risk-free government bonds, $B_{t}$ and liquidity and $\tau^{k}$ is the marginal tax rate on capital income.

The entrepreneur receives income from his assets at the beginning of the period and uses it to purchase consumption goods, $C_{t}$, at price $P_{t}$, capital goods $i_{e,t}$, at price $P_{t}^{K}$, equity claims $\Delta N_{e,t+s}^{+}$ at price $Q_{t}^{B}$ and government bonds at price $P_{t}$. Some entrepreneurs may find convenient to sell equity claims $\Delta N_{e,t+s}^{-}$ at a price $Q_{t}^{A}$. For now I am assuming that $Q_{t}^{A} \leq Q_{t}^{B}$, so that no arbitrage opportunity exists for entrepreneurs on the financial market for equity. This will be derived as an equilibrium result when discussing the role of financial intermediaries in section 3.2.

An entrepreneur can increase his equity stock by purchasing and installing capital goods $i_{e,t}$ by means of the technology $A_{e,t}$, where $A_{e,t} \sim U[A^{low}, A^{high}]$. He can also increase his assets by purchasing new equity claims from financial markets $\Delta N_{e,t+s}^{+}$, while he can decrease them by selling equity claims, $\Delta N_{e,t+s}^{-}$:

$$N_{e,t+s} = A_{e,t+s}i_{e,t+s} + \Delta N_{e,t+s}^{+} - \Delta N_{e,t+s}^{-} + (1 - \delta) N_{e,t+s-1}.$$ (8)

Moreover, the sale of financial claims is constrained exogenously as in KM. Entrepreneurs who decide to purchase and install capital goods can write claims on a fraction $\theta A_{e,t+i_{e,t}}$ of their new capital stock and sell it on the market. Similarly, entrepreneurs may find it convenient to sell old equity units to finance the installation of the new ones. I assume that in each period in time, they can sell up to a fraction $\phi$ of their existing assets:

$$\Delta N_{e,t+s}^{-} \leq \theta A_{e,t+s}i_{e,t+s} + \phi (1 - \delta) N_{e,s+t-1}.$$ (9)
Note that the discount factor $\beta^t b_t$ 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 $\varepsilon_t^b \sim iidN(0, \sigma_t^2)$.

The maximization problem (6), subject to (7), (8) and (9) and complemented with the non-negativity constraints:

$$i_{c,t+s} \geq 0$$

$$\Delta N^+_t \geq 0$$

$$\Delta N^-_{t} \geq 0$$

$$B_{c,t+s} \geq 0$$

can be solved at time $t+s$ for the optimal levels of:

$$\{C_{c,t+s}, i_{c,t+s}, \Delta N^+_{c,t+s}, \Delta N^-_{c,t+s}, N_{c,t+s}, B_{c,t+s}\}$$

given a set of prices and rates of return:

$$\{P_t, P^K_t, Q^B_{t+s}, Q^A_{t+s}, R^K_t, R^B_{t+s}\}$$

a draw of the installation technology $A_{c,t+s}$, a given portfolio of assets $\{N_{c,t+s-1}, B_{c,t+s-1}\}$ at the start of the period and a realization of the aggregate shocks.

Given as new capital and old equity units are equivalent assets and offer the same stream of expected returns in the future, entrepreneurs will always treat them as perfect substitutes.

Following Kurlat (2009), I posit the existence of a solution where a fraction $\chi_{s,t}$ of entrepreneurs decide to sell claims up to their constraint (9) to borrow resources and use their good technology to install new capital goods. I call these agents Sellers. Another portion $\chi_{k,t}$ prefer to take advantage of their technology of intermediate quality without buying or selling claims (Keepers). The remaining lot is composed of entrepreneurs with bad technology draws who prefer to buy financial claims from the banks (Buyers) to installing capital in their backyard.

Given that $Q^B_{t+s} \geq Q^A_{t+s}$, depending on the technology level for each entrepreneur it can be that entrepreneurs decide to install capital goods and sell claims on the financial markets so to borrow resources, install capital goods using their own income, or forgo installation of capital goods and buy claims on other entrepreneurs’ capital stock (fig. 1).

- **SELLERS** (index $e = s$): $P^K_t \leq Q^A_t$.

In this case, the relative price of a unit of installed capital, $P^K_t / A_{s,t}$, is lower than the real price at which the entrepreneur can issue new equity claims or sell old ones, $Q^A_t$, as well as lower than the price at which he can buy financial claims on other people’s capital stock, $Q^B_t$. The entrepreneur can then profit from building new physical assets at a relative
price \( \frac{p^K_t}{A^K_{t-1}} \) and selling equity claims to the financial intermediaries at price \( Q^A_t \). The optimal decision then implies that the entrepreneur borrows the largest amount possible from other entrepreneurs:

\[
\Delta N^+_{s,t} = \theta A_{s, t} i_{s,t} + \phi (1 - \delta) N_{s,t-1}
\]

(11)

and avoids buying assets from the market:

\[
\Delta N^+_{s,t} = 0
\]

(12)

I can also shows that, in analogy with KM, in steady state entrepreneurs with a good technology will use up their returns on liquid assets but will not accumulate new ones. I solve the model assuming that the economy does not depart from this allocation and that:

\[
B_{s,t} = 0.
\]

(13)

Substituting (11), (12) and (13) into (7), Sellers’ budget constraint in real terms becomes:

\[
C_{s,t} + \tilde{Q}^A_{s,t} N_{s,t} = (1 - \tau^k) R^K_{s,t} N_{s,t-1} + R^B_{s,t-1} B_{s,t-1} + \left[ Q^A_t \phi + \tilde{Q}^A_{s,t} (1 - \phi) \right] (1 - \delta) N_{s,t-1}
\]

(14)

with:

\[
\tilde{Q}^A_{s,t} = \frac{p^K_{s,t} - \theta q^A_t}{1 - \theta}
\]

where the right-hand-side of (14) is the net worth of a generic seller, \( s \).

- **KEEPERS** (index \( e = k \)): \( Q^A_t \leq \frac{p^K_t}{A^K_{t-1}} \leq Q^B_t \)

The relative price of a unit of installed capital, \( \frac{p^K_t}{A^K_{t-1}} \), is higher than what the market maker pays for each equity claim sold or issued, \( Q^A_t \), but lower than the price at which entrepreneurs can acquire new equity from others, \( Q^B_t \). As a result, the entrepreneurs will not draw resources from financial markets by issuing new claims or selling their assets:

\[
\Delta N^-_{k,t} = 0
\]

nor will they buy financial assets:

\[
\Delta N^+_{k,t} = 0, \quad B_{k,t} = 0
\]
so that their budget constraint (7) in real terms becomes:

\[ C_{e,t} + \frac{P^K}{A_{k,t+s}} N_{k,t} = (1 - \tau^k) R^K N_{k,t-1} + R^B B_{k,t-1} + \frac{P^K}{A_{k,t}} (1 - \delta) N_{k,t-1} \]  \( (15) \)

- **BUYERS** (index \( e = b \)): \[ \frac{P^K}{A_{b,t}} \geq Q^B_t \]

The relative price of a unit of installed capital, \( \frac{P^K}{A_{k,t+s}} \), is higher than both the market price of equity \( Q^B_t \) and of the amount obtained from market makers for each units of equity sold or issued, \( Q^A_t \). These entrepreneurs will decide not install new physical capital but will acquire financial claims at their market price \( Q^B_t \). Savers enjoy the lowest rate of return on each unit of equity among entrepreneurs, as they suffer from the result of having an inefficient technology and having to bear a portion of the intermediation cost. Buyers can accumulate government bonds, \( B_{b,t} \), in non-arbitrage with equity claims, to self-insure and overcome their future borrowing and liquidity constraints on equity sales in the event that a good technology draw arrives in the next few periods. Their budget constraint in real terms will then become:

\[ C_{b,t} + Q^B_t N_{b,t} + B_{b,t} = (1 - \tau^k) R^K N_{b,t-1} + R^B B_{s,t-1} + Q^B_t (1 - \delta) N_{b,t-1} \]  \( (16) \)

The three budget constraints (14), (15), (16) now display the net worth of each kind of entrepreneur on their right-hand side. By properties of the log-utility function that characterizes this group of agents, optimal consumption at each point in time can be obtained as a fixed fraction \((1 - \beta b_t)\) of the entrepreneur’s net worth. Appendix A characterizes the optimal bundle of consumption, investment and asset holding for all three types of entrepreneurs.

### 3.2 Financial Intermediaries

Financial intermediaries (or banks) manage the transfer of resources between Sellers and Buyers of financial claims.

In each period, a multitude of intermediaries compete to acquire equity claims from Sellers, \( \Delta N^{-}_i,t \), at price \( Q^A_t \) and sell the same quantity \( \Delta N^{+}_s,t = \Delta N^{+}_s,t \) to Buyers at a price \( Q^B_t \). To do this, they bear an intermediation cost equal to \( \tau^t Q^A_t \) for each financial claim they process. Their nominal profits are then:

\[ \Pi^I_t = Q^B_t \Delta N^{+}_{i,t} - (1 + \tau^I_t) Q^A_t \Delta N^{-}_{i,t} \]  \( (17) \)

where units sold and bought represent the same number of units of capital so that:

\[ \Delta N^{+}_{i,t} = \Delta N^{-}_{i,t} \]  \( (18) \)

Perfect competition among intermediaries implies that their profits are equal to zero in equilibrium so that:

\[ Q^B_t = (1 + \tau^I_t) Q^A_t \]

The ‘bid’ price, \( Q^B_t \), offered to buyers, is equal to the ‘ask’ price, \( Q^A_t \), augmented by the spread, \( \tau^I_t \).
I assume that the intermediation costs $\tau_t$ 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 $\varepsilon_t^\tau \sim N (0, \sigma^2_{\tau})$.

A shock that increases the intermediation cost, reduces the expected return on savings to the Buyers by raising $Q^B_t$. At the same time, it lowers the amount of resources that are transferred to investing entrepreneurs for each unit of equity sold. The price of equity claims sold by investing entrepreneurs, $Q^A_t$, falls and their cost of borrowing rises. The immediate result of the negative shock on $\tau_t^q$ is that investment drops with potential effects on output and consumption dynamics, discussed at length in section 3.

How can we rationalize this reduced-form description of financial intermediation? In a different model, with heterogeneous equity claims, Sellers can be assumed to possess private information on the quality of their assets and on the their future payoffs. Some assets are of good quality while others can be lemons and a Buyer cannot distinguish the two before a transaction with a Seller is finalized. Kurlat (2009) follows Akerlof (1970) and shows that, in a dynamic general equilibrium model similar in flavor to KM, sales of good quality assets is pro-cyclical and respond to aggregate shocks. After a persistent negative productivity shock, for example, current and future returns on capital decrease, aggregate savings are reduced and the price of financial assets plummets. This induces entrepreneurs who wish to finance their investment opportunities to hold onto their good quality assets, waiting for better opportunities in the future. Lemons are worthless and sellers always have an incentive to place them on the market at any price. The composition of asset quality on financial market worsens and this increases the adverse selection problem: the higher probability of purchasing a lemon asset on the market will drive buyers demand for those claims even lower, generating an amplification effect on the drop of the asset price and on the value of net worth of entrepreneurs in the economy. In particular, Kurlat (2009) shows that an adverse selection friction in his model with lemon and non-lemon assets is equivalent to a model with homogeneous equity claims like mine, where financial transactions are hit by a tax wedge. In his formulation, the tax wedge is a reduced form representation of the share of lemon claims over total claims traded on the market. In Kurlat’s formulation, this tax wedge evolves endogenously and depends positively on the share of lemons traded in every period and the proceeds from the tax are rebated to the government. The wedge introduces a spread between the expected cost of borrowing perceived by Sellers and the expected return on savings perceived by Buyers. I assume that this cost is proportional to the amount of claims traded and that it follows an exogenous random process and can be hit by a series of iid shocks over time.

### 3.3 Final Good Producers

At each time $t$, competitive firms operate to produce a homogenous consumption good as a combination of differentiated intermediate goods. These products are aggregated in the final good sector according to a standard Dixit-Stiglitz technology of the kind:

$$Y_t = \left[\int_0^1 Y_t(i)^{1+\lambda_{p,t}} di\right]^{1+\lambda_{p,t}}$$
where $Y_t$ is a homogenous consumption good, $Y_t(i)$ are the inputs supplied by the intermediate goods' sector and $\lambda_{p,t}$ is the degree of substitutability between the differentiated inputs. The log of $\lambda_{p,t}$ follows an ARMA(1,1) exogenous process:

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

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

Firms purchase intermediate goods $Y_t(i)$ from their monopolistic producers at prices $P_t(i)$ and sell the homogeneous final good $Y_t$ at price $P_t$. Standard profit maximization of the final good producers and their zero profit condition allow me to write the price of the final good, $P_t$, as a CES aggregator of the prices of the intermediate goods, $P_t(i)$:

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

and the demand for intermediate good $i$ as:

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

### 3.4 Intermediate Goods Producers

Intermediate goods are produced under monopoly by a firm with the following production technology:

$$Y_t(i) = \max \left\{ A_t^{1-\alpha} K_{t-1} (i)^\alpha L_t(i)^{1-\alpha} - A_t F; 0 \right\}$$

where $K_{t-1}(i)$ and $L_t(i)$ are capital and labor inputs for firm $i$. $A_t$ represents non-stationary labor-augmenting technological progress. The growth rate of $A_t$ follows an exogenous AR(1) process:

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

where $\gamma$ is the steady-state growth rate of output in the economy and $\varepsilon_t^z \sim N \left(0, \sigma_z\right)$. Finally, $A_t F$ is a fixed cost indexed by $A_t$ that is chosen to make average profits across the measure of firms equal to zero in steady state (Rotemberg and Woodford (1993) and Christiano, Eichenbaum, and Evans (2005)).

These intermediate firms minimize their costs and employ homogenous 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 maximize their monopolistic profits, knowing that at each point in time 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, $\xi_p$, are assumed to update their prices according to the indexation rule:

$$P_t(i) = P_{t-1}(i) \pi_{t-1}^{i_p} \pi_1^{1-i_p}$$
where $\pi_t = \frac{p_t}{p_{t-1}}$ is the gross rate of inflation and $\pi$ is its steady state value (Calvo (1983)). This means that a fraction $\xi_p$ of intermediate firms will set their prices as a geometric average of past and steady-state inflation.

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

$$E_t \sum_{s=0}^{\infty} \xi_p^s \beta^s \Lambda_{t+s} \left\{ P_t(i) \left( \prod_{j=0}^{s} \pi_j \right) \right\} Y_{t+s} - \left[ W_t L_t(i) + R^K_t K_t(i) \right]$$

subject to the demand function for good $Y(i)$, (21), and to the production function (22). Households own shares of the intermediate firms: current and future profits (24) are evaluated according to the marginal utility of a representative household, $\Lambda_t^w$.

### 3.5 Capital Producers

Capital good producers operate in regime of perfect competition. Producer $j$ purchases consumption goods from the final goods market, $Y_{j,t}$, and transform them one-to-one into investment goods, $I_{j,t}$:

$$I_{j,t} = Y_{j,t}.$$

Producer $j$ then has access to a capital production technology that allows him to produce $i_{j,t}$ units of capital goods for an amount $I_{j,t}$:

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

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

Producer $j$ sells capital goods to the entrepreneurs on a competitive market at a price $P^K_t$. They will choose the optimal amount of inputs, $I_{j,t}$ as to maximize their profits:

$$\max_{I_{j,t}} \sum_{s=0}^{\infty} \beta^s \Lambda_{t+s} \left\{ P^K_t i_{j,t+s} - P_{t+s} I_{j,t+s} \right\}$$

s.t.

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

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, $\Lambda_t^w$. Free entry on the capital goods producing sector requires profits to be zero in equilibrium, so that the value of capital goods sold in every period $t$ across all capital producers has to be equal to the nominal value of aggregate investment:

$$P^K_t i_t = P_t I_t.$$
3.6 Employment Agencies

The economy is populated by a unit measure of households, indexed by \( w \), who consume and supply a differentiated labor force to employment agencies.

A large number of such agencies combines the differentiated labor into a homogenous labor input \( L_t \), by means of the Dixit-Stiglitz technology:

\[
L_t = \left[ \int_0^1 L_{w,t}^{-1 + \lambda_{w,t}} dw \right]^{1 + \lambda_{w,t}}
\]

where \( \lambda_{w,t} \) is the degree of substitutability of specialized labor inputs, \( L_{w,t} \) 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:

\[
\log (1 + \lambda_{w,t}) = (1 - \rho_w) \log (1 + \lambda_w) + \rho_w \log (1 + \lambda_{w,t-1}) + \varepsilon_t^w + \theta \varepsilon_{t-1}^w
\]

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

Agencies hire specialized labor, \( L_{w,t} \) at monopolistic wages, \( W_{w,t} \), and provide homogenous 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:

\[
L_{w,t} = \left( \frac{W_{w,t}}{W_t} \right)^{-\frac{1 + \lambda_{w,t}}{\lambda_{w,t}}} L_t
\]

The nominal wage paid by the intermediate firms to the employment agencies is equal to:

\[
W_t = \left[ \int_0^1 W_{w,t}^{-\frac{1}{\lambda_{w,t}}} dz \right]^{\lambda_{w,t}}
\]

an aggregation of the different \( W_{w,t} \), the wage granted to household \( w \) in exchange for their specialized labor.

3.7 Households

Households maximize their lifetime utility:

\[
\sum_{s=0}^{\infty} \beta^s \left[ \log (C_{w,t+s} - hC_{w,t+s-1}) - \omega \frac{L_{w,t+s}^{1+u}}{1+u} \right]
\]

subject to their nominal budget constraint:

\[
P_{t+s}C_{w,t+s} + Q_{t+s}^B \Delta N_{w,t,s}^+ - Q_{t+s}^A \Delta N_{w,t,s}^- + B_{w,t+s} = \left( 1 - \tau^L \right) W_{w,t+s} L_{w,t+s} + R_{t+s}^K N_{w,t,s-1} + R_{t+s}^B B_{w,t+s-1} + T_{t+s} + Q_{w,t} + \Pi_{t+s}
\]
and to limited participation constraints on financial markets:

\[ B_{w,t} = 0 \]
\[ \Delta N^+_{w,t} = 0 \]
\[ \Delta N^-_{w,t} = 0 \]

Workers do not borrow or accumulate assets.\(^1\) As a result, in a generic time \( t \) consumption \( C_{w,t} \) is financed by labor earnings, \( W_{w,t}L_{w,t} \), net of distortionary taxes \( \tau L_{w,t} \) and lump-sum transfers, \( T_t \), and profits earned from ownership of intermediate firms, banks and capital producers, \( \Pi_t \). The budget constraint of the household becomes:

\[ P_{t+s}C_{w,t+s} = (1 - \tau L_{w,t+s})W_{w,t+s} + T_{t+s} + Q_{w,t} + \Pi_t \]

In every period only a fraction \( (1 - \xi_w) \) of workers re-optimizes the nominal wage. To make aggregation simple, I assume that workers are able to insure themselves against negative realizations of their labor income that occur in each period \( t \), by trading claims \( Q_{w,t} \) with other workers before they are called to re-optimize \( W_{w,t} \).

The wage is set monopolistically by each household as in Erceg, Henderson, and Levin (2000): a fraction \( (1 - \xi_w) \) of workers supplies labor monopolistically and sets \( W_{w,t} \) by maximizing:

\[ E_t \sum_{s=0}^{\infty} \beta^{t+s} \left\{ \frac{-\omega}{1 + \nu} L_{w,t+s}^{1 + \nu} \right\} \]

subject to the labor demand of the employment agencies:

\[ L_{w,t+s} = \left( \frac{W_{w,t}}{W_t} \right)^{1 + \lambda_{w,t}} \frac{1}{\omega_{w,t}} L_t \]

The remaining fraction \( \xi_w \) is assumed to index their wages \( W_{w,t} \) in every period according to a rule:

\[ W_{w,t} = W_{w,t-1} \left( \pi_{t-1} e^{z_{t-1}} \right)^{\xi_w} \left( \pi e^\gamma \right)^{1 - \xi_w} \]

that describe their evolution as a geometric average of past and steady state values of inflation and labor productivity.

---

\(^1\)Kiyotaki and Moore (2008) derive this as an equilibrium result of their model that holds as long as, in a dynamic equilibrium, the expected rate of return on financial assets is lower than the intertemporal rate of substitutions of households. This is a rather extreme assumption to make, in a model economy where a large fraction of total output is paid out in the form of wage bill. Empirical work on life-cycle consumption dynamics in fact suggest that around 20% of people in the US economy live hand-to-mouth existences (Hurst and Willen (2007), Gurinhas and Parker (2002)). In practice it would be possible to allow for a certain degree of savings at the household level, by introducing idiosyncratic shocks and borrowing constraints, similar to the random investment opportunities that occur along entrepreneurs’ life cycle. Random health expenses (Kiyotaki and Moore, 2005) or unexpected taxation shocks (Woodford, 1990) could in practice create an incentive in favor of households’ precautionary saving behavior. I decided to keep the model tractable and to reflect the evidence available in aggregate data that shows that the business sector in the US economy is able to produce enough savings to finance its own capital expenditures and does not borrow from other sectors of the economy, including households.
3.8 Monetary Authority

The central bank sets the level of the nominal interest rate, $R^B_t$, according to a Taylor rule of the kind:

$$\frac{R^B_t}{R^B_{t-1}} = \left( \frac{R^B_{t-1}}{R^B_t} \right)^{\rho_R} \left[ \left( \frac{\bar{\pi}_t}{\pi} \right) \phi_{\pi} \right]^{1-\rho_R} \left( \frac{\Delta X_{t-s}}{\gamma} \right)^{\phi_Y} \eta_{mp,t}$$  \hspace{1cm} (30)

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, $\pi$, as well as to the deviations of the average growth rate of GDP, $X_t = C_t + I_t + G_t$, in the previous year $\Delta X_{t-s} = \sum_{s=0}^{3} \log X_{t-s} - \log X_{t-s-1}$ from its steady state value $\gamma$. Moreover, $\eta_{mp,t}$ represents an iid monetary policy shock:

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

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

3.9 Fiscal Authority

The government runs a balanced budget in every period. The fiscal authority issues debt, $B_t$, and collects distortionary taxes on labor income and capital rents, $\tau^k R^k_t K_{t-1}$ 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, $R^B_{t-1} B_{t-1}$:

$$B_t + \tau^k R^k_t K_{t-1} + \tau^l W_t L_t = R^B_{t-1} B_{t-1} + G_t + T_t.$$

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:

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

and $\varepsilon^g_t \sim iid N (0, \sigma^2_{g})$.

My model requires an empirically plausible description of the dynamics of the supply of liquid assets that originates from the public authority To obtain that I follow Leeper, Plante, and Traum (2009) in the empirical work they conduct on the dynamics of fiscal financing in a DSGE model of the US economy.\footnote{Differently from Leeper et al. (2009), at this stage I do not allow for taxation on final consumption and do not include correlation among the stochastic components of the fiscal rules.} Similarly to their work, I assume that lump-sum transfers to workers, $T_t$, follow a rule that displays two main features. On one hand, transfers depend on output dynamics and can act as automatic stabilizers along the business cycle. On the other hand fiscal variables respond to deviations of the debt to GDP ratio, $B_t / X_t$, from a target level, $BoX$, and so to keep the stock of debt stationary along time. This insures 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)). To obtain a fiscal rule that resembles the one in Leeper, Plante, and Traum (2009) de-trended model 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 $BoY$ from a specific target, $BoY$:

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

Transfers then increase when output growth falls below its steady state value. On the other hand, transfers fall when $B_t/Y_t$ increases, 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 (as in Woodford (1990)): different agents accumulate government bonds than those who bear the burden of taxation. Workers do not save, so that they are not able to smooth out their fiscal contribution along time. Entrepreneurs, on the other hand, do not save for tax-smoothing purposes, but accumulate government bonds to self-insure to overcome their borrowing and liquidity constraints on equity sales in the event that a good investment opportunity arrives.

### 3.10 Aggregation and Market Clearing

Aggregation across entrepreneurs is made easy by the log-preferences assumption and by independence of the realizations of installation technology idiosyncratic shocks, $A_{e,t}$, with the amount of capital and bonds assets that agents enter the period with. Log-utility implies linearity of their consumption, investment and portfolio decisions with respect to the state variables, $N_{t-1}$ and $B_{t-1}$.

An equilibrium in this economy is defined as a sequence of prices and rates of return $\{P_t, P^K_t, Q^A_t, Q^B_t, W_t, R^K_t, R^B_t\}$ such that:

- final goods producers choose input $\{K_{t-1}, L_t\}$ and output $\{Y_t\}$ levels to maximize their profits subject the available technology;
- intermediate goods producers set their prices $\{P_t (i)\}$ to maximize their monopolistic profits subject to the demand from final producers (21) and their production function (22);
- capital producers choose the optimal level of input and output $\{Y^I_t, i_t\}$ that maximize their profits (25) under their technological constraint (26);
- entrepreneurs choose optimal consumption, investment, equity sales and purchases as well as asset levels:

$$\{C_{e,t}, i_{e,t}, \Delta N^+_{e,t}, \Delta N^-_{e,t}, N_{e,t}, B_t\}$$

---

3 Appendix A presents the complete set of optimality conditions of the entrepreneurs’ problem, under the assumption that the installation technology $A_{e,t}$ follows a Uniform distribution $U[\text{low}, \text{high}]$. This assumption allows me to derive a closed form aggregate expression for the optimal amount of investment carried out by sellers.
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 (9) and the non-negativity conditions (10);

- Banks maximize their profits (17), to intermediate an amount of equity claims $\Delta N_t^+ = \Delta N_t^-$ 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, $L_{w,t}$;
- households choose consumption, monopolistic wages to maximize their lifetime utility (28) subject to their flow of funds constraint (29);
- Markets clear. Summing over the individual flow of funds constraints, output at time $t$, $Y_t$, is absorbed by consumption of investors, savers and workers, by investment and government spending and financial intermediation costs:

$$Y_t = \int_b C_s,t ds + \int_k C_k,t dk + \int_b C_b,t db + C_t^W + I_t + G_t + \tau_t q_t \Delta N_t$$

$$= C_t + I_t + G_t + \tau_t q_t \Delta N_t$$

where GDP is instead defined as:

$$X_t = C_t + I_t + G_t$$

Total bond supply, $B_t$, has to equal to the sum of buyers’ individual demands:

$$B_t = \int B_{e,t} de = B_t^B$$

The equity market clears when the aggregate equity holdings of the $(1 - \chi_{s,t} - \chi_{k,t})$ measure of buyers are equal to the sum of their depreciated equity stock, $(1 - \chi_{s,t} - \chi_{k,t}) (1 - \delta) N_{t-1}$, plus the aggregate amount of new and old equity that the $\chi_{s,t}$ measure of sellers can issues, $\theta A_t^S I_t^S + \phi (1 - \delta) \chi_{s,t} N_t$:

$$N_{t+1}^B = \theta A_t^S I_t^S + \phi (1 - \delta) \chi_{s,t} N_{t-1} + (1 - \delta) (1 - \chi_{s,t}) N_{t-1}$$

The labor market clears when the amount of hours demanded by intermediate producers equals the total supply of labor from households:

$$\int_0^1 L_t (i) di = \int_0^1 L_{w,t} dw$$

A forthcoming technical appendix contains the derivation of the set of equilibrium conditions of the model.
3.11 Reconciling the Model with the Compustat Cash Flow Analysis

How can I map the model with the empirical analysis on Compustat firms’ cash flows? As already evidenced in section 2, entrepreneurs can be considered as firms who earn operating cash flows from their business operations and use it to finance new capital expenditures.

Starting from the accounting cash flow identity introduced in section 2:

\[
DIV_{e,t} + CAPX_{e,t} - (NFI_{e,t} + \Delta CASH_{e,t}) + \left( CF_{e,t}^D + CF_{e,t}^{EO} \right) = CF_{e,t}^O
\]

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 3:

\[
P_{C_e,t} + \frac{P_{t}^K i_{e,t}}{DIV_{e,t}} - \frac{q_t^A \phi (1 - \delta) N_{e,t-1}}{NFI_{e,t}} + \frac{(B_{e,t-1} - B_{e,t})}{\Delta CASH_{e,t}} - \theta q_t^A A_{e,t} i_{e,t} = R_{K}^N N_{e,t-1} \frac{NFI_{e,t}}{CF_{e,t}^O}
\]

The returns on the equity stock correspond to the operating cash flows. Entrepreneur’s nominal consumption, \(PC_{e,t}\), 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, \(q_t^A \phi (1 - \delta) N_{e,t-1}\), while variations in the amount of liquidity, \(\Delta CASH_{e,t}\), correspond in the model to net acquisitions of government bonds, \(R_{K}^N N_{e,t-1} - B_t\). Finally transfers from debt and equity holders, \(CF_{e,t}^D + CF_{e,t}^{EO}\), correspond to issuances of equity claims on the new capital goods installed, \(\theta q_t^A A_{e,t} i_{e,t}\).

From (32), it is easy to derive the model equivalent of the financing gap share. Entrepreneurs with the best technology to install capital goods (sellers) are willing to borrow resources and to use up their liquid assets to carry on their investment. Their aggregate financing gap over the \(\chi^1_t\) measure of sellers can be written as:

\[
FG_{b,t} = \int \left[ \frac{R_{K}^N N_{b,t-1}}{CF_{b,t}^O} - \frac{PC_{b,t}}{DIV_{b,t}} - \frac{P_{t}^K i_{b,t}}{CAPX_{b,t}} \right] db
\]

\[
= \int q_t^A \phi (1 - \delta) N_{t-1} + \frac{(B_{i-1} - B_{i,t})}{\Delta CASH_{b,t}} - \theta q_t^A A_{b,t} i_{b,t} db
\]

\[
= q_t^A \phi (1 - \delta) \chi^1_t N_{t-1} + \theta A_{b,t} i_{e,t} + R_{i-1}^B \chi^1 B_{s,t-1}.
\]

so that the financing gap share is equal to the ratio of the market value of the resources raised by external finance, \(q_t^A \theta A_{b,t} i_{e,t}\), those raised by liquidation of selling illiquid securities, \(q_t^A \phi (1 - \delta) \chi^1_t N_{t-1}\), and from the sale of liquid assets, \(R_{i-1}^B \chi^1 B_{s,t-1}\) over aggregate investment, \(I_t\):

\[
FG_{S_t} = \frac{q_t^A \phi (1 - \delta) \chi^1_t N_{t-1} + \theta A_{b,t} i_{e,t} + R_{i-1}^B \chi^1 B_{s,t-1}}{I_t}.
\]
4 Estimation

In this section I describe the estimation of the model in section 3 on US data using Bayesian methods. I start with a description of the data and the prior distributions chosen for the model parameters and for certain moments implied by the model. 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 implied by the estimated parameters. I conclude with a description of the smoothed shocks along the sample considered and an historical decomposition of the observed data during the last recession.

4.1 Data and Prior Selection

I estimate the model by Bayesian methods on sample that spans from 1989Q1 to 2010Q1. To estimate the model parameters I use the following vector of eight observable time series, obtained from Haver Analytics:

\[
\begin{bmatrix}
\Delta \log X_t, \Delta \log I_t, \Delta \log C_t, R^K_B, \pi_t, S_p_t, \log (L_t), \Delta \log \frac{W_t}{P_t}
\end{bmatrix}.
\]

The dataset is composed of the log growth rate of real per-capita GDP, \(X_t = C_t + I_t + G_t\), investment, \(I_t\), and aggregate consumption, \(C_t\), the federal funds rate mapped into the model nominal risk-free rate, \(R^K_B\), the GDP price deflator, \(\pi_t\), the spread of high-yield B-rated corporate bonds from the Merrill Lynch’s High Yield Master file versus AAA corporate yields of comparable maturity, \(S_p_t\),\(^4\) the log of per-capita hours worked and the growth rate of real hourly wages, \(\frac{W_t}{P_t}\). Notice that I choose the observed spread to map in the model to the difference between the cost that entrepreneurs expect to pay to raise resources on financial markets against the yield on risk-free government bonds, up to a measurement error \(\eta_t^{S_p} \sim N(0, \sigma^2_{\eta^{S_p}})\):\(^5\)

\[S_p_t = E_t \left[ \log \left( \frac{R^K_{t+1} + (1 - \delta) Q^A_t}{Q^A_t} \right) - R^K_B \right] + \eta_t^{S_p}\]

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

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 reported 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. I set a Gamma prior on the steady state annual intermediation cost, \(400 \times \tau_{ss}^\eta\), with mean equal to 250 basis points and standard deviation equal to

\(^4\)The choice of this particular spreads series uniforms to the literature that finds high-yield spreads to have a significant predictive content for economic activity (Gertler and Lown, 1999). In particular these spreads are similar to the mid credit quality spectrum spreads that Gilchrist and Zakrajsek (2008) find to be effective in forecasting unemployment and investment.

\(^5\)The measurement error is intended to capture differences between the AAA corporate bond yields and the federal funds rate, \(R^K_B\), as well as to correct for the imperfect mapping of yields of the return on equity in the model and the yield on state-non-contingent bonds in the data.
50, following \( ? \)'s calibration of intermediation costs to the median spread between the Federal Reserve Board index of commercial and industrial loan rates and the federal funds rate, over the period 1986-2007. I use my analysis of quarterly Compustat cash flow data to set the prior mean and standard deviation on the steady state level of the financing gap share. I use a Beta distribution with mean equal to 0.35 and standard deviation equal to 0.05. Similarly, I use Compustat and Flow of Funds data evidence to choose a prior on the steady state share of the financing gap that is covered by portfolio liquidations of equity claims, \( q^A_{ss} \left( \phi (1 - \delta) \chi_{s,ss} N_{ss} \right) \), and government bonds, \( R^B_{ss} x_{s,ss} B_{s,ss} \):

\[
PL_{ss} = \frac{Q^A_{ss} \left( \phi (1 - \delta) \chi_{s,ss} N_{ss} \right) + R^B_{ss} x_{s,ss} B_{s,ss}}{FG_{ss}} = 23\%.
\]

The prior that I set on portfolio liquidations, \( PL_{ss} \), is a Beta with mean equal to .23 and a standard deviation of .10.

I also help the identification of \( \phi \) by calibrating the share of government liquidity held by entrepreneurs over GDP, \( B_{SS} / Y_t \). I choose to calibrate the amount of liquid assets in circulation in the economy by referring to the flow of funds data on corporate asset levels (table L.102). There, I identify a broad set of government-backed liquid assets held by firms that include Treasuries, Currency, Checking and Saving deposits, Municipal Bonds, and GSE and Agency-backed private bonds. Along the sample considered, corporate holdings of government-backed liquid assets amounts to a share of around 5% of GDP. I therefore fix \( BoY = 0.05 \). This is clearly an understatement of the extent of the average amount of government-backed liquidity over GDP present in the US economy, where the public debt over GDP alone in the same time frame amounts to an average of around 60%. I make this choice because aggregate flow of funds data suggest that firms are not the primary holders of government bonds and because the primary goal of this work is to offer a realistic picture of the balance sheet and cash flow statements of US corporations to study the interaction between financial market conditions and investment decisions.

This brings the discussion to the calibration of fiscal parameters that govern the government budget constraint in steady state:

\[
B_{ss} + \tau^k R^k_{ss} K_{ss} + \tau^l W_{ss} L_{ss} = R^B_{ss} B_{ss} + \left( 1 - \frac{1}{g_{ss}} \right) Y_{ss} + T_{ss}
\]

(33)

To calibrate the tax rates on capital and labor income, \( \tau^k \) and \( \tau^l \), I rely on work on fiscal policy in DSGE models by Leeper, Plante, and Traum (2009). I calibrate the distortionary tax rate on labor and capital income, \( \tau^l \) and \( \tau^k \), to 23% and 18% respectively. 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. Having pinned down the level of government-backed liquidity, the steady state share of lump-sum transfers to households over GDP can be found by solving (33). Transfer dynamics instead govern the aggregate supply of liquid assets in general equilibrium over time by means of the taxation rule:

\[
\frac{T_t / Y_t}{T_{ss} / Y_{ss}} = \left( \frac{\Delta \log Y_{t-s}}{\gamma} \right)^{-\varphi_Y} \left( \frac{B_t / Y_t}{BoY} \right)^{-\varphi_B}
\]

where I calibrate \( \varphi_B = 0.4 \) as in Leeper, Plante, and Traum (2009), a value that makes this fiscal rule passive by reducing transfers when the share of government debt over GDP deviates from its steady state value. This locks the economy on a stable equilibrium path for the growth rate of the price level, with no conflict with the monetary
authority Taylor rule (Woodford (2003)). I fix the elasticity of transfer to deviation of output growth from it steady state, \( \varphi_Y = 0.13 \), at the value that Leeper, Plante, and Traum (2009)’s estimate for transfer reactions to output deviations from steady state in a stationary model. Notice that the transfer policy is countercyclical (when output growth is low, transfers to households are higher).

A few more choices of priors require a brief discussion. In particular, the parameters governing the distribution of idiosyncratic technology of entrepreneurs \( A_e; t \sim U \left[ A_{low}^{low}, A_{high}^{high} \right] \). I set priors on \( A_{low}^{low} \) and on the difference \( d = A_{high}^{high} - A_{low}^{low} \), so that combined with prior mean values for the financial parameters, I can approximately match the steady state share of Sellers in the model with the average share of Compustat firms that rely on financial markets in every quarter, 45%. Finally, I calibrate the quarterly rate of capital depreciation to 0.025, a standard value in the RBC and DSGE literature.

The model is buffeted by iid random innovations:

\[
\begin{bmatrix}
 \varepsilon^{z}_{t}, \varepsilon^{mp}_{t}, \varepsilon^{g}_{t}, \varepsilon^{p}_{t}, \varepsilon^{w}_{t}, \varepsilon^{Tq}_{t}, \varepsilon^{tb}_{t}
\end{bmatrix}
\]

that respectively hit seven exogenous processes: the growth rate of total factor productivity, \( z_t \), deviations from the Taylor rule \( \eta_{mp}; t \), the share of government spending over GDP, \( g_t \), the price and wage mark-ups, \( \lambda^p_t \) and \( \lambda^w_t \), the financial intermediation wedge, \( \tau^q_t \), and the discount factor, \( b_t \).

To conclude, the priors on the persistence parameters for the exogenous processes are all Beta distributions. All have mean equal to 0.6 and standard deviation 0.2, except for the persistence of the neutral technology process, \( \rho_z \). The monetary policy shock is assumed to be iid, because the Taylor rule already allows for autocorrelation in the determination of the risk-free rate. The priors on the standard deviations of the innovations expressed in percentage deviations are inverse Gammas with mean 0.5 and standard deviation equal to 1, excluding the shock to the monetary policy rule, \( \varepsilon^{mp}_{t} \), to the price and wage mark-ups, \( \varepsilon^{p}_{t} \) and \( \varepsilon^{w}_{t} \), and to the discount factor, where the prior has a mean of 0.10 and a standard deviation of 1. I set a prior on the standard deviation of the measurement error on the spread that wants to be conservative with a mean of 15 basis points and a standard deviation of 5.

I complement this set of calibrated parameters and exogenous priors, with prior information on the second moments of the observed variables computed over a pre-sample that spans from 1954q3 to 1988q4. Pre-sample data is available for all the series, excluding the spread, \( Sp_t \). In particular, I follow Christiano, Trabandt, and Walentin (2009) 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. This allows me to help the identification of the highly-parametrized model and to help the estimation procedure to identify regions of the parameter space that can generate business cycle fluctuations of plausible magnitude. Table 4 reports the mean and standard deviations of the moment priors.

## 5 Results

This section reports the results of the Bayesian estimation of the model parameters, devolving particular attention to the coefficients that govern the financial structure of the model.
5.1 Parameter Estimates and Impulse Responses

Table 2 reports the median and 90% confidence intervals for the set of model parameters, while table 5 reports the estimated implied moments of financial variables. I compute the confidence interval by running a Markov chain Monte Carlo exploration of the posterior function.

Estimates of conventional parameters such as those governing price and wage rigidities, the investment adjustment cost friction as well as the degree of persistence and magnitudes of traditional shocks are in line with previous finding in the literature. The estimated steady state quarterly spread ranges between 32 and 84 basis points, despite the prior set around the sample mean of the high-yield spread of 250. The estimation favors steady state equilibria where financial intermediation costs are low and attributes the observed cyclical fluctuations in the spread to large realizations of the financial shock.

Table 5 shows that the estimated steady state value of the financing gap share assumes values that are consistent with Compustat evidence. The 90% confidence interval for the model-implied moment ranges between [0.327, 0.375], compatible with the 33.15% fraction of total investment funded using financial markets found in Compustat data in section 2. The estimated steady state share of the financing gap that is covered by liquidation of assets ranges between [37%, 43%], higher than the 25% average over the whole sample period available in Compustat, but largely within the range of plausible values assumed by the variable along the sample (see figure 2).

Figure 3 reports the impulse responses to a one-standard-deviation financial shock, evaluated at the estimated parameter mode. The persistence of the responses reflects the high autocorrelation of the exogenous process for the intermediation cost, \( q_t \). The plots are intuitive and show a recession of plausible magnitude, where the negative response of output, consumption and investment on impact is significant at a 90% confidence level. When the financial intermediation cost rises, the price of equity sold on the market drops by 4% and the implied spread between the cost of raising external resources of entrepreneurs and the risk free rate rises by 150 basis points on an annual basis. Consequently, investment drops by 2%, while consumption growth is reduced on impact by 0.2%. As a consequence, the growth rate of output falls by 0.6%.

A remarkable feature of the impulse responses in figure 3 is the fact that a negative financial shock in the model delivers a sizable drop in the price of traded assets. The impulse response to a financial intermediation shock can be compared to the dynamics of the model following a negative liquidity shock as modeled in Kiyotaki and Moore (2008). A sudden drop in the liquidity of financial assets can be engineered by exogenously reducing the share of assets that entrepreneurs can sell in every period, \( \phi \), as in KM’s original set-up. Figure 4 reports the impulse responses for output, investment, consumption and the price of equity to an exogenous drop in \( \phi \), evaluated at the posterior mode parameter estimates for my model. The graphs show that by restricting the supply of financial claims on the market, a negative liquidity shock results in a rise in their equilibrium price (bottom right panel). This supply effect dominates over the reduction in the demand for financial claims that have suddenly become less liquid. A similar result is documented by Nezafat and Slavík (2009), who find that in the KM set-up, similar negative shocks to the ability of entrepreneurs to issue new claims and borrow against the new investment (an exogenous drop in \( \theta \) in the model) also deliver a rise in asset prices.
Most recently, Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) show that, in the KM set-up, significant drops in asset prices can be achieved by the interaction of negative liquidity shocks with a binding zero lower bound on the nominal interest rate and price rigidities. If the zero lower bound binds and prices are sticky, the expected deflation generated by a negative liquidity shock translates into a rise in the real interest rate on government bonds. Since bonds are traded in non-arbitrage with equity claims, then the price of capital has to drop significantly to increase the rate of return on equity and re-equilibrate financial markets. The drop in asset prices in the calibration of their model amplifies the negative real effects of a liquidity shock, giving rise to recessive outcomes comparable in size to the Great Depression.

5.2 Model Fit

How well does the model fit the features of the data series used for the estimation? Table 6 reports confidence intervals for the standard deviations of the variables relative to output volatility and compares them to the sample data standard deviations. The table also includes the standard deviations implied by the endogenous priors on the second moments of the observables described in section 5.1.

The model is able to match the absolute volatility of investment, as well as the standard deviation of the risk-free-rate observed in the data. The estimation also delivers standard deviations that are compatible with pre-sample evidence for inflation and hours worked and tries to balance the differences in the volatility of real wages growth across the two periods. The model however comes short when trying to match the standard deviations of output and consumption. As discussed in section 3.7, workers in the model earn and consume a large fraction of total GDP, with no access to financial market that can help smooth out the effect of aggregate shocks on labor earnings over time. The increased volatility in households’ consumption reflects on total output and does not help achieve successful results in matching the relative volatility of the observables (Table 6).

Table 7 reports the autocorrelation coefficients of order one of the observables, compared to those found in the data. The model is able to reproduce significant positive autocorrelations for all the observables. The model matches the autocorrelations coefficients for output, hours and the spread at a 90% confidence level, but falls short in generating the right magnitude of the same coefficients for investment, consumption inflation and real wages.

One more element that prevents the model from matching the autocorrelation structure of real variables is the difference in the first moments of the growth rates of output, consumption and investment in the data during the sample period considered. While GDP grows at a quarterly rate of 0.34%, consumption scores a higher 0.47%, and investment seems to fluctuate around a zero trend. The model, on the other hand, posits that all three variables grow at the same common rate, \( \gamma = [0.26, 0.34] \) with 90% confidence. The estimation procedure observes that on average consumption and investment growth are respectively above and below their steady state level along the sample period. As a consequence, the estimation assigns more weight to the intertemporal preference shock as a candidate for explaining business cycle fluctuations relative to comparable DSGE model estimations in the literature (see variance decomposition in table 8).
5.3 Variance Decomposition

This section quantifies the relative importance of shocks to business cycle fluctuations, by analyzing the unconditional variance decomposition implied by the estimated model.

Table 8 reports the variance decomposition at the mode with the relevant 90% confidence intervals. Each column reports the contribution of different shocks in explaining the total volatility of the observed variables. The sixth column 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 70% of the volatility of investment. The shock is also able to explain 80% of the unconditional variance of the risk-free rate and 60% of inflation’s.

The financial intermediation wedge, \( \tau_t \), maps closely to the observed high-yield spread series. The estimation procedure naturally favors the financial shock over others because it can account alone for 97% of changes in the observed spread, while generating plausible business cycle dynamics (see section 5.5). This result is in line with the view that traditional aggregate shocks are not able to reproduce sizable time-varying risk premia in models where agents show a low degree of risk-aversion (Mehra and Prescott (1985), Hansen and Jagannathan (1991)).

In particular, column 1 in table 8 shows how the neutral technology shock seems to have very limited relevance in explaining aggregate fluctuations. The TFP shock accounts for a modest [4%, 9%] share of GDP volatility, in contrast with the RBC and Neo-Keynesian DSGE empirical literature where this value ranges above 20%. The exogenous nature of the financial intermediation shock can be identified as one of the reasons that drive this result. Following Kurlat (2009), it is plausible to interpret the financial intermediation wedge as a reduced-form representation of an adverse selection friction, that arises on markets with information asymmetries and trading of heterogeneous assets (see Section 3 for more details). Aggregate shocks that increase the marginal product of capital, such as positive TFP shocks, favor trading of good quality assets and ameliorate the adverse selection problem, reducing the intermediation wedge endogenously. This form of interaction and financial amplification of other aggregate shocks is not currently present in the model, but is the subject of my ongoing research efforts.

5.4 Smoothed Shocks and Historical Decomposition of the Last Recession

In this section I present the historical contribution of the financial shock to the dynamics of output growth along the sample and run some counterfactual exercises to study the contribution of aggregate shocks to the dynamics of the last recession.

Figure 5 provides a time series representation of the evolution of quarterly output growth conditional on the presence of financial shocks alone (red dotted line) and compares it to the observed data series (black solid line). The two lines show remarkably similar features and the financial shock seems to drive output growth variations alone in the boom of the 2000s. The shock is also identified as the main cause of the recessions both in 1990-1991, when the junk bond market and the savings and loans collapsed, as well as in 2008-2010, marked by the upheaval on the subprime mortgage market.

Figure 6 offers a closer look at the contribution of shocks in the model to the evolution of output growth during the last recession. I concentrate on the role of the financial shock, as well as of the neutral technology shock and the
two policy shocks, the random deviations from the Taylor rule and the government spending shock. I compute the counterfactual smoothed series for output growth at the posterior mode.

The top panel on the left shows what output growth would have been in absence of the financial shock (red dashed line) compared to the data (blue solid line). According to the estimation, the contraction in output growth observed in the data would have been delayed to the second half of 2008 and be limited in magnitude.

It is interesting to notice how the top right panel suggests that the past recession was characterized by an increase in total factor productivity, in line with recent findings by Fernald (2009). As evidenced by the red dashed line, in absence of positive technology shocks, output would have contracted by an additional 0.5% at the trough and the recovery would have been slower.

The bottom left panel also suggests that government spending shocks played an important role in reducing the impact on output of the recession. In absence of positive government spending shocks, the red dashed line shows that output would have fallen by an additional 1% at the trough. On the other hand, the bottom right panel and the smoothed series of monetary policy shocks in figure 7 seem to suggest that, although the reduction in the fed funds rate helped sustain economic growth at the onset of the recession, monetary policy interventions became ineffective and that the zero-lower bound on the nominal interest rate became binding in the second half of 2008. The series of positive monetary policy shocks in figure 7 suggest that the nominal interest rate has been consistently higher than the value implied by the estimated Taylor rule.6

5.5 Why is the Financial Shock so Important?

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 comovement between consumption and investment observed in the data. 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 different from changes in total factor productivity, that can trigger positive comovement of hours worked, consumption and investment. In fact, any shock that increases the equilibrium quantity of hours worked on impact has to 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.

In this section I explore the reason why the posterior maximization favors the financial shock as the main driver of business cycle fluctuations. I find that nominal rigidities, and in particular sticky wages are the key element in driving aggregate consumption, investment and hours worked in the same direction on impact after a financial intermediation shock.

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6Research by Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) suggests that unconventional monetary policy 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 in place. For estimation purposes, I abstract from imposing the zero lower bound on the nominal interest rate.
5.6 Comovement of investment and consumption

In my model there are two classes of agents: entrepreneurs and households. Entrepreneurs optimize their stream of consumption through time and save by accumulating equity claims as well as government bonds. They do not supply hours worked on the labor market. Households, on the other hand, have no access to financial markets and consume the realization of their income in every period. This feature of the model allows me to intuitively describe the inter-temporal and the intratemporal transmission channels of an intermediation shock, by studying the effects on each of the two sets of agents separately.

Figure 8 shows the impulse response functions of the model variables to a one-standard-deviation shock to the financial intermediation cost. In the figure, I include a break-down of total consumption growth into the contribution of the consumption of entrepreneurs ($C_e^t$) and of the households ($C_w^t$). I compare the impulse responses at the posterior mode (black dashed line) with the impulse responses of the model under the hypothesis that wages are perfectly flexible.

On the intertemporal margin, if the intermediation spread, $\tau^q_t$, rises and intermediation of financial claims becomes more expensive, entrepreneurs with a good investment opportunity perceive an increase in their cost of borrowing: the price of equity claims drops and entrepreneurs can rely on a reduced amount of external resources to install new capital. As a consequence investment, $I_t$, plunges. On the other side of the financial market, entrepreneurs with inefficient technologies expect lower real returns on traded financial assets and consequently reduce their savings and increase their consumption. On aggregate, investment and savings drop, while consumption of entrepreneurs, $C_e^t$, rises.  

On the intratemporal margin, instead, under sticky wages (black dashed line) the model is able to make households’ consumption drop on impact. A drop in the aggregate demand for final goods has two effects. First the drop in aggregate demand translates into a downward shift in the demand for labor inputs. If workers cannot reoptimize their wages, the decrease in labor demand translates into a large drop in the equilibrium amount of hours worked. As a result, the wage bill falls. Secondly, the fall in aggregate demand reduces the marginal costs of intermediate monopolists and increases their price mark-up. The rise in the equilibrium mark-up increases firms’ profits. Profits are zero in steady state, but fluctuate in a dynamic stochastic equilibrium. Households own the intermediate firms and the rise in their profits helps them sustain their consumption after the shock hits. In equilibrium the reduction in the wage bill dominates over the rise in firms’ profits, pushing down households’ and aggregate consumption. The drop in hours amplifies the negative effect of the shock on aggregate production and output and produces the right

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7Recently, Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010) have emphasized that KM’s model of liquidity shocks can produce positive comovement between consumption and investment when the economy is characterized by a certain degree of nominal rigidities. When the liquidity shock hits, aggregate demand falls but prices now can only adjust slowly. What happens to the real rate of interest? This can be defined approximately as the difference between the nominal interest rate and expected future inflation:

$$r^B_t \approx R^B_t - E_t (\pi_{t+1})$$

If prices are expected to drop and the nominal interest rate cannot be decreased, the real interest rate will rise. The price of capital will have to drop to re-establish non-arbitrage between government bonds and equity claims. The collapse in asset prices can reduce the value of entrepreneurs’ net worth and consequently hurt their level of consumption, together with investment. In their set-up, the feedback of the movement in asset prices on net worth and consumption is particularly pronounced when the nominal interest rate hits the zero lower bound: in that case any expected future drop in the price level translates into an increase of the real interest rate of the same magnitude with potential disastrous effects on every component of aggregate output.

8The assumption that households own intermediate firms is controversial, but necessary to keep the entrepreneurs’ optimal consumption, investment and trading decisions tractable.
positive comovement between investment and consumption on impact.

On the other hand, if wages are flexible (blue solid line), the reduction in labor demand translates into lower wages and higher mark-ups for the firms than in the sticky wages case. Higher firms’ profits generate a positive income effect that prompts households to decrease their labor supply. The equilibrium outcome shows a large negative adjustment in the wage rate, while hours worked drop by a lower amount than under sticky wages. Households’ wage bill falls, but they are able to keep a smooth consumption profile by relying on higher firms’ profits. As a consequence, aggregate consumption does not drop on impact.

6 Conclusions

In this paper I have addressed the question of how important are shocks to the ability of the financial sector in driving the business cycle. The main finding of this research is that the contribution of financial shocks to cyclical fluctuations is very large and accounts for around 40% of output and 70% of investment volatility, when estimated on the last 20 years of US macro data.

To establish this result, I have estimated a dynamic general equilibrium model with nominal rigidities and financial frictions where entrepreneurs rely on external finance and trading of financial claims to fund their investments. The model features stylized financial intermediaries (banks) that 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 comovement of investment and consumption that is observed in the data along the business cycles.

References


Chari, V. V. and P. Kehoe (2009). Confronting models of financial frictions with the data. Presentation (mimeo).


APPENDIX A

Equations (14), (15) and (16) are the entrepreneurs’ budget constraint expressed in terms of their net worth. The assumption of log-utility allows me to write optimal consumption for the three sets of entrepreneurs as a linear function of their net worth in real terms:

\[ C_{s,t} = (1 - \beta b_t) \left\{ (1 - \tau^k) r_t^K N_{s,t-1} + r_{t-1}^B B_{s,t-1} + \left[ q_{l,t}^A \phi + q_{s,t}^A (1 - \phi) \right] (1 - \delta) N_{s,t-1} \right\} \]
\[ C_{k,t} = (1 - \beta b_t) \left\{ (1 - \tau^k) r_t^K N_{k,t-1} + r_{t-1}^B B_{k,t-1} + \frac{p_{t}^K}{A_{k,t}} (1 - \delta) N_{k,t-1} \right\} \]
\[ C_{b,t+s} = (1 - \beta b_t) \left\{ (1 - \tau^k) r_t^K N_{b,t-1} + r_{t-1}^B B_{b,t-1} + q_{l,t}^B (1 - \delta) N_{b,t-1} \right\} \]

Substituting back optimal consumption in the flow of funds constraints (7), I can derive the optimal capital accumulation decisions for each category of entrepreneurs in a similar fashion and combine it with the optimal decisions for \( \Delta N_{i_t}^-, \Delta N_{i_t}^+, N_t \) and \( B_t \).

Sellers have good technology draws. They want to install the maximum amount of new capital they can and borrow up to their liquidity constraint (34): their technology is so good that it allows them to build new capital at a real price \( \frac{p_{t}^K}{A_{s,t}} < q_{t}^A \) and resell it at price \( q_{t}^A \) to banks, profiting from the difference on each new unit sold. Clearly their relative price of capital \( \frac{p_{t}^K}{A_{s,t}} \) is lower than the real price at which they could buy assets from the bank, \( q_{t}^B \), so that their net financial acquisitions are equal to zero, \( \Delta N_{s,t}^+ = 0 \). Government bonds sell at non-arbitrage with financial claims on equity, so that also their market rate of return is not appealing to sellers and \( B_{s,t} = 0 \).

\[ \Delta N_{s,t}^- = \theta A_{s,t} I_{s,t} + \phi (1 - \delta) N_{s,t-1} \quad (34) \]
\[ \Delta N_{s,t}^+ = 0 \]
\[ N_{s,t} = (1 - \theta) A_{s,t} I_{s,t} + (1 - \phi) (1 - \delta) N_{s,t-1} \]
\[ B_{s,t} = 0 \]

\[ i_{s,t} = \frac{\beta b_t \left\{ (1 - \tau^k) r_t^K N_{s,t+1} + r_{t}^B B_{s,t-1} + q_{s,t}^A (1 - \phi) (1 - \delta) N_{s,t-1} \right\} - (1 - \beta b_t) q_{l,t}^A (1 - \phi) (1 - \delta) N_{s,t-1}}{(p_{t}^K - \theta q_{t}^A A_{s,t})} \]
\[ = \frac{\beta b_t}{(p_{t}^K - \theta q_{t}^A A_{s,t})} \left\{ (1 - \tau^k) r_t^K N_{s,t-1} + r_{t}^B B_{s,t-1} + q_{s,t}^A (1 - \phi) (1 - \delta) N_{s,t-1} \right\} - \frac{(1 - \beta b_t)}{(1 - \theta)} \frac{1}{A_{s,t}} (1 - \phi) (1 - \delta) N_{s,t-1} \quad (35) \]

Keepers’ technological draw is good, but not enough for them to profit from building capital goods and selling equity claims on them at price \( q_{t}^A \), so that \( \Delta N_{k,t}^- = 0 \). At the same time, their relative price to build new capital is more convenient than the market price that banks charge to purchase new equity claims, so that \( \Delta N_{k,t}^+ = 0 \). Similarly to sellers, it can be shown that keepers in equilibrium don’t buy bonds as their rate of return is lower than the one
granted by their installation technology.

\[
\Delta N_{k,t}^+ = 0 \\
\Delta N_{k,t}^- = 0 \\
N_{k,t} = A_{k,t}I_{k,t} + (1 - \delta) N_{k,t-1} \\
B_{k,t} = 0
\]

Optimal investment is found by substituting optimal consumption and asset holdings in the flow of funds constraint, to obtain:

\[
i_{k,t} = \frac{\beta_b \left\{ (1 - \tau^k) r^t N_{k,t-1} + r^B B_{k,t-1} \right\} - (1 - \beta_b) \left\{ \frac{p_{k+1}^K}{A_{k+1}} (1 - \delta) N_{k,t-1} \right\}}{p_t^K} \\
= \frac{\beta_b}{p_t^K} \left\{ (1 - \tau^k) r^t N_{k,t-1} + r^B B_{k,t-1} \right\} - (1 - \beta_b) \left\{ \frac{1}{A_{k,t}} (1 - \delta) N_{k,t-1} \right\} \tag{36}
\]

Buyers possess the worst technologies among entrepreneurs. They are willing to buy equity claims from banks and forgo using their installation technology. They are also willing to pay the highest price to secure government bonds. They accumulate liquid assets to insure against the possibility of encountering a new investment opportunity in the future and being constrained in their borrowing and in the amount of assets they can sell. Storing government bonds is a way of saving that overcomes the inefficiencies of trading equities through financial intermediaries.

The non-arbitrage condition between equity and government bonds for buyers defines his portfolio decision \( \{ N_{b,t}, B_{b,t} \} \):

\[
E_t \left[ \chi_{s,t+1} \frac{R^B}{C_{t+1}^{s,t+1}} + \chi_{k,t+1} \frac{R^B}{C_{t+1}^{k,t+1}} + \left(1 - \chi_{s,t+1} - \chi_{k,t+1}\right) \frac{R^B}{C_{t+1}^{b,t+1}} \right] \\
= E_t \left[ \chi_{s,t+1} \frac{(1-\tau^k) r^t_N}{C_{t+1}^{s,t+1}} + \left(1 - \chi_{s,t+1} - \chi_{k,t+1}\right) \frac{(1-\tau^k) r^t_N}{C_{t+1}^{b,t+1}} \right] \\
+ \chi_{k,t+1} \frac{(1-\tau^k) r^t_N}{C_{t+1}^{k,t+1}} + \left(1 - \chi_{s,t+1} - \chi_{k,t+1}\right) \frac{(1-\tau^k) r^t_N}{C_{t+1}^{b,t+1}}
\]

where:

\[
\chi_{s,t+1} = \Pr \left\{ \frac{p_{t+1}^B}{A_{e,t+1}} \leq q_{t+1}^A \right\} = pr \left\{ A_{c,t+1} \geq \frac{q_{t+1}^A}{p_{t+1}^B} \right\}
\]

is the probability of becoming a seller at time \( t + 1 \) and:

\[
\chi_{k,t} = \Pr \left\{ q_t^A \leq \frac{p_t^B}{A_{e,t}} \leq q_t^B \right\} = \Pr \left\{ \frac{q_t^B}{p_t^B} \leq A_{c,t} < \frac{q_t^A}{p_t^B} \right\}
\]

is the probability of becoming a keeper, while \( C_{t+1}^{bs}, C_{t+1}^{bk}, C_{t+1}^{bb} \) are future expected consumption levels of a buyer today who will become a seller, a keeper, or stay a buyer in the next period, respectively. They are derived as a
portion of next period’s net worth and are function of period $t$ optimal asset holdings $\{N_{b,t}, B_{b,t}\}$:

$$C^{b_S}_{t+1} = (1 - \beta b_{t+1}) \left\{ (1 - \tau^K) r^K_{t+1} N_{b,t} + r^B_{t} B_{b,t} + [q^A_{t+1} + \bar{q}^A_{s,t+1} (1 - \phi)] (1 - \delta) N_{b,t} \right\}$$

$$C^{b_K}_{t+1} = (1 - \beta b_{t+1}) \left\{ (1 - \tau^K) r^K_{t+1} N_{b,t} + r^B_{t} B_{b,t} + \frac{p^K_{t+1}}{\bar{A}_{k,t+1}} (1 - \delta) N_{b,t} \right\}$$

$$C_{b,t+s} = (1 - \beta b_{t}) \left\{ (1 - \tau^K) r^K_{t} N_{b,t-1} + r^B_{t} B_{b,t} + q^B_{t} (1 - \delta) N_{b,t} \right\}$$


## Tables and Figures

Table 1: Compustat Evidence on Corporate Investment Financing

<table>
<thead>
<tr>
<th>Variable X</th>
<th>Mean(X)</th>
<th>StdDev(X)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FGS</strong></td>
<td>33.15%</td>
<td>4.48%</td>
</tr>
<tr>
<td>FGS - Annual (Chari - Kehoe method)</td>
<td>16.26%</td>
<td>4.53%</td>
</tr>
<tr>
<td>FGS - Quarterly (Chari - Kehoe method)</td>
<td>34.83%</td>
<td>5.47%</td>
</tr>
<tr>
<td><strong>WKS</strong></td>
<td>26.32%</td>
<td>6.13%</td>
</tr>
<tr>
<td><strong>DIVS</strong></td>
<td>22.98%</td>
<td>7.13%</td>
</tr>
<tr>
<td>External Finance / FG</td>
<td>73.42%</td>
<td>24.04%</td>
</tr>
<tr>
<td>Portfolio Liquidations / FG</td>
<td>26.58%</td>
<td>24.04%</td>
</tr>
</tbody>
</table>

Mean and standard deviations of variables. Source: Compustat. Sample Period 1989Q1 - 2010Q1

1. Financing Gap Share of Capital Expenditure defined in equation 5.
4. Share of Total Financing Gap due to working capital needs.
5. Weight of Dividend payouts on Total Financing Gap.
6. Share of Financing Gap funded by external sources (debt and/or equity).
7. Share of Financing Gap funded by portfolio liquidations.
Table 2: Calibrated Values, Priors and Posterior Estimates for the Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Prior(^1)</th>
<th>Mode</th>
<th>5%(^2)</th>
<th>95%(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A^{low})</td>
<td>Entrepreneurs's tech distribution (level)</td>
<td>(N(0.90, .010))</td>
<td>0.878</td>
<td>[0.760 - 1.025]</td>
<td></td>
</tr>
<tr>
<td>(d)</td>
<td>Entrepreneurs's tech distribution (width)</td>
<td>(IG(0.025, 0.05))</td>
<td>0.035</td>
<td>[0.026 - 0.039]</td>
<td></td>
</tr>
<tr>
<td>((\beta^{-1} - 1) \times 100)</td>
<td>Discount factor</td>
<td><em>Calibrated</em></td>
<td>0.900</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(h)</td>
<td>Habit</td>
<td><em>Calibrated</em></td>
<td>0.900</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\log L_{ss})</td>
<td>Labor Supply</td>
<td>(N(2, 0.50))</td>
<td>2.564</td>
<td>[1.615 - 3.211]</td>
<td></td>
</tr>
<tr>
<td>(\nu)</td>
<td>Inverse Frisch</td>
<td>(G(2, 0.50))</td>
<td>1.447</td>
<td>[1.072 - 2.130]</td>
<td></td>
</tr>
<tr>
<td>(\theta)</td>
<td>Borrowing Constraint</td>
<td>(B(0.30, 0.10))</td>
<td>0.238</td>
<td>[0.218 - 0.254]</td>
<td></td>
</tr>
<tr>
<td>(\phi \times 100)</td>
<td>Liquidity Constraint</td>
<td>(G(0.50, 0.10))</td>
<td>0.082</td>
<td>[0.062 - 0.106]</td>
<td></td>
</tr>
<tr>
<td>(BoY)</td>
<td>Liquidity over GDP</td>
<td><em>Calibrated</em></td>
<td>0.050</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\varphi^B)</td>
<td>Fiscal Rule - Debt</td>
<td><em>Calibrated</em></td>
<td>0.500</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\varphi^B)</td>
<td>Fiscal Rule - Output</td>
<td><em>Calibrated</em></td>
<td>0.130</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\tau^k)</td>
<td>Capital Tax Rate</td>
<td><em>Calibrated</em></td>
<td>0.184</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\tau^l)</td>
<td>Labor Tax Rate</td>
<td><em>Calibrated</em></td>
<td>0.223</td>
<td>[ - - - ]</td>
<td></td>
</tr>
<tr>
<td>(\alpha)</td>
<td>Share of Capital</td>
<td>(B(0.30, 0.10))</td>
<td>0.339</td>
<td>[0.317 - 0.362]</td>
<td></td>
</tr>
<tr>
<td>(S'')</td>
<td>Investment Adjustment Costs</td>
<td>(G(2, 0.50))</td>
<td>1.212</td>
<td>[0.895 - 1.940]</td>
<td></td>
</tr>
<tr>
<td>(\lambda_p)</td>
<td>Price Mark-up</td>
<td>(IG(0.15, 0.05))</td>
<td>0.062</td>
<td>[0.048 - 0.080]</td>
<td></td>
</tr>
<tr>
<td>(\xi_p)</td>
<td>Calvo prices</td>
<td>(B(0.70, 0.10))</td>
<td>0.807</td>
<td>[0.734 - 0.846]</td>
<td></td>
</tr>
<tr>
<td>(\iota_p)</td>
<td>Indexation Prices</td>
<td>(B(0.50, 0.15))</td>
<td>0.146</td>
<td>[0.089 - 0.306]</td>
<td></td>
</tr>
<tr>
<td>(\lambda_w)</td>
<td>Wage Mark-up</td>
<td>(IG(0.15, 0.05))</td>
<td>0.129</td>
<td>[0.087 - 0.201]</td>
<td></td>
</tr>
<tr>
<td>(\xi_w)</td>
<td>Calvo wages</td>
<td>(B(0.70, 0.10))</td>
<td>0.735</td>
<td>[0.664 - 0.779]</td>
<td></td>
</tr>
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</table>
Table 3: Calibrated Values, Priors and Posterior Estimates for the Model Parameters (Continued)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Explanation</th>
<th>Prior (^1)</th>
<th>Mode</th>
<th>5% (^2)</th>
<th>95% (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\omega_w)</td>
<td>Indexation Wages</td>
<td>(B(0.50, 0.15))</td>
<td>0.164</td>
<td>[ 0.090</td>
<td>0.235</td>
</tr>
<tr>
<td>(\phi^\pi)</td>
<td>Taylor rule - Inflation</td>
<td>(N(1.7, 0.30))</td>
<td>2.144</td>
<td>[ 1.918</td>
<td>2.299</td>
</tr>
<tr>
<td>(\phi^g)</td>
<td>Taylor rule - Output Growth</td>
<td>(N(0.125, 0.05))</td>
<td>0.284</td>
<td>[ 0.257</td>
<td>0.314</td>
</tr>
<tr>
<td>(\rho^R)</td>
<td>Taylor rule - Persistence</td>
<td>(B(0.60, 0.20))</td>
<td>0.858</td>
<td>[ 0.825</td>
<td>0.877</td>
</tr>
<tr>
<td>(\pi_{ss})</td>
<td>SS Inflation</td>
<td>(N(0.50, 0.10))</td>
<td>0.592</td>
<td>[ 0.548</td>
<td>0.742</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>SS Output Growth</td>
<td>(N(0.30, 0.05))</td>
<td>0.305</td>
<td>[ 0.269</td>
<td>0.342</td>
</tr>
<tr>
<td>(\tau_q)</td>
<td>SS Spread</td>
<td>(N(0.625, 0.10))</td>
<td>0.173</td>
<td>[ 0.087</td>
<td>0.212</td>
</tr>
<tr>
<td>(\theta_p)</td>
<td>MA(1) Price Mark-up</td>
<td>(B(0.80, 0.10))</td>
<td>0.714</td>
<td>[ 0.673</td>
<td>0.853</td>
</tr>
<tr>
<td>(\theta_w)</td>
<td>MA(1) Wage Mark-up</td>
<td>(B(0.80, 0.10))</td>
<td>0.671</td>
<td>[ 0.398</td>
<td>0.772</td>
</tr>
<tr>
<td>(\rho_z)</td>
<td>AR(1) TFP shock</td>
<td>(B(0.40, 0.20))</td>
<td>0.411</td>
<td>[ 0.309</td>
<td>0.480</td>
</tr>
<tr>
<td>(\rho_g)</td>
<td>AR(1) Gov’t spending</td>
<td>(B(0.60, 0.20))</td>
<td>0.978</td>
<td>[ 0.956</td>
<td>0.981</td>
</tr>
<tr>
<td>(\rho_p)</td>
<td>AR(1) Price Mark-up</td>
<td>(B(0.60, 0.20))</td>
<td>0.930</td>
<td>[ 0.895</td>
<td>0.959</td>
</tr>
<tr>
<td>(\rho_w)</td>
<td>AR(1) Wage Mark-up</td>
<td>(B(0.60, 0.20))</td>
<td>0.819</td>
<td>[ 0.791</td>
<td>0.911</td>
</tr>
<tr>
<td>(\rho_{\tau_q})</td>
<td>AR(1) Financial Spread</td>
<td>(B(0.60, 0.20))</td>
<td>0.977</td>
<td>[ 0.966</td>
<td>0.981</td>
</tr>
<tr>
<td>(\rho_b)</td>
<td>AR(1) Intertemporal pref.</td>
<td>(B(0.40, 0.20))</td>
<td>0.991</td>
<td>[ 0.983</td>
<td>0.992</td>
</tr>
<tr>
<td>(\sigma_z)</td>
<td>Stdev TFP Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.496</td>
<td>[ 0.456</td>
<td>0.542</td>
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<tr>
<td>(\sigma_{mp})</td>
<td>Stdev MP Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.123</td>
<td>[ 0.111</td>
<td>0.144</td>
</tr>
<tr>
<td>(\sigma_g)</td>
<td>Stdev Gov’t Spending Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.354</td>
<td>[ 0.321</td>
<td>0.402</td>
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<tr>
<td>(\sigma_p)</td>
<td>Stdev Price Mark-up Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.151</td>
<td>[ 0.121</td>
<td>0.175</td>
</tr>
<tr>
<td>(\sigma_w)</td>
<td>Stdev Wage Mark-up Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.282</td>
<td>[ 0.256</td>
<td>0.346</td>
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<tr>
<td>(\sigma_{\tau_q})</td>
<td>Stdev Financial Shock</td>
<td>(IG(0.50, 1))</td>
<td>4.431</td>
<td>[ 3.981</td>
<td>5.388</td>
</tr>
<tr>
<td>(\sigma_b)</td>
<td>Stdev Preference Shock</td>
<td>(IG(0.50, 1))</td>
<td>0.026</td>
<td>[ 0.024</td>
<td>0.029</td>
</tr>
<tr>
<td>(\sigma_\eta)</td>
<td>Stdev Meas Error Spread</td>
<td>(IG(0.25, 1))</td>
<td>0.525</td>
<td>[ 0.472</td>
<td>0.657</td>
</tr>
</tbody>
</table>

Standard deviations of the shocks are scaled by 100 for the estimation with respect to the model.
1 N stands for Normal, B Beta, G Gamma and IG Inverse-Gammmal distribution
2 Posterior percentiles from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm.
Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Table 4: Priors on Theoretical Moments

<table>
<thead>
<tr>
<th>Moment</th>
<th>Prior Type</th>
<th>Prior Mean</th>
<th>Prior Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Var}(\Delta \log X_t)$</td>
<td>N</td>
<td>1.15</td>
<td>0.18</td>
</tr>
<tr>
<td>$\text{Var}(\Delta \log I_t)$</td>
<td>N</td>
<td>16.35</td>
<td>2.63</td>
</tr>
<tr>
<td>$\text{Var}(\Delta \log C_t)$</td>
<td>N</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td>$R_B^p$</td>
<td>N</td>
<td>0.84</td>
<td>0.23</td>
</tr>
<tr>
<td>$\text{Var}(\pi_t)$</td>
<td>N</td>
<td>0.43</td>
<td>0.10</td>
</tr>
<tr>
<td>$\text{Var}(\log L)$</td>
<td>N</td>
<td>10.74</td>
<td>2.36</td>
</tr>
<tr>
<td>$\text{Var}(S_{pl})$</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\text{Var}(\Delta \log w_t)$</td>
<td>N</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>$\text{Mean}(\text{FGS})$</td>
<td>B</td>
<td>0.35</td>
<td>0.05</td>
</tr>
<tr>
<td>$\text{Mean}(\text{PLS})$</td>
<td>B</td>
<td>0.23</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Estimated steady state level of financing gap share (FGS), external finance over total investment (EXTFIN/I), external finance over financing gap (EXTFIN/FG), portfolio liquidations over total financing gap (PL/FG), share of firms that record negative financing gaps.

Model implied moments are compared with sample averages from Compustat, computed on a sample period from 1989q1 to 2010q1. Posterior percentiles from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm. Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 5: Compustat Moments - Estimated Model vs. Data

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model Median</th>
<th>5%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\overline{\text{FGS}}$</td>
<td>0.3315</td>
<td>0.351</td>
<td>0.327</td>
<td>0.375</td>
</tr>
<tr>
<td>$\text{EXTFIN}_t / \text{FG}_t$</td>
<td>0.73</td>
<td>0.597</td>
<td>0.568</td>
<td>0.624</td>
</tr>
<tr>
<td>$\text{PL}_t / \text{FG}_t$</td>
<td>0.27</td>
<td>0.403</td>
<td>0.376</td>
<td>0.432</td>
</tr>
<tr>
<td>$\text{Pr}(\text{FG}&lt;0)$</td>
<td>0.450</td>
<td>0.567</td>
<td>0.546</td>
<td>0.594</td>
</tr>
</tbody>
</table>

Estimated steady state level of financing gap share (FGS), external finance over total investment (EXTFIN/I), external finance over financing gap (EXTFIN/FG), portfolio liquidations over total financing gap (PL/FG), share of firms that record negative financing gaps.

Model implied moments are compared with data averages. Source: Compustat. Sample period: 1989q1 to 2010q1. Posterior percentiles from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm. Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Table 6: Model Fit : Standard Deviations

<table>
<thead>
<tr>
<th>Observables</th>
<th>Data</th>
<th>Model</th>
<th>Prior Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>5% - 95%</td>
<td></td>
</tr>
<tr>
<td>Stdev(Δ log X_t)</td>
<td>0.63</td>
<td>0.83 [ 0.72 - 0.96 ]</td>
<td>1.07</td>
</tr>
<tr>
<td>Stdev(Δ log I_t)</td>
<td>2.58</td>
<td>2.37 [ 2.01 - 2.79 ]</td>
<td>4.04</td>
</tr>
<tr>
<td>Stdev(Δ log C_t)</td>
<td>0.50</td>
<td>0.69 [ 0.60 - 0.79 ]</td>
<td>0.54</td>
</tr>
<tr>
<td>Stdev(R^B)</td>
<td>0.58</td>
<td>0.74 [ 0.44 - 0.74 ]</td>
<td>0.92</td>
</tr>
<tr>
<td>Stdev(π_t)</td>
<td>0.27</td>
<td>0.53 [ 0.39 - 0.74 ]</td>
<td>0.66</td>
</tr>
<tr>
<td>Stdev(log L_t)</td>
<td>4.75</td>
<td>2.93 [ 1.89 - 4.55 ]</td>
<td>3.28</td>
</tr>
<tr>
<td>Stdev(Sp_t)</td>
<td>0.52</td>
<td>1.20 [ 1.20 - 1.89 ]</td>
<td>-</td>
</tr>
<tr>
<td>Stdev(Δ log w_t)</td>
<td>0.75</td>
<td>0.56 [ 0.48 - 0.66 ]</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Standard deviations of observable variables. Model implied vs. Data.
Posterior percentiles from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm.
Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.

Table 7: Model Fit : Autocorrelations of Order 1

<table>
<thead>
<tr>
<th>Observables</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>5% - 95%</td>
</tr>
<tr>
<td>Corr(Δ log X_t, Δ log X_{t-1})</td>
<td>0.47</td>
<td>0.32 [ 0.13 - 0.48 ]</td>
</tr>
<tr>
<td>Corr(Δ log I_t, Δ log I_{t-1})</td>
<td>0.60</td>
<td>0.23 [ 0.05 - 0.40 ]</td>
</tr>
<tr>
<td>Corr(Δ log C_t, Δ log C_{t-1})</td>
<td>0.51</td>
<td>0.32 [ 0.13 - 0.49 ]</td>
</tr>
<tr>
<td>Corr(R^B, R^B_{t-1})</td>
<td>0.93</td>
<td>0.98 [ 0.94 - 0.99 ]</td>
</tr>
<tr>
<td>Corr(π_t, π_{t-1})</td>
<td>0.52</td>
<td>0.91 [ 0.76 - 0.97 ]</td>
</tr>
<tr>
<td>Corr(log L_t, log L_{t-1})</td>
<td>0.93</td>
<td>0.96 [ 0.88 - 0.98 ]</td>
</tr>
<tr>
<td>Corr(Sp_t, Sp_{t-1})</td>
<td>0.81</td>
<td>0.84 [ 0.57 - 0.95 ]</td>
</tr>
<tr>
<td>Corr(Δ log w_t, Δ log w_{t-1})</td>
<td>0.035</td>
<td>0.49 [ 0.28 - 0.64 ]</td>
</tr>
</tbody>
</table>

Autocorrelation of Order 1 of Observable Variables. Model implied vs. Data
Data source: Haver Analytics, Sample period 1989Q1 - 2010Q1
Posterior percentiles from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm.
Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Table 8: Posterior Variance Decomposition

<table>
<thead>
<tr>
<th></th>
<th>TFP</th>
<th>MP</th>
<th>Gov't</th>
<th>Price Mark-up</th>
<th>Wage Mark-up</th>
<th>Financial</th>
<th>Preference</th>
<th>Meas. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \log X_t$</td>
<td>6.424</td>
<td>12.502</td>
<td>11.278</td>
<td>7.366</td>
<td>5.988</td>
<td>42.518</td>
<td>13.141</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[4.320 - 9.317]</td>
<td>[9.112 - 16.611]</td>
<td>[8.483 - 14.803]</td>
<td>[5.162 - 10.244]</td>
<td>[3.925 - 9.219]</td>
<td>[34.861 - 49.935]</td>
<td>[10.967 - 15.720]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$\Delta \log I_t$</td>
<td>5.999</td>
<td>7.328</td>
<td>0.338</td>
<td>10.485</td>
<td>3.422</td>
<td>69.122</td>
<td>2.766</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[4.037 - 8.940]</td>
<td>[5.519 - 9.769]</td>
<td>[0.211 - 0.526]</td>
<td>[7.245 - 14.932]</td>
<td>[2.393 - 4.935]</td>
<td>[63.219 - 74.146]</td>
<td>[1.975 - 4.055]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$\Delta \log C_t$</td>
<td>17.880</td>
<td>7.800</td>
<td>6.066</td>
<td>2.427</td>
<td>18.950</td>
<td>6.410</td>
<td>39.809</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[13.612 - 23.116]</td>
<td>[5.420 - 10.886]</td>
<td>[4.245 - 8.435]</td>
<td>[1.553 - 3.668]</td>
<td>[15.524 - 22.700]</td>
<td>[4.011 - 9.447]</td>
<td>[35.876 - 43.996]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$R^p_t$</td>
<td>0.572</td>
<td>0.785</td>
<td>0.897</td>
<td>0.751</td>
<td>1.141</td>
<td>88.970</td>
<td>6.588</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[0.375 - 0.874]</td>
<td>[0.595 - 1.071]</td>
<td>[0.538 - 1.656]</td>
<td>[0.521 - 1.120]</td>
<td>[0.760 - 1.713]</td>
<td>[84.468 - 91.649]</td>
<td>[4.483 - 10.908]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$\pi_t$</td>
<td>8.532</td>
<td>2.548</td>
<td>0.506</td>
<td>11.394</td>
<td>5.578</td>
<td>64.111</td>
<td>6.582</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[5.485 - 13.472]</td>
<td>[1.725 - 3.720]</td>
<td>[0.295 - 0.951]</td>
<td>[8.751 - 15.076]</td>
<td>[3.478 - 8.428]</td>
<td>[55.592 - 71.306]</td>
<td>[4.765 - 9.929]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$\log L_t$</td>
<td>2.807</td>
<td>4.633</td>
<td>7.458</td>
<td>22.564</td>
<td>40.322</td>
<td>18.039</td>
<td>2.417</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[1.184 - 5.908]</td>
<td>[2.842 - 7.012]</td>
<td>[4.734 - 13.214]</td>
<td>[15.388 - 32.349]</td>
<td>[27.729 - 53.072]</td>
<td>[10.928 - 27.978]</td>
<td>[1.811 - 3.232]</td>
<td>[0.000 - 0.000]</td>
</tr>
<tr>
<td>$S_{pt}$</td>
<td>0.001</td>
<td>0.000</td>
<td>0.056</td>
<td>0.019</td>
<td>0.001</td>
<td>96.937</td>
<td>0.007</td>
<td>2.972</td>
</tr>
<tr>
<td></td>
<td>[0.001 - 0.003]</td>
<td>[0.000 - 0.001]</td>
<td>[0.030 - 0.128]</td>
<td>[0.010 - 0.035]</td>
<td>[0.000 - 0.002]</td>
<td>[94.269 - 98.327]</td>
<td>[0.004 - 0.012]</td>
<td>[1.598 - 5.639]</td>
</tr>
<tr>
<td>$\Delta \log w_t$</td>
<td>11.747</td>
<td>2.571</td>
<td>2.152</td>
<td>22.756</td>
<td>53.235</td>
<td>3.559</td>
<td>3.119</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>[8.303 - 16.211]</td>
<td>[1.481 - 4.062]</td>
<td>[1.402 - 3.236]</td>
<td>[17.489 - 29.148]</td>
<td>[46.370 - 60.596]</td>
<td>[2.084 - 5.843]</td>
<td>[1.887 - 5.115]</td>
<td>[0.000 - 0.000]</td>
</tr>
</tbody>
</table>

Variance Decomposition of the observables. Median values and 90% confidence intervals reported. Posterior percentiles obtained from 2 chains of 100,000 draws generated using a Random walk Metropolis algorithm. Acceptance rate 23%. Burning period: initial 20,000 draws. Observations retained: one in every 10 draws.
Figure 1: Financing Gap Share, as computed in equation (5) (black solid line). The series is compared to results obtained using Chari and Kehoe (2009)'s methodology applied to annual data (red dashed line) and quarterly data (blue dashed line).
Figure 2: Share of Total Financing Gap funded by liquidations of portfolio assets. Source: Compustat. Sample period 1989Q1 - 2010Q1.
Figure 3: Impulse responses to a one standard deviation financial shock. The dashed lines represent 90 percent posterior probability bands around the posterior median.
Figure 4: Impulse responses to an exogenous liquidity shock à la Kiyotaki and Moore (2008).
Figure 5: Quarterly output growth in the data (black solid line) and in the model (red dashed line) with only financial shocks.
Figure 6: Quarterly output growth in the data (blue lines) and in the model (red dashed lines) without financial shocks (top-left), TFP shocks (top-right panel), government spending shocks (bottom-left panel) and monetary policy shocks (bottom-right panel).
Figure 7: Smoothed shocks during last recession. Financial shock (top-left), TFP shock (top-right), monetary policy shock (bottom-left) and government spending shock (bottom-right).
Figure 8: Impulse response functions to a one standard deviation financial shock. Comparison between sticky wages (black dashed line, $\xi_w = 0.735$) and flexible wages (blue solid line).