Credit Constraints, Firms' Precautionary Investment, and the Business Cycle*

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Abstract

This paper studies the macroeconomic implications of firms' precautionary real investment behavior in response to the anticipation of future financing constraints. Firms increase their demand for liquid and safe but low-return investments in anticipation of future borrowing constraints in order to decrease the probability of having to forego future profitable investment opportunities. I show in a calibrated model that this behavior is at the source of a novel and poweful amplification and propagation channel of macroeconomic shocks. Furthermore, it can account for the observed business cycle patterns of the aggregate and firm-level composition of real investment, a set of observations which is at odds with the existing models studying the macroeconomic implications of financial frictions, in which the expectation of future credit constraints does not directly affect firms' current actions.

Keywords: Investment, Financial Frictions, Business Cycles, Idiosyncratic Production Risk

JEL Classification Numbers: D86, D92, E22, E32, G31, G32

1 Introduction

There is a large body of research on the role of financial frictions in amplifying business cycles. Most of this work is focused on studying how firms' investment *capacity* is affected by tighter borrowing constraints in recessions or following a tightening of monetary policy, either directly through a balance sheet channel (Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999)) or indirectly through a decreased supply of intermediated finance (Holmstrom and Tirole (1997), Bolton and Freixas (2003), Van den Heuvel (2007)). In either case, all of these theories describe how firms are *constrained in the amount* they can invest following a shock.

There has been little focus in the literature however on an amplification and propagation mechanism that studies how changes in the likelihood of being credit constrained in the future may be affecting firms' *willingness* to invest and firms' preference for the *type* of investment they carry out. In short, firms that anticipate being credit constrained in the future may wish to retain more liquid balance sheets by investing less or investing differently.

Empirical evidence suggests indeed that firms' precautionary behavior in anticipation of future expected financial constraints is a key determinant of their financial and investment decisions. Recent surveys by Graham and Harvey (2001) and Bancel and Mittoo (2002) find that CFOs consider financial flexibility (having enough internal funds to avoid having to fore-go positive Net Present Value projects in the future) to be the primary determinant of their policy decisions. Almeida, Campello and Weisbach (2004) report that the expectation of future financing problems significantly affects firms' investment policies, and Caggesse and Cunat (2007) find that it significantly affects hiring decisions.

The relevance of this approach is further enhanced by two observations. On the one hand, despite the fact that a small fraction of agents are observed to be financially constrained at any given point in time, a much larger fraction may anticipate the possibility of being constrained in the future. The importance of this distinction between the effect of the *anticipation* of constraints and the *contemporaneous* effect of constraints has already been pointed out in studies of the buffer stock behavior of consumers. On the other hand, the subset of firms that suffer most from financial constraints and hence for which these considerations are relevant (small and privately-owned firms) is a very sizeable portion of economic activity, and in the US accounts for about one half of private-sector GDP and employment. [1]

As is suggested in the empirical evidence mentioned above, firms may insulate themselves from potential future credit rationing by adjusting their financial policies, their

[1] Data from the U.S. Small Business Administration Report 2003 show that non-farm businesses with less than 500 employees account for about half of private-sector GDP, employ more than half of private-sector labour, and over 1992-2002 generated between 60-80% of net new jobs annually.

hiring decisions, their cash holdings, or their investment strategies. This paper focuses on the effects on investment decisions.[2] A number of questions arise. Can a mechanism capturing this precautionary element in firms' behavior have significant effects on aggregate investment and output dynamics? Can it account for the behavior of the composition of real investment across the business cycle, which current models studying the macroeconomic implications of agency costs cannot account for? Are frictions preventing optimal risk and liquidity management by firms a powerful amplification mechanism of macroeconomic shocks?

These questions are dealt with by analyzing a dynamic stochastic general equilibrium model of a production economy subject to aggregate and idiosyncratic uncertainty. In the model, entrepreneurial firms in the capital-producing sector have access every period to a highly profitable but risky long-term technology, and also have access to a safe but low-return short-term investment opportunity. They may suffer from credit constraints when seeking external finance, and the dynamic nature of the model allows me to study the intertemporal implications of investment and financing decisions in the face of financing restrictions.

In this paper I first describe theoretically the mechanism for the proposed precautionary channel of amplification of macroeconomic shocks. Entrepreneurs have an incentive to invest in long-term projects in downturns, but can only pledge the returns of their short-run safe investments as collateral when attempting to obtain external finance. This results in strongly countercyclical credit constraints. If a negative aggregate productivity shock hits the economy, firms anticipate its effects to persist and as a result anticipate that credit availability will remain tight in the short and medium term making it harder to deal with possible future idiosyncratic liquidity shocks. This induces firms to shift the composition of their investment towards less volatile and more liquid, but less profitable, activities, and amplifies the effect of the initial shock.

Secondly, I show in a calibrated model that this precautionary behavior has quantitatively significant implications. Under the benchmark calibration, the risk-averse behavior induced by intertemporal financing concerns results in aggregate investment being twice as sensitive to productivity shocks, bringing us closer to empirical evidence. Furthermore, I show that the extent to which this mechanism acts as an amplifier or a dampener of macroeconomic fluctuations depends crucially on how persistent the aggregate shocks are.

[2] With regards to financial policies, I take the approach that firms have a limited ability to use their capital structure to gain financial flexibility due to financial constraints. For example, a large fraction of firms do not have the flexibility to switch between debt and equity, or the ability to issue commercial paper. In any case, in the model firms borrow using state contingent contracts subject to collateral constraints, and decide optimally the extent to which they want to hedge using that contract or by adjusting their investment decisions.

The third main result is that this model is able to account for the business cycle patterns of aggregate and firm-level composition of investment. This is in line with evidence presented in a number of recent empirical papers. Aghion, et al. (2007) find using a firm-level data-set that while the share of R&D investment over total investment is countercyclical for firms that do not face credit constraints, it becomes pro-cyclical for credit constrained firms. Furthermore, this is only observed in downturns, when the share of R&D for these firms falls drastically. Almeida, Campello and Weisbach (2004) find on the other hand that financially constrained firms' cash flow sensitivity of cash increases significantly in recessions, while it is unchanged for unconstrained firms. Aghion, et al. (2005) give evidence using data on the aggregate composition of investment of a panel of countries that the share of structural (long-term) investment over total investment decreases following shocks that can be expected to make firms more likely to be credit constrained in the near future, and also document that this effect is stronger for less financially developed economies. They find, importantly, that the effect of financial development on the strength of the financial accelerator does not act through a mechanism that alters the amount of investment, but rather the composition, something which is at odds with the main prediction in existing macro models of credit frictions, in which the effects of the expectations of future potential financial constraints are ignored.

These observations are at odds with the existing models of macroeconomic implications of agency costs in which expectations of future constraints do not affect firms' current actions. In my model, however, a worsening of expected credit conditions causes the composition of investment to shift to safer but lower return technologies (contrary to the Schumpeterian idea of "cleansing" recessions). Also, composition shifts to activities with a higher degree of asset tangibility, and towards activities that use more liquid collateral and collateral whose value is less pro-cyclical. Absent alternative safer investment technologies, firms increase their investment in liquid, marketable securities and cash.

Relationship with the Literature

This paper is closely related to the strand of literature studying the macroeconomic implications of endogenous borrowing constraints for firms, such as Bernanke and Gertler (1989), Holmstrom and Tirole (1997), Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999), Bolton and Freixas (2003), Krishnamurthy (2003), Rampini (2004) and Van den Heuvel (2007). The majority of the papers in this literature does not study issues of risk-sharing and insurance, and instead focus mainly on how credit frictions affect the ability of firms to invest.[3] Krishnamurthy (2003) and Rampini (2004) are an exception however. Krishnamurthy (2003) studies how introducing state-contingent

[3]Stochastic models in this literature abstract from issues of risk management by making certain modelling choices that make risk irrelevant for entrepreneurs, such as assuming risk neutrality, linear production technologies, or permanently binding credit constraints.

claims eliminates the Kiyotaki and Moore (1997) mechanism, and shows that an aggregate constraint on the capacity of the economy to provide such insurance against aggregate shocks reinstates the mechanism, only that the constraint is on the side of the suppliers of finance. I extend that analysis along three key dimensions. Firstly, Krishnamurthy (2003) does not study the ex-ante effects of limited insurance capacity on the optimal investment choice of firms, which is the key element of the new mechanism I introduce in this paper. Secondly, I extend the model to a fully dynamic setup. Finally, I integrate the analysis in a fully general equilibrium model to be able to assess quantitatively the importance of this channel. A paper closely related in spirit is Rampini (2004), in which a model is introduced that delivers pro-cyclical entrepreneurial activity and amplification of technology shocks. The main difference with my paper is that his mechanism relies on entrepreneurs' risk aversion as the only motive for risk management, while in my setup demand for insurance is production-related.

There is another strand of literature that studies the macroeconomic impact of uninsurable idiosyncratic labour-income risk (Huggett (1993), Aiyagari (1994), Krusell and Smith (1998)) or uninsurable investment risk (Acemoglu and Zilibotti (1997), Angeletos and Calvet (2006)) in the neoclassical growth model, to analyze issues related to capital accumulation, equilibrium real interest rates and output growth rates. They do not study however if and how market incompleteness varies across the cycle, and how this endogeneity of the risk-sharing opportunities affects cyclical fluctuations.

Regarding the corporate finance literature, a number of theoretical papers have identified the different sources of firms' insurance demand. One such motive is that if firms face costs of raising external finance, or indeed the prospect of being credit rationed, they may find it optimal to hedge against low cash-flow realizations to avoid having to fore-go positive NPV projects, a motive studied formally in Froot, Scharfstein and Stein (1993).[4]

The remainder of the paper is organized as follows. Section 2 presents some empirical evidence. Section 3 studies in detail the problem faced by entrepreneurs in a partial equilibrium set-up. Section 4 embeds this analysis in a fully general equilibrium dynamic stochastic model. The steady state of the model, and the calibration, are discussed in section 5. Section 6 presents the main results of the model. Finally, section 7 concludes.

[4]Other motives have also been pointed out in the literature, such as hedging as a way to avoid non-linear costs of financial distress (Greenwald and Stiglitz (1993), Smith and Stulz (1985)), to resolve conflicts of interest between bond-holders and equity-holders, or between managers and providers of finance, and hedging to avoid tax non-linearities (Smith and Stulz (1985)).

2 Empirical Evidence

In this section I present some basic evidence on the cyclical pattern of firm-level investment and of the composition of such investment, distinguishing between firms that are likely to suffer from financing constraints and those that are not. I use firm-level quarterly data on over 5,000 U.S. publicly listed firms from the first quarter of 2005 (Q1-2005) to the last quarter of 2009 (Q4-2009)from the *Capital IQ* database, with the objective of comparing the behavior of firms during a boom period (Q1-2005 to Q2-2007), during a financial crisis and pre-recessionary period (Q3-2007 to Q1-2008), and during a recession and the first phase of the recovery (Q2-2008 to Q2-2009). I also use data on credit conditions from the *National Federation of Independent Business*, which run a monthly survey in the U.S. in which they ask small business owners, amongst other things, whether loan availability has changed compared to the previous three months.

I measure total investment as the sum of capital expenditures, research and development (R&D) expenditures, inventory accumulation, acquisitions, and real estate investment. All of the items are obtained from the Cash-Flow statement except for R&D expenditures, which is reported in the Income statement. For the purpose of the empirical exercise in this section, I will categorize R&D expenditures and acquisitions as *risky* investment, and the rest as *safe* investments. Capital expenditures, however, may well contain investments that can be considered to be risky, illiquid and long-term, and, in particular, certain R&D investments will require capital expenditures to support them and should thus be considered to be risky. Despite this fact, it is safe to argue that capital expenditures are relatively safer and more liquid than R&D expenditures.

The likelihood of facing financial constraints is captured using data on firm size, ratings, and liquidity. To avoid issues of endogeneity I use firm characteristics as of the period comprising Q3-2005 to Q2-2006 to create two groups of firms that I track through the subsequent three periods (boom, early crisis, and recession). Firms are considered to have a high likelihood of facing financial constraints in the future if they are in the bottom quartile of the size distribution, have no access to a line of credit, and have liquid assets as a share of total assets in the bottom quartile, or if they are rated and have a rating below BB-. Firms are considered to have a low likelihood of facing financial constraints in the future if they are in the upper quartile of the size distribution, have access to a line of credit, and have liquid assets (cash, short term investments and undrawn lines of credit) as a share of total assets in the upper quartile, or if their bond ratings are investment grade. This classification leaves more than 50% of firms outside of any of the two samples. All of these criteria are standard in the literature except for availability of lines of credit, which by and large has not been used in the empirical literature because of lack of readily available data. Sufi (2009) finds, however, that access to a line of credit

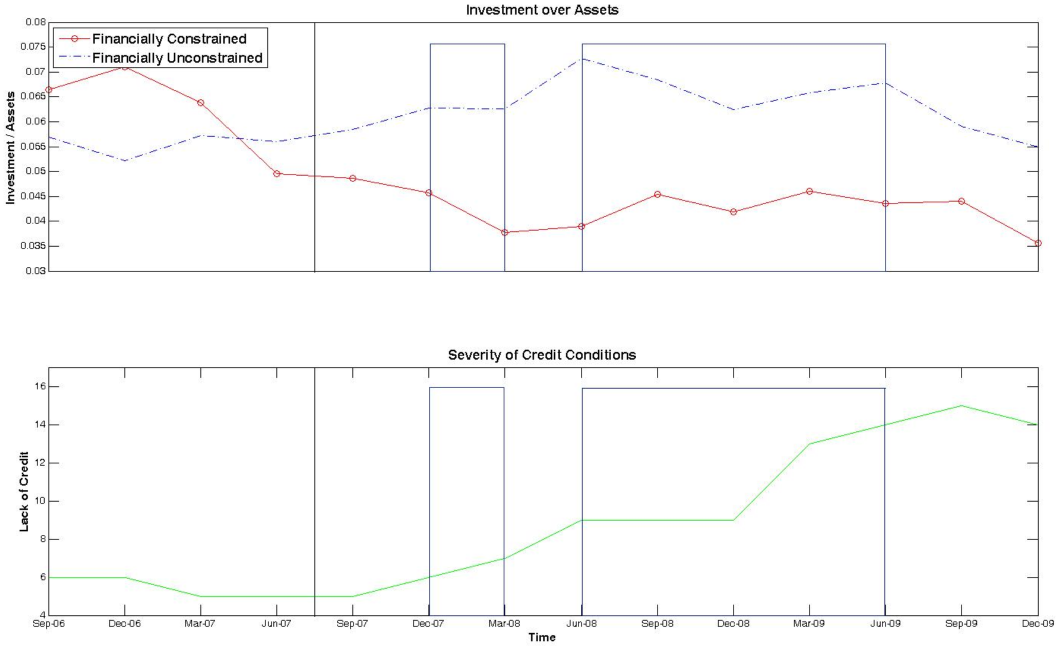

Figure 1: Upper panel: Cross-sectional average of total investment as a share of assets for U.S. financially constrained and unconstrained firms. Data from Capital IQ. Lower panel: Indicator of severity of credit conditions. Data from the monthly survey of the NFIB. Line indicates onset of the crisis (August 2007), and boxes indicate recession quarters.

is a way to measure financial constraints that dominates others commonly used in the literature.

In the upper panel of figure 1 I plot the cross-sectional average of total investment as a share of assets for the two groups of firms, from Q1-2005 to Q4-2009. In the lower panel I plot the measure of credit conditions, where higher values indicate *worse* credit conditions. Firms in the financially constrained group started to decrease their investment around the summer of 2007 when it dropped from an average 6.5% during the previous year to around 5% of assets, a level at which they stay until early 2008 when investment decreases further. Further significant declines only happen towards the end of the sample. At the same time non-financially constrained firms show robust investment patterns throughout 2006, 2007 and 2008, and only show declines in 2009 following 5 quarters of recession and in the face of severely reduced loan availability. Two features stand out; first, constrained firms start cutting back on investment significantly before credit conditions worsen and the recession begins, while unconstrained firms do not. These results are statistically significant (see Table 3). Secondly, the severity of credit conditions do not seem to affect investment for either group until late in the sample period.[5]

[5]The patterns described here could be due to industry effects because there is a relationship between

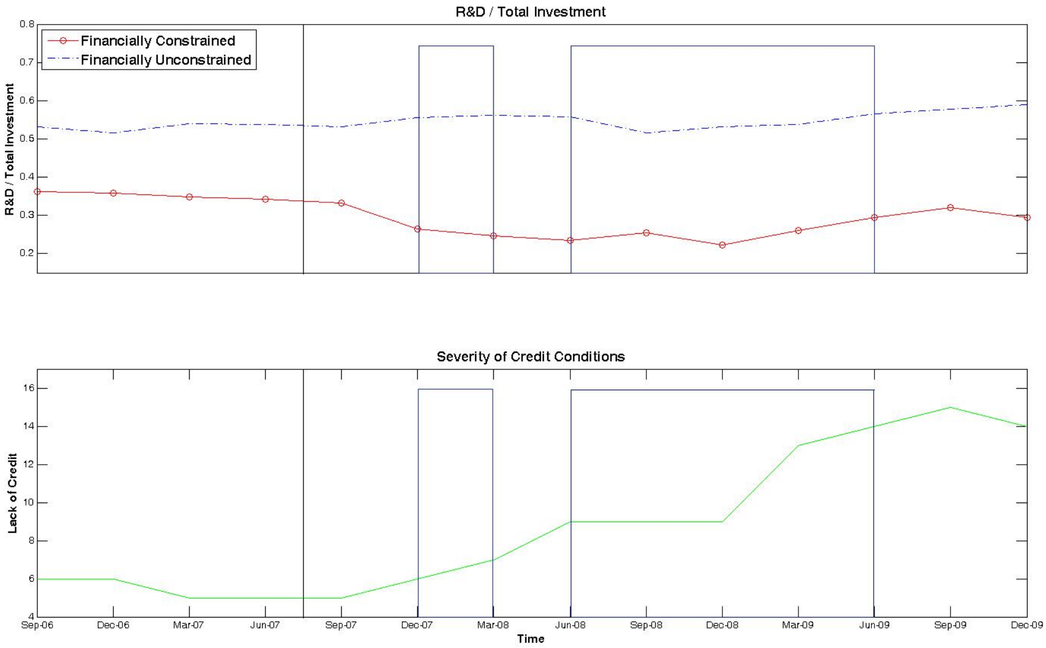

Figure 2: Upper panel: Cross-sectional average of R&D investment as a share of total investment for U.S. financially constrained and unconstrained firms. Data from Capital IQ. Lower panel: Indicator of severity of credit conditions. Data from the monthly survey of the NFIB. Line indicates onset of the crisis (August 2007), and boxes indicate recession quarters.

In the upper panel of figure 2 I plot the cross-sectional average of the share of risky investment over total investment for the two groups of firms, from Q1-2005 to Q4-2009. In the lower panel again I plot the measure of credit conditions. Firms in the financially constrained group decrease the share of risky investment in the fourth quarter of 2007, and stay at that level until Q2-2009 when they start increasing it again slightly, just when credit conditions worsen. Unconstrained firms show a pretty constant patter of R&D investment throughout the sample. Statistical significance of these results is shown in Table 3.

To summarize the preliminary evidence in this section, the data seem to suggest that *1)* firms that anticipate the possibility of being financially constrained in the future may be less willing to invest in the present, and *2)* firms that anticipate the possibility of being financially constrained in the future may bias their investment towards safer and more liquid projects.

our groupings and the industries that are represented in each group. To check for this, I conduct this analysis for 3 digit SIC code industries individually as well, confirming the results.

Figure 3: Investment Patterns in Pre-Crisis and Early Crisis Periods

Panel A: Total Investment over Assets

	Boom period	Crisis (pre-recession)	t-Statistic (difference)
Constrained	6.11%	4.42%	3.51
Unconstrained	5.53%	6.22%	1.77

Panel B: Risky Investment over Total Investment

	Boom period	Crisis (pre-recession)	t-Statistic (difference)
Constrained	37.10%	28.95%	2.13
Unconstrained	54.12%	56.34%	0.66

3 Partial Equilibrium Model of Entrepreneurial Investment

In this section I study a partial equilibrium model of entrepreneurial investment, which will be embedded later on in the following section into a general equilibrium framework. I postpone the detailed analysis of the whole economy setup to section 4, and just provide a brief sketch here for the benefit of clarity. I consider an infinite horizon, discrete-time economy, populated by *three types of agents*: households, entrepreneurs and firms. Entrepreneurs constitute the capital-producing sector of the economy and may face financial constraints, and firms make up the consumption-good producing sector and do not suffer from financial constraints. I return now to analyze the entrepreneurs' problem in detail.

There are overlapping-generations of two-period lived entrepreneurs, and within each generation there is a continuum of them. Entrepreneurs are risk-neutral and maximize expected utility of consumption in their final period.

3.1 Investment opportunities

An entrepreneur alive in period t (which could either be a newborn or a second-period entrepreneur) can invest in two different technologies, both of which produce capital (to be used by final consumption good producing firms) using consumption goods as the sole input. The difference between both technologies is that one produces safe returns but is less productive, while the other is more productive but risky. We will see later that this will have implications for how much firms can borrow to finance each of the two types of projects. One could think of the first technology as purchasing new IT equipment, expanding an existing production plant, or accumulating inventories, while the second technology could be thought of as research & development or as marketing expenses (both risky, intangible investments). Both production processes take place *within* the period, and hence are not subject to aggregate uncertainty, which is resolved at the beginning of the period.

In particular, investing an amount $i_{s,t}$ in the safe technology produces a return $a_s i_{s,t}^{\alpha}$ in terms of capital goods, where $a_s > 0$, to be sold at price q_t. Investing $i_{r,t}^{\alpha}$ in the risky technology produces a return of $a_r i_{r,t}^{\alpha}$ capital goods plus $a_r e i_{r,t}^{\alpha}$ consumption goods with probability 1/2, and nothing otherwise, where $e > 0$.[6] I assume that $(a_r/2) > a_s$. The uncertainty regarding the risky technology is idiosyncratic and is resolved within the period of investment.

An entrepreneur born in period t will make a first investment choice at the beginning of t and a second one at the beginning of period $t+1$, and the investment options are identical in both. A second-period entrepreneur in period $t+1$ will face the following decision problem:

$$\max_{i_{s,t+1}, i_{r,t+1}} q_{t+1} a_s i_{s,t+1}^{\alpha} + 1/2(q_{t+1} + e) a_r i_{r,t+1}^{\alpha} - b_{t+1}, \tag{1}$$

$$\text{s.t.} \tag{2}$$

$$i_{s,t} + i_{r,t} = w_{t+1} + b_{t+1} \tag{3}$$

where w_{t+1} is the wealth with which an entrepreneur enters period $t+1$, and b_{t+1} is the position in safe bonds (borrowing if $b_{t+1} > 0$, lending if $b_{t+1} < 0$).

3.2 First-Best Solution

Absent any borrowing constraints, optimal investment and borrowing positions are:

$$\begin{aligned} i_{s,t+1} &= (\alpha q_{t+1} a_s)^{\frac{1}{1-\alpha}} && (4) \\ i_{r,t+1} &= [\alpha a_r / 2(q_{t+1} + e)]^{\frac{1}{1-\alpha}} && (5) \\ b_{t+1} &= (\alpha q_{t+1} a_s)^{\frac{1}{1-\alpha}} + [\alpha a_r / 2(q_{t+1} + e)]^{\frac{1}{1-\alpha}} - w_{t+1}. && (6) \end{aligned}$$

One of our objects of interest is the study of the cyclical behavior of risky, productive investment as a share of safe investment, which in this case is given by:

$$\frac{i_{r,t+1}}{i_{s,t+1}} = \left(\frac{a_r (q_{t+1} + e)}{2 q_{t+1} a_s} \right)^{\frac{1}{1-\alpha}}. \tag{7}$$

[6] The term $e i_{r,t}^{\alpha}$ is meant to capture the present discounted value of the long-term component of this type of investment. It could be thought of as the present value of the future earnings arising from a research and development initiative, for example.

This ratio turns out to be countercyclical, or, in other words, in a world without credit constraints the share of R&D and other risky activities *increases* in downturns. In good times, short run returns are high (q_{t+1} is high, which is the only element driving the immediate returns), and relatively more so than long-run returns given that the mean-reverting process driving q_{t+1} is dampened by the constant term e, making returns to the risky activity fluctuate less across the business cycle, and be relatively more(less) interesting in downturns(booms) compared to the safe activity. This interpretation follows the Schumpeterian view of recessions as "cleansing periods".

3.3 Credit constraints

When we consider credit frictions this result may no longer hold. I assume that the returns to the safe technology are fully pledgeable, while the returns to the more productive but risky one cannot be pledged. This particular form of credit constraints can be rationalized in one of two ways. On the one hand, the realization of the risky technology could be non-contractible (for example because it is not observable), and entrepreneurs would have an incentive to claim that they have been unsuccessful and default on their debt payments. Another rationale could arise from the term of the investment. The risky technology is meant to capture longer term investments such as R&D and marketing, which carry a substantial amount of intangible capital and offer little collateral to back borrowing by the entrepreneur. The safer activity, on the other hand, produces liquidity in the form of short run returns in a relatively fast manner providing collateral for borrowing.

Credit constraints will bind as long as first best borrowing is above the pledgeable amount, or:

$$(\alpha q_{t+1} a_s)^{\frac{1}{1-\alpha}} + [\alpha a_r/2(q_{t+1}+e)]^{\frac{1}{1-\alpha}} - w_{t+1} > q_{t+1} a_s \left(\alpha q_{t+1} a_s\right)^{\frac{\alpha}{1-\alpha}} \tag{8}$$

This is more likely to happen in downturns for the following two reasons. First, short-run returns are lower in downturns, making the expected excess return on long-run over short-run investment even higher. Given that long-run returns are not collateralizable, borrowing capacity is diminished through this effect. Second, borrowing capacity is further reduced because of the decrease in short-run returns itself. In sum, the combination of low short-run profits and a shift of the opportunity cost trade-off towards the long-run risky activity being relatively more attractive than the short-run activity in recessions than in booms means that borrowing constraints are more likely to bind in negative aggregate states. This means that the long-run risky activity may be less countercyclical than in the unconstrained scenario, or indeed procyclical.

When introducing credit constraints, the distinction between the first and second period becomes crucial. In the second (final) period, entrepreneurs only care about maximizing expected profits, given that they are risk neutral and exit the economy following that period. In the first period, however, the have to also take into account the possibility that credit constraints may imply that their second period profit function is non-linear in beginning-of-period wealth. This introduces a risk management concern that further complicates their first-period investment decisions. I will come back to this point below in section 3.4. Now, we will focus on what goes on in the second period when credit constraints bind. In period $t+1$ an entrepreneur with wealth w_{t+1} solves the following optimization problem:

$$\max_{i_{s,t+1}, i_{r,t+1}} q_{t+1} a_s i_{s,t+1}^{\alpha} + 1/2(q_{t+1} + e) a_r i_{r,t+1}^{\alpha} - b_{t+1}, \tag{9}$$

$$s.t.$$

$$i_{s,t} + i_{r,t} = w_{t+1} + b_{t+1} \tag{10}$$

$$b_{t+1} \leq q_{t+1} a_s i_{s,t+1}^{\alpha} \tag{11}$$

Optimization assuming that the credit constraint binds delivers the following optimal choices:

$$\begin{aligned} i_{s,t+1} &= (\alpha q_{t+1} a_s)^{\frac{1}{1-\alpha}} && (12) \\ i_{r,t+1} &= w_{t+1} + q_{t+1}^{\frac{1}{1-\alpha}} a_s^{\frac{1}{1-\alpha}} (\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}) && (13) \\ b_{t+1} &= \alpha^{\frac{1}{1-\alpha}} (q_{t+1} a_s)^{\frac{2-\alpha}{1-\alpha}}. && (14) \end{aligned}$$

And the ratio of risky to safe investment is given by expression (15):

$$\frac{i_{r,t+1}}{i_{s,t+1}} = \frac{w_{t+1} q_{t+1}^{\frac{-1}{1-\alpha}} + a_s^{\frac{1}{1-\alpha}} (\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})}{(\alpha a_s)^{\frac{1}{1-\alpha}}}. \tag{15}$$

The ratio of risky to safe investment is shown to depend crucially on beginning of period wealth w_{t+1} and on the price of capital q_{t+1}. Lower net worth affects risky investment most, given that it does not generate any pledgeable returns and hence cannot be used to provide collateral for borrowing. A lower price of capital on the other hand affects the safe investment more. This is because both the return to the safe technology and its ability to generate collateral are affected by decreasing capital prices. The risky investment is only partially affected, as it generates no collateral and part of its returns are not driven by q_{t+1}. In summary, the variation of the ratio across the business cycle is ambiguous in general, as opposed to the first best scenario when it is countercyclical.

3.4 Precautionary Behavior

So far we have analyzed entrepreneurs' decision problem when they faced no credit constraints, and when they faced credit constraints in the present, but did not expect them to bind in the future (in that particular case because they die immediately after the current period). Now I will analyze the behavior of an entrepreneur who may or may not be credit constrained today but anticipates she might be credit constrained in the *future*.

In order to do so, we need study the decision problem of the entrepreneur in the first period of her life, who anticipates she might be credit constrained in the second period. In period t a new-born entrepreneur with wealth w_t solves the following two-period optimization problem:

$$\max_{i_{s,t+1}, i_{r,t+1}} E_t \left(q_{t+1} a_s i_{s,t+1}^{\alpha} + 1/2 \left(q_{t+1} + e \right) a_r i_{r,t+1}^{\alpha} - b_{t+1} \right), \tag{16}$$

$$s.t.$$

$$i_{s,t+1} + i_{r,t+1} = w_{t+1} + b_{t+1} \tag{17}$$

$$w_{t+1} = \begin{cases} q_t a_s i_{s,t}^{\alpha} + \left(q_t + e \right) a_r i_{r,t}^{\alpha} - b_t \text{ with } p = 1/2 \\ q_t a_s i_{s,t}^{\alpha} - b_t \text{ with } p = 1/2 \end{cases} \tag{18}$$

$$i_{s,t} + i_{r,t} = w_t + b_t \tag{19}$$

$$b_t \leq q_t a_s i_{s,t}^{\alpha} \tag{20}$$

$$b_{t+1} \leq q_{t+1} a_s i_{s,t+1}^{\alpha} \tag{21}$$

Where w_t is the wealth owned by an entrepreneur when she is born. She obtains that wealth from contributing her endowment of labor to the consumption good producing firms in exchange for a wage w_t^e, so that $w_t = w_t^e$.

Several possible cases could occur. Entrepreneurs could be constrained or unconstrained in period t, and they could be always unconstrained, always constrained, or sometimes constrained in period $t+1$, and six possible combinations of period t and $t+1$ scenarios thus arise. Let's first study the case in which entrepreneurs are unconstrained in the present, but may be constrained in the future (in some aggregate states of nature). Denoting with C the set of states s_{t+1} in which the entrepreneur is credit constrained in her second period $(t+1)$, the decision problem can be written as:

$$\max_{i_{s,t+1}, i_{r,t+1}} P(s \notin C) E_t [q_{t+1} a_s i_{s,t+1}^{\alpha} + 1/2 \left(q_{t+1} + e\right) a_r i_{r,t+1}^{\alpha} - (i_{s,t+1} + i_{r,t+1} - w_{t+1}) | s \notin C\}$$

$$+ P(s \in C) E_t \{ (q_{t+1} + e) \left(w_{t+1} + q_{t+1}^{\frac{1}{1-\alpha}} a_s^{\frac{1}{1-\alpha}} (\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}) \right)^{\alpha} | s \in C \},$$

$s.t.$

$$w_{t+1} = \begin{cases} q_t a_s i_{s,t}^{\alpha} + \left(q_t + e\right) a_r i_{r,t}^{\alpha} - b_t \text{ with } p = 1/2 \\ q_t a_s i_{s,t}^{\alpha} - b_t \text{ with } p = 1/2 \end{cases} \tag{22}$$

$$i_{s,t} + i_{r,t} = w_t + b_t \tag{23}$$

$$b_t \leq q_t a_s i_{s,t}^{\alpha} \tag{24}$$

The potential for binding constraints in some future states of nature introduces an important non-linearity in the relationship between the net worth w_{t+1} entrepreneurs transfer into their second period and returns from investment in that period. Profits in period $t + 1$ in states in which the entrepreneur is unconstrained are linear in beginning-of-period wealth w_{t+1}, while they are concave in w_{t+1} in those states in which credit constraints bind (see figure 4). A number of implications follow from this. First, an entrepreneur that does not expect any borrowing constraints in the future does not care about the risk associated to her first period investment; she will simply maximize expected returns. Second, the potential for future credit constraints introduces a motive for risk management, and discourages risky investment by the entrepreneur. Third, this production-related risk aversion increases in downturns. This is for two reasons. On the one hand, as I show above, the likelihood of being credit constrained is higher in downturns. On the other hand, the nature of the production function implies that, conditional on being credit constrained in the future, entrepreneurs care more about risk when expected future economic conditions deteriorate because in those circumstances q_{t+1} is low, making credit constraints very tight and resulting in very low investment levels when the risky investment has turned out unsuccessful in the first period. The decreasing absolute risk aversion implied by the production function and the borrowing constraints makes entrepreneurs very averse to this scenario, and this constitutes the second reason why risk aversion increases in anticipation of worsening economic conditions.

In the extreme scenario in which credit constraints are expected to bind in every state of nature in period $t + 1$, the optimal ratio of risky to safe investment is given by:

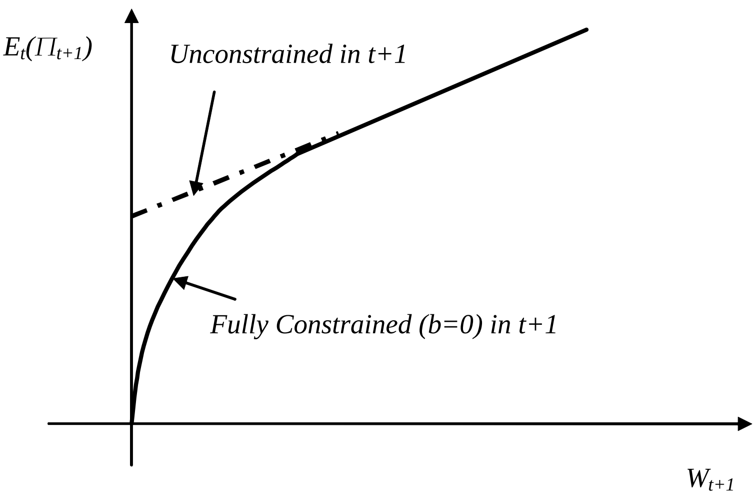

Figure 4: Concavity of the expected profit function with respect to beginning of period wealth W_{t+1}.

$$\frac{i_{r,t}}{i_{s,t}} = \left(\frac{a_r(q_{t+1}+e)}{q_{t+1}a_s}\right)^{\frac{1}{1-\alpha}} \Psi(q_t, i_{s,t}, i_{r,t}, w_t) \tag{25}$$

$$= \left(\frac{i_{r,t}}{i_{s,t}}\right)_{FB} \Psi(q_t, i_{s,t}, i_{r,t}, w_t). \tag{26}$$

where

$$\Psi(\cdot) = \left(\frac{\left(q_t a_s i_{s,t}^{\alpha} + (q_t+e)\, a_r i_{r,t}^{\alpha} - b_t + q_{t+1}^{\frac{1}{1-\alpha}} \lambda\right)^{\alpha-1}}{\left(q_t a_s i_{s,t}^{\alpha} + (q_t+e)\, a_r i_{r,t}^{\alpha} - b_t + q_{t+1}^{\frac{1}{1-\alpha}} \lambda\right)^{\alpha-1} + \left(q_t a_s i_{s,t}^{\alpha} - b_t + q_{t+1}^{\frac{1}{1-\alpha}} \lambda\right)^{\alpha-1}}\right)^{\frac{1}{1-\alpha}},$$

and

$$\lambda = a_s^{\frac{1}{1-\alpha}} (\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}})$$

Given that $\Psi(\cdot) < 1$, the share of risky investment is smaller than the unconstrained optimal ratio (first best ("FB") ratio) even if credit constraints are not binding in the present. In other words, the expectation of future credit constraints disencourages investment in the risky project, relative to a situation in which credit constraints are not expected to bind in the future.

4 General Equilibrium

In this section I embed the entrepreneurial sector in a general equilibrium framework. Figure 5 contains an explanatory chart to aid in understanding the interrelationships in the model economy. Consider an infinite horizon, discrete-time economy, populated by *three types of agents*: households (measure $1-\eta$), entrepreneurs (measure η) and firms (measure 1), where within each type there is a continuum of agents. There are *two types of goods*: consumption goods and capital. Entrepreneurs produce capital using consumption goods, and are subject to agency problems when seeking external finance. They are financed using their own net worth and external funds from households. Firms produce the consumption good using labour (from households and entrepreneurs) and capital, and are not subject to any agency problems.

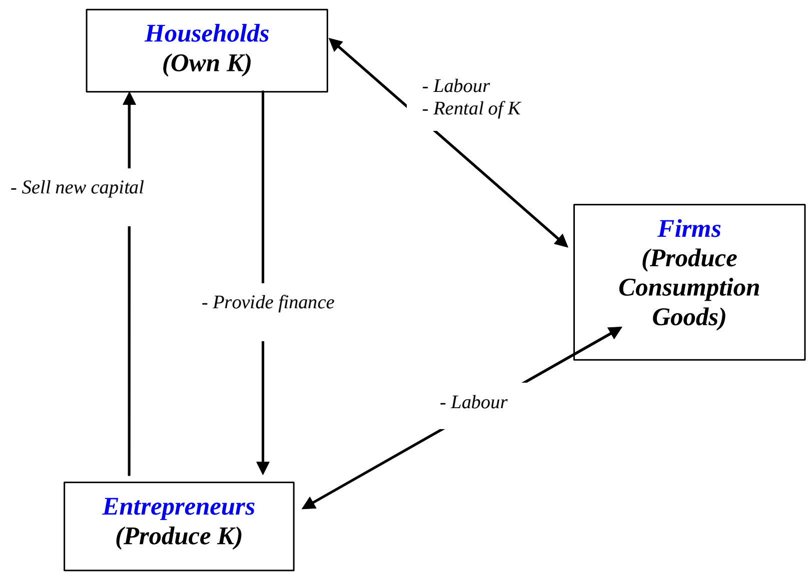

Figure 5: *The Economy - Agents and their Economic Relationships*

Having already explained the entrepreneurial investment decision problem, I now turn to analyze the choices faced by households and firms. In order to understand the sequence of events in this economy, Table 1 summarizes what happens within each period. In what follows, all variables in upper case indicate aggregate quantities.

4.1 Households

There is a continuum of risk-averse households, who maximize expected lifetime utility of consumption, c_t, and leisure, $(1-l_t)$, taking as given wages w_t, the price of capital q_t, and the equilibrium rate of return on capital r_{t+1}:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t). \tag{27}$$

Households choose their labor supply, and their optimal labor-leisure choice is given by

$$\frac{u_l(t)}{u_c(t)} = w_t, \tag{28}$$

where $u_c(t)$ and $u_c(t)$ are respectively the marginal utility of consumption and the marginal disutility of labor in period t.

The optimal savings and consumption choice is given by the euler equation:

$$u_c(t) = \beta E_t \left[u_c(t+1) \frac{q_{t+1}(1-\delta) + r_{t+1}}{q_t} \right]. \tag{29}$$

All savings are invested in capital, and the total stock of capital is then rented by consumers to firms who use it for production the following period and pay in return an interest rate of r_{t+1}.

4.2 Firms

Firms produce the consumption good using a constant returns to scale production function:

$$Y_t = \theta_t F(K_t, H_t, H_t^e) \tag{30}$$

where K_t is the stock of investment goods, H_t is aggregate labour supplied by households, and $H_t^e = H^e$ is labour supplied by entrepreneurial agents (which is constant).

Perfect competition in the factor markets implies the following factor prices:

$$r_t = \theta_t F_1(t) - 1 \tag{31}$$

$$w_t = \theta_t F_2(t) \tag{32}$$

$$w_t^e = \theta_t F_3(t) \tag{33}$$

4.3 Entrepreneurial R&D Spillovers

Entrepreneurs' R&D activity generates spillovers on other entrepreneurs' capital producing technologies. In particular, the productivity of the safe technology is affected by spillovers through a multiplicative factor such that output of an entrepreneur that invests $i^{\alpha}_{s,t+1}$ is $j_t a_s i^{\alpha}_{s,t+1}$, where

$$\log(j_{t+1}) = \rho h \log(j_t) + (h_{t+1} - 1) \tag{34}$$

and

$$\log(h_{t+1}) = \rho_h \log(h_t) + \kappa(ei^{\alpha}_{r,t} - ei^{\alpha}_{r,t-1}). \tag{35}$$

4.4 Market Clearing and Recursive Equilibrium Conditions

There are four markets that need to clear in this economy: capital, consumption goods, entrepreneurial labour, and household labour. Labour supplied by households is equal to $H_t = (1-\eta)L_t$ and entrepreneurs supply labour inelastically and in the aggregate provide $H^e_t = \eta$.

The aggregate resource constraint (goods market equilibrium) in terms of expenditures is given by:

$$\begin{aligned} Y_t &= (1-\eta)C_t + \eta C^e_t + \eta \sum_{i=Y,L,U} \pi^i \, I^i_{s,t} \\ &\quad + \eta \sum_{i=Y,L,U} \pi^i \, I^i_{r,t} + \eta \sum_{i=L,U} \pi^i W^i_{t+1}. \end{aligned} \tag{36}$$

The first two terms in (36) capture aggregate consumption by both households (C_t) and entrepreneurs (C^e_t). The third and fourth terms capture investment in the safe and risky technologies respectively by the three groups of entrepreneurs (young, old lucky and old unlucky), while the fifth term deals with aggregate savings of young entrepreneurs.[7]

The market for capital used by consumption goods producing firms clears at the price of q_t, according to the expression:

$$K_{t+1}(q_t) = (1-\delta)K_t + \frac{Y^e_t(q_t)}{q_t},$$

where Y^e_t is entrepreneurial production of new capital.

The recursive competitive equilibrium is defined by decision rules for K_{t+1}, C_t, H_t, $\{I^i_{s,t}\}_{i=Y,L,U}, \{I^i_{r,t}\}_{i=Y,L,U}, W^L_{t+1}, W^U_{t+1}$, B^Y_t, B^L_t, B^U_t, q_t and r_t, as a function of K_t, θ_t, and $\{W^i_t\}_{i=L,U}$. The appendix provides a detailed explanation of these recursive equilibrium conditions, and of the computational procedure used to solve this model.

[7]Households can only transfer resources from one period to the next by purchasing capital (even if they could use a safe storage technology with no return they would not use it as it would be rate-of-return dominated by investment in k_{t+1}). Entrepreneurs on the other hand can only transfer any resources they have at the end of the period through a safe (zero-return) storage technology.

Table 1: Sequence of Events within One Period

1	θ_t, the aggregate productivity shock, is realized.
2	Firms hire labor from households and entrepreneurs and rent capital from households. These inputs are used to produce the consumption good, $Y_t = \theta_t F(K_t, H_t, H_t^e)$.
3	Households make their consumption and savings choice. Savings are used to purchase new capital from entrepreneurs.
4	Entrepreneurs borrow from households, and decide how to allocate their investment into risky and safe projects.
5	Entrepreneurial production takes place. Loans are repaid to households.
6	Households purchase all of the investment goods (new capital) from entrepreneurs. Old entrepreneurs consume and die.

5 Calibration and Analysis of Steady State

5.1 Calibration

I calibrate the economy to reproduce basic features of the U.S economy on a quarterly basis. In addition the calibration is designed so the results are comparable with the existing quantitative studies on agency costs and business cycle fluctuations, such as Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999).

Concerning the calibration of preferences, the utility function for households is chosen to be iso-elastic of the form:

$$u(c_t, l_t) = \frac{c_t^{1-\gamma} - 1}{1-\gamma} + v(1 - l_t),$$

with v chosen so that households work one-third of their available time in the steady state. The intertemporal preference rate is set at $\beta = 0.995$, selected to deliver an average real interest rate of 2 percent, and the risk aversion parameter γ is set at 2, although different values (between 1 and 4) are also tested for robustness.

The final good aggregate production technology is assumed to be Cobb-Douglas of the form:

$$Y_t = \theta_t K_t^{\alpha} H_t^{1-\alpha-\alpha^e} H_t^{\alpha^e},$$

with a capital share (α) of 0.36, a household labour share ($1-\alpha-\alpha^e$) of 0.639, and an entrepreneurial labour share (α^e) of 0.001. The share of entrepreneurial labour is positive to ensure that young entrepreneurs have positive net worth with probability one, and small so that the model dynamics closely resemble the standard RBC dynamics when the financial frictions in the model are removed. The capital depreciation rate is set to $\delta = 0.023$ to match the capital/output ratio.

The technology shock, θ_t, follows the process

$$\log \theta_{t+1} = \rho \log \theta_t + \sigma_\varepsilon \varepsilon_{t+1}$$

where $\sigma = .01$ and $\rho = 0.95$, as is standard in the real business cycle literature, and $\varepsilon_{t+1} \sim N(0,1)$.

The calibration of parameters concerning the entrepreneurial sector can be divided into three categories: those that control entrepreneurs' financing constraints, those that affect their investment opportunities, and those that determine the extent to which their R&D activity has positive spillover effects on other firms.

The model does not explicitly address whether external finance for entrepreneurs takes the form of debt or equity, although the fixed-repayment contract strongly resembles debt. We will consider w_t, the wealth of entrepreneurs, to be the combination of retained earnings and *inside* equity, and b_t to be debt and the only source of external finance, on the basis of the following argument: in small and medium enterprises a much larger share of equity-holders can be considered insiders, because (i) managers are more likely to own a larger share of the company, (ii) the prevalence of sponsor backed equity will be larger, and (iii) any equity-holder is bound to be closer to management than in a large publicly quoted firm in which arms-length share ownership is more prevalent. On top of this a large literature on R&D financing has documented that R&D is primarily financed by retained earnings and equity rather than debt (Himmelberg and Petersen (1994), Aghion, Bond, Klemm, and Marinescu (2004)), so our calibration of the debt-to-assets ratio will reflect this. The parameters affecting financing constraints, z_e^s and z_e^r, are set to target a mean debt to assets ratio of 10% (based on Himmelberg and Petersen (1994), who document a 6% average, and on the average debt to assets ratio for Compustat publicly listed firms, which is 25% according to Bates, Kahle, and Stulz(2009)), and also to target the observed correlation of the debt to assets ratio with GDP (Covas and den Haan (2009) report that a one standard deviation in output is associated with a 1% increase in debt-to-assets for the smallest 25% of their sample of Compustat firms).

The entrepreneurial technology parameters are calibrated as follows. The share of capital is set at the same level as for the consumption-good producing firms ($\alpha^K = 0.36$). The productivity factor for the safe technology, z_S, the long term return of the risky technology, e, and the idiosyncratic risk of the risky technology, λ, are set to match three empirical counterparts: a return to the safe technology of 2%, a premium on the expected return to the risky technology of 7% and a Sharpe ratio of 0.5.

The share of entrepreneurs η is set to match the documented size of the private (non-listed) sector in the U.S. economy, which roughly accounts for half of employment and investment. Finally, the spillover parameters are calibrated to match the estimated long-run output elasticity of intra-industry R&D of 0.1-0.4 (see Nadiri (1993)).

As will be explained in the next section, I will compare the full model described so far with one in which financial constraints exist for entrepreneurs but can only affect them contemporaneously. That version is described in sub-section 3.3, and in essence means that entrepreneurs do not have a motive for behaving in a precautionary fashion. The calibration of that model is the same except for η, which is adjusted so that both models have the same steady-state level of aggregate capital.

5.2 Analysis of the Steady State

The steady state of this economy is obtained by eliminating the volatility of the aggregate productivity parameter, but preserving idiosyncratic uncertainty. I conduct two comparative statics analyses in which I compare the behavior of two versions of the model economy. One version models entrepreneurs as suffering from financial constraints but with no motive to behave in a precautionary fashion. This version corresponds to the entrepreneurial model described in section 3.3 and I label it FA (short for "Financial Accelerator", in reference to previous models in the literature such as Bernanke, Gertler and Gilchrist (1999)). The second version is the full model in which entrepreneurs behave in a precautionary fashion and is described in section 3.4, and I label this version PREC.

In a first comparative static exercise, I study the sensitivity of the share of risky investment to variations in the idiosyncratic volatility of the risky technology and the results are in the left panel of figure 6. Risk does not influence investment decisions of entrepreneurs in the FA model as they are risk neutral and do not face any further investment opportunities; they simply maximize expected profits from current investment. Entrepreneurs in the PREC model, on the other hand, take risk into account and their choice of risky investment is very sensitive to risk as it compromises their ability to benefit from investment opportunities in the second period.

In the second comparative static exercise, I study the sensitivity of the share of risky investment to variations in the severity of financing constraints and the results are in the right panel of figure 6. The behavior of the models is markedly different; entrepreneurs with no precautionary concerns actually decrease their share of risky investment when access to credit is easier, while the opposite is true for entrepreneurs in the precautionary model. The reason for the former is that under the assumption that borrowing constraints are permanently binding and given that the safe technology is the only one that provides

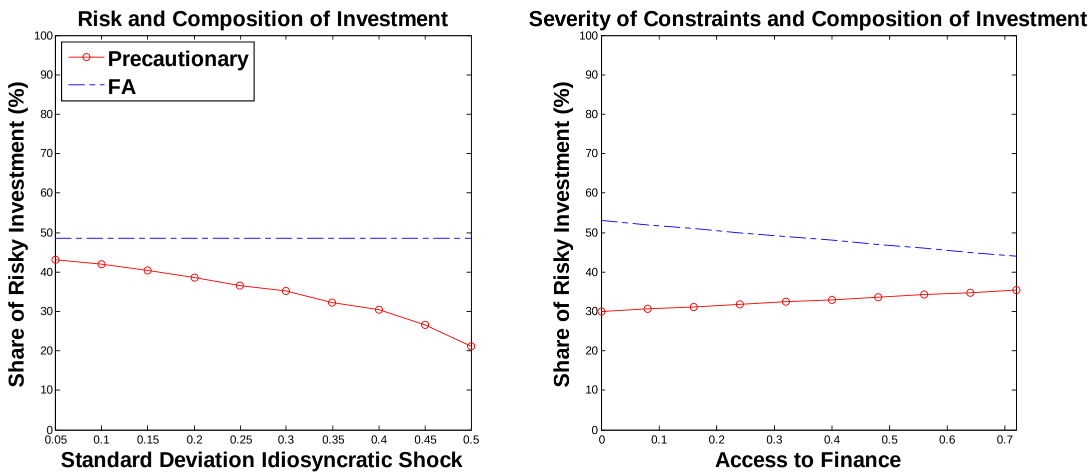

Figure 6: Comparative statics for the share of risky investment in the steady state as a function of the volatility of the idiosyncratic shock (left panel) and the ease of access to finance (right panel). The model with financial constraints but no precautionary mechanism (FA) is compared to the full model with precautionary behavior (right panel).

pledgeable output against which to borrow, the risky technology becomes relatively less interesting as the ability to borrow against the safe technology improves. This effect is also present in the precautionary model but is dominated by the negative precautionary effect.

6 The Financial Accelerator and the Composition of Investment

In this section I report the quantitative findings concerning aggregate investment and output dynamics. The model is simulated by calculating a second order approximation of the equilibrium conditions around the deterministic steady state and solving the resulting system of difference equations. I then study in section 6.1 the model's implications for the behavior of the composition of investment over the business cycle. In section 6.2 I examine the role of this novel transmission mechanism in amplifying and propagating aggregate productivity shocks.

To be able to identify the contribution of the different elements of the model I study the behavior of three different versions: a standard, frictionless, real business cycle model (RBC), a standard financial accelerator framework (FA), and the precautionary investment model introduced in this paper (PREC). The benchmark RBC model is obtained by eliminating any constraints on borrowing, although two differences remain with re-

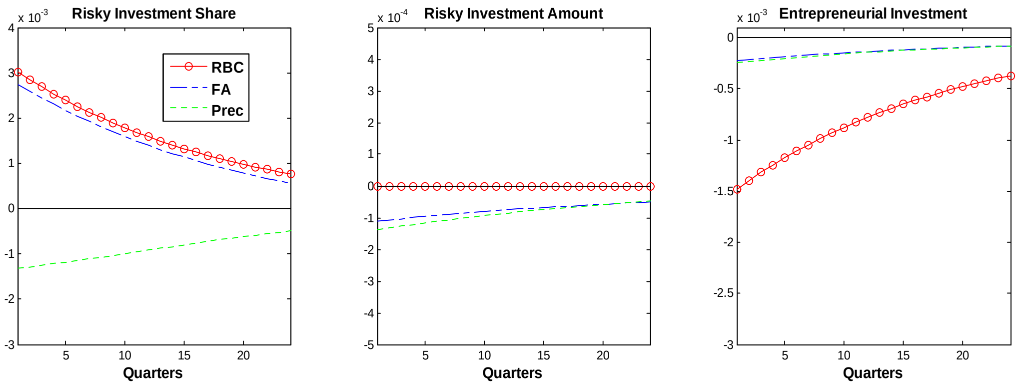

Figure 7: Impulse response functions to a 1% negative shock to aggregate productivity of the consumption-good producing firms.

spect to the standard RBC framework. On one hand, in the standard framework capital is produced using consumption goods by means of a one-to-one technology while in my version there is a capital producing sector with decreasing returns to scale. On the other hand, part of the wage bill of firms reverts to entrepreneurs.

The FA version on the other is obtained by making the entrepreneurs' decision problem static by shortening their existence to only one period instead of two. This way, entrepreneurs only care about credit constraints if and when they bind, but there is no role for future expected financing shortages. I adopt the latter approach. Finally, switching from the FA model to the PREC model requires adding an second period to the lifetime of entrepreneurs, and adjusting the size of the entrepreneurial sector (see the calibration section for details).

6.1 The Composition of Investment across the Business Cycle

The cyclical dynamics of the composition of firms' investment are at the heart of the amplification mechanism I describe in this paper. In order to study those dynamics, I simulate the three versions of the model and plot the impulse response functions of selected aggregates to a negative 1% aggregate productivity shock, the results of which are shown in Figure 7.

The RBC version of the model delivers results that follow a Schumpeterian view, in which recessions are periods when firms carry out structural changes to correct for inefficiencies in the organization or to redirect their strategy by innovating or investing in new products or markets. The left panel shows how following a negative technology shock the share of risky investment increases. This is because the profitability of the safe activity decreases, influenced by the decrease in demand for new capital from firms who are investing less given the lower aggregate returns, while the long-term returns of the risky activity remain constant. This is also evident in the middle panel, which captures total investment in the risky activity, and which is flat; to the extent that returns to the risky technology occur far in the future, their expected value will be largely acyclical, and hence so will be investment in such activities.

The reaction of the share of risky investment in the FA model is remarkably similar to that of the RBC version; the share of risky investment also increases in this model. The intuition is straightforward. The same Schumpeterian effect is in play in the FA version, and it is in fact enhanced by the financing constraints. Under the assumption that the safe investment is the only investment that produces collateral against which to borrow, and given that the price of capital decreases, a given amount of safe investment generates less pledgeable income in recessions, making the safe investment even less attractive relative to the risky activity when compared to normal times. Key to this result is the nature of this exercise, in which we are studying dynamics in the neighborhood of a steady state in which financial constraints are permanently binding. If constraints were allowed to become slack in the steady state, but only bind if the economy falls into a downturn, then this result might be somewhat reversed, as the risky activity would be most affected given that it does not produce collateral. The amount of investment in the risky activity decreases, as does total investment.

Finally, in the PREC model risky investment falls as a share of total investment following a negative productivity shock. Two opposing forces are at play. On the one hand, the shift in the relative profitabilities of safe and risky activities pushes the investment share towards the safe activity. On the other hand, the precautionary behavior of entrepreneurs provides an incentive to invest in the safe activity. The reason for the latter effect is that, after a negative technology shock, constraints in the following period are expected to be more binding because net worth will be lower and pledgeability will decrease. This means that the negative effect of net worth dispersion introduced by the risky technology on expected future output the following period is even more severe, given that the effect of the negative technology shock is to decrease expected net worth but keeping volatility constant.

6.2 Amplification of shocks

I now turn to examine whether the precautionary mechanism acts to (contemporaneously) amplify or dampen the effect of technology shocks, and whether it acts to propagate the effects of the shock through time. Before doing so I briefly show that any improvement in matching cyclical investment composition data does not compromise the ability to match more standard business cycle facts, and in fact improves the ability to replicate

Table 2: Summary of Numerical Results - Comparison of Outcomes (Real U.S. data for 1985-2005 from Bachmann, et al (2008))

Model	Y	C	I	$\frac{\sigma_C}{\sigma_Y}$	$\frac{\sigma_I}{\sigma_Y}$	$\frac{\sigma_Y}{\sigma_{tech}}$	$\frac{\sigma_I}{\sigma_{tech}}$	σ_q (%)
Prec	1.47	0.77	5.12	0.73	4.28	2.43	7.46	4.6
FA	1.24	0.53	4.11	0.71	3.94	1.86	6.05	2.3
RBC	1.31	0.44	4.30	0.58	3.58	1.43	4.84	0
Data	1.36	0.94	4.87	0.69	5.39	2.01	11.14	-
C- R (2004)	-	-	-	-	-	1.47	-	-

aggregate investment dynamics. In Table 2 I report the volatility of key macroeconomic variables in the data and in three different types of models. The PREC model in its baseline calibration provides a close match with respect to U.S. data in the volatilities of the key macroeconomic variables. In particular, it brings us closer to matching aggregate investment volatility versus both the RBC and the FA models.

In order to study amplification and propagation again I compare the responses of aggregate investment and output in the three models described above (RBC, FA and PREC). First, the dynamics of the standard RBC model are well known, and are shown in Figure 8. The response of investment and output mimics closely the evolution of the underlying technology process. In essence, there is little propagation in this version. The price of capital q_t reacts most in the RBC version because entrepreneurial production of capital is not as affected as it would be in the presence of credit constraints; supply of new capital remains robust, and the decrease in demand drives q_t sharply down. There are no spillover effects as the level of aggregate entrepreneurial investment in the R&D technology is constant at the level that sustains the steady state level of capital, and given that only positive or negative variations with respect to that level may generate positive or negative spillover effects, there are none in this version of the model.

Financial imperfections as in the standard FA model amplify and add persistence to the effects of technology shocks. Contemporaneous output amplification is small relative to the RBC case, but the effects on propagation are stronger. This is due to the effect of R&D spillovers, given that, despite the fact that the composition of entrepreneurial investment shifts towards R&D, the level of R&D decreases, thus generating negative

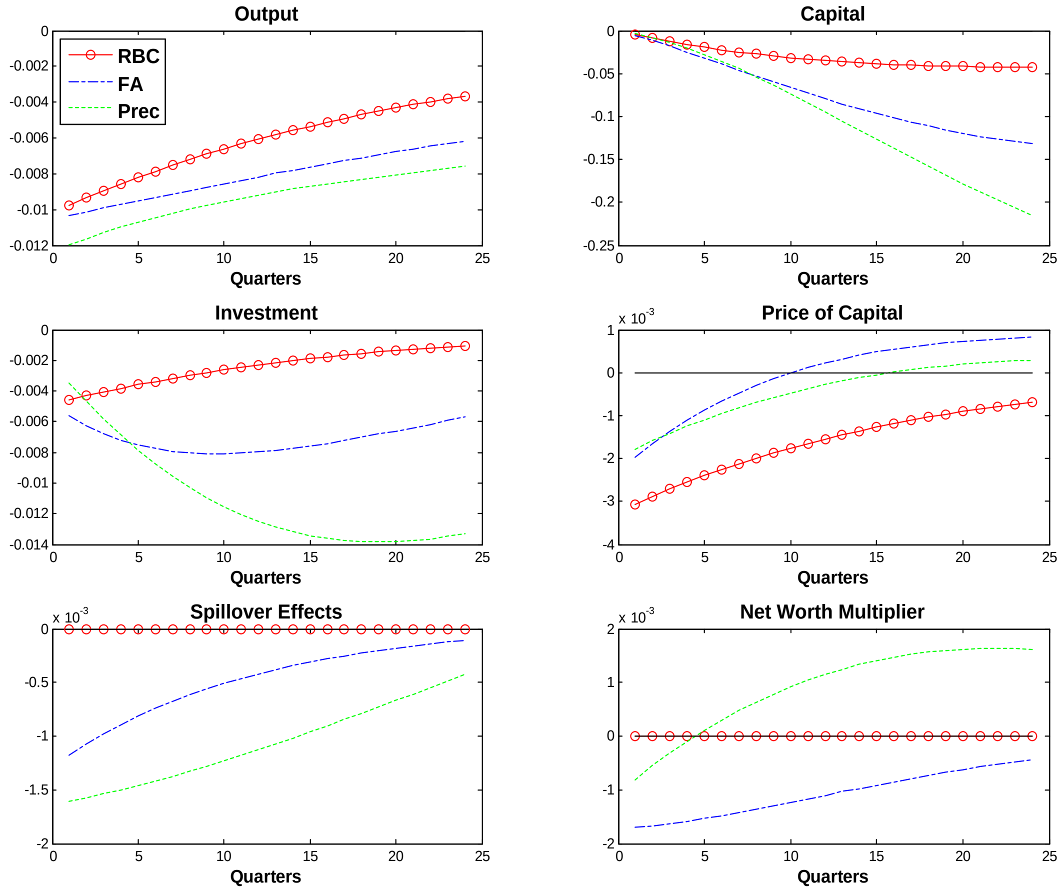

Figure 8: Impulse response functions to a 1% negative shock to aggregate productivity of the consumption-good producing firms.

spillover effects that persist through time. Thus, the gap between the output effects in the RBC and the FA models grows monotonically within the time frame of 24 quarters considered in this exercise. Investment in new capital by firms shows a hump-shaped response, and only starts recovering after ten quarters, when aggregate productivity has recovered and when the negative spillover effects have subsided. In fact, the recovery of demand for new capital drives the price of capital above its steady state level after 10 quarters, driven by a still limited supply of new capital given that entrepreneurs are still investing relatively more in the risky technology which does not produce new capital in the short run. Firms' leverage (the net worth multiplier minus one) decreases and remains below its steady state level for a long period. This reflects two effects at work; production has shifted towards the riskier activity which produces less pledgeable output, and pledgeability of the safe technology has itself decreased. Both effects push leverage in the same direction, and have a high degree of persistence.

Finally, the effect of financial imperfections in the PREC version is to amplify and add persistence to the effects of technology shocks even further. Contemporaneous output amplification is slightly larger than in the FA and RBC cases, and the effects on propagation are significantly stronger, especially if one takes into account the accumulated effects through time. This again is due to the effect of R&D spillovers given that the level of R&D investment decreases relatively more than in the FA case and generates significant negative spillover effects that persist through time. The gap between the output and spillover effects in the FA and PREC remains large and relatively constant within the time frame of 24 quarters considered in this exercise. Investment in new capital by firms shows again a hump-shaped response and a large fall that takes as much as 20 quarters to achieve its trough. This is one mechanism making the price of capital remain below its steady state level for a relative long period of time. The fact that entrepreneurs have shifted their production towards a larger share of safe investments that produce more capital in the short term relative to the risky technologies also act to keep the price of capital low. Firms' leverage shows an interesting pattern, as it first decreases and ends up increasing significantly after about 6 quarters, with the help of the shift towards the safe collateralizable technology and the recovery of asset prices.

7 Discussion and Conclusion

This paper introduces a model in which risk-neutral entrepreneurs behave in a risk averse manner, and in which the source of risk aversion has to do with investment opportunities and financial constraints. The model also provides a theoretical underpinning for the countercyclicality of financing constraints. I then use this framework to explore the implications of firms' risk-averse behavior for the role of credit market imperfections in amplifying or dampening shocks to the macro-economy.

There exists a large body of research on the role of financial frictions in amplifying macroeconomic shocks. Most work has been focused on how firms' *investment capacity* is affected in recessions by tighter borrowing constraints or by a decreased supply of intermediated finance, and has studied how firms are constrained in the amount they can invest ex-post. There has been little focus however on a propagation mechanism that studies how cyclical changes in the risk-sharing capacity of the financial system may be affecting firms' *willingness to bear risk* and acting to propagate the cycle by affecting the risk profile of their investment portfolio (the *composition* as well as the amount).

This paper is motivated by two sets of observations. On the one hand, there is evidence that constrained firms shift the composition of their investment towards safer and more liquid technologies in recessions, while this is not the case for unconstrained firms. On the other hand there is evidence that credit constrained firms display a precautionary behavior induced by future expected financing constraints that significantly affects their real and financial policies.

Based on these observations, I incorporate these precautionary effects into a dynamic stochastic general equilibrium framework to study their macroeconomic implications. I use this framework to address two important questions. Can a mechanism capturing this precautionary element have significant consequences for aggregate investment and output dynamics? Can this mechanism account for the observed variation in the composition of aggregate and firm-level investment across the business cycle?

This paper identifies a novel amplification mechanism of macroeconomic shocks based on time-varying risk-sharing opportunities that affect firms' preference for the risk profile of their portfolio of investment projects. This amplification mechanism is shown to be quantitatively large. On the other hand, this framework is able to account for the empirically documented cyclical variation in the composition of real investment, a feature which the existing models studying the macroeconomic implications of financial constraints cannot account for. In particular, it is shown how following worsening expected financing conditions, firms shift to safer but lower return investments, or, absent alternative investment opportunities, to liquid securities and cash, and how these effects are stronger for high agency cost firms and for firms in highly volatile industries.

A next step in this research agenda is to study if this mechanism can be potentially enhanced by financial intermediaries' own credit constraints, creating a powerful feedback mechanism between entrepreneurial investment choices, asset prices, and banks' balance sheet conditions and insurance capacity. The ability of financial intermediaries and capital markets to satisfy firms' liquidity demand may itself be subject to similar countercyclical constraints as non-financial firms, creating the potential for feedback effects between firms' investment decisions and intermediaries' balance sheet conditions. A main source of risk and liquidity management for firms are financial intermediaries, both using ex-ante protection through credit lines, and ex-post protection by borrowing on the spot market. Several empirical studies have found that loan supply to small firms is curtailed in downturns and following monetary policy shocks (Gertler and Gilchrist (1993)). The feedback effect through entrepreneurial capital valuations and financial intermediaries' commitment capacity could work as follows. Following a negative aggregate shock, firms increase their demand for ex-ante protection by financial intermediaries through credit lines. Intermediaries, however, are also subject to limited commitment and collateral constraints, and need to back their loan commitments using the loans extended to entrepreneurs as collateral. Intermediaries' ability to provide these loan commitments may decrease both due to lower valuation of existing loans, and lower demand for loans. This introduces a premium on liquidity services by banks, and forces firms to rely even more on operational hedging by adjusting the riskiness of their production technologies, reinforcing the initial effect. This further depresses the valuation of capital, and in turn the valuation of the loan portfolio of banks, further limiting their liquidity commitment capacity. The theoretical underpinnings and the quantitative relevance of this extension is left for future research.

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