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Collateral Crises

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Gary Gorton* and Guillermo Ordoñez**

Abstract

How can a small shock sometimes cause a large crisis when it does not at other times? Financial fragility builds up over time because it is not optimal to always produce costly information about counterparties. Short-term, collateralized, debt (e.g., demand deposits, money market instruments) -private money- is efficient if agents are willing to lend without producing costly information about the value of the collateral backing the debt. But, when the economy relies on this informationally-insensitive debt, information is not renewed over time, generating a credit boom during which firms with low quality collateral start borrowing. During the credit boom output and consumption go up, but there is increased fragility. A small shock can trigger a large change in the information environment; agents suddenly produce information about all collateral and find that much of the collateral is low quality, leading to a decline in output and consumption. A social planner would produce more information than private agents, but would not always want to eliminate fragility.

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1 Introduction

Financial crises are hard to explain without resorting to large shocks. But, the recent crisis, for example, was not the result of a large shock. The Financial Crisis Inquiry Commission (FCIC) Report (2011) noted that with respect to subprime mortgages: "Overall, for 2005 to 2007 vintage tranches of mortgage-backed securities originally rated triple-A, despite the mass downgrades, only about 10% of Alt-A and 4% of sub-prime securities had been 'materially impaired'-meaning that losses were imminent or had already been suffered-by the end of 2009" (p. 228-29). Park (2011) calculates the realized principal losses on the $1.9 trillion of AAA/Aaa-rated subprime bonds issued between 2004 and 2007 to be 17 basis points as of February 2011.[1] The sub-prime shock was not large. But, the crisis was large: the FCIC report goes on to quote Ben Bernanke's testimony that of "13 of the most important financial institutions in the United States, 12 were at risk of failure within a period of a week or two" (p. 354). A small shock led to a systemic crisis. The challenge is to explain how a small shock can sometimes have a very large, sudden, effect, while at other times the effect of the same sized shock is small or nonexistent.

One link between small shocks and large crises is leverage. Financial crises are typically preceded by credit booms, and credit growth is the best predictor of the likelihood of a financial crisis.[2] Furthermore, often house prices rise concurrently with the credit boom. Clearly, economy-wide high leverage is related to system-wide fragility, but this begs the question of why there was a credit boom to start with and why is it related house prices?

In this paper we develop a theory of financial crises, based on the dynamics of the production and evolution of information in short-term debt markets, which is private money (e.g., demand deposits and money market instruments). We explain how credit booms arise, leading to financial fragility where a small shock can have large consequences. We build on the micro foundations provided by Gorton and Pennacchi (1990) and Dang, Gorton, and Holmström (2011) who argue that short-term debt,

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[1]Park (2011) examined the trustee reports from February 2011 for 88.6% of the notional amount of AAA subprime bonds issued between 2004 and 2007.

[2]See, for example, Claessens, Kose, and Terrones (2011), Schularick and Taylor (2009), Reinhart and Rogoff (2009), Borio and Drehmann (2009), Mendoza and Terrones (2008) and Collyns and Senhadji (2002). Jorda, Schularick, and Taylor (2011) (p. 1) study 14 developed countries over 140 years (1870-2008): "Our overall result is that credit growth emerges as the best single predictor of financial instability."

in the form of bank liabilities or money market instruments, is designed to provide transactions services by allowing trade between agents without fear of adverse selection. This is accomplished by designing debt to be "information-insensitive," that is, such that it is not profitable for any agent to produce private information about the assets backing the debt, the collateral. But, in a financial crisis there is a sudden loss of confidence in short-term debt in response to a shock; it becomes information-sensitive, and agents produce information, and determine whether the backing collateral is good or not.

In this paper we build on these micro foundations to investigate the role of such information-insensitive debt in the macro economy. We do not explicitly model the trading motive for short-term information-insensitive debt. Nor do we explicitly include financial intermediaries. We assume that households have a demand for such debt and we assume that the short-term debt is issued directly by firms to households to obtain funds and finance efficient projects. The debt that firms issue is backed by collateral. In reality, this collateral may be a portfolio of loans or a portfolio of bonds, or specific bonds, as in private bank notes in the Free Banking Era prior to the U.S. Civil War or modern day sale and repurchase agreements (repo), short-term debt in which the lender receives bonds as collateral.

Information production about the backing collateral is costly to produce, and agents do not find it optimal to produce information at every date. The key dynamic in the model concerns how the perceived quality of collateral evolves if (costly) information is not produced. Collateral is subject to idiosyncratic shocks so that over time, without information production, the perceived value of all collateral tends to be the same because of mean reversion towards a "perceived average quality," such that some collateral is known to be bad, but it is not known which specific collateral is bad. Agents endogenously select what to use as collateral. Desirable characteristics of collateral include a high perceived quality and a high cost of information production. In other words, optimal collateral would resemble a complicated, structured, claim on housing or land, e.g., a mortgage-backed security.

When information is not produced and the perceived quality of collateral is high enough, firms with good collateral can borrow, but in addition some firms with bad collateral can borrow. In fact, consumption is highest if there is never information production, because then all firms can borrow, regardless of their true collateral quality. The credit boom increases consumption because more and more firms receive

financing and produce output. In our setting opacity can dominate transparency and the economy can enjoy a blissful ignorance. If there has been information-insensitive lending for a long time, that is, information has not been produced for a long time, there is a significant depreciation of information in the economy - all is grey, there is no black and white - and only a small fraction of collateral with known quality.

In this setting we introduce aggregate shocks that may decrease the perceived value of collateral in the economy. It is not the leverage per se that allows a small negative shock to have a large effect. The problem is that after a credit boom, in which more and more firms borrow with debt backed by collateral of unknown type (but with high perceived quality), a negative aggregate shock affects more collateral than the same aggregate shock would affect when the credit boom was shorter or if the value of collateral was known. Hence, the size of the downturn depends on how long debt has been information-insensitive in the past.

A negative aggregate shock reduces the perceived quality of all collateral. This may or may not trigger information production. If, given the shock, households have an incentive to learn the true quality of the collateral, firms may prefer to cut back on the amount borrowed to avoid costly information production, a credit constraint. Alternatively, information may be produced, in which case only firms with good collateral can borrow. In either case, output declines because the short-term debt is not as effective as before the shock in providing funds to firms.

In our theory, there is nothing irrational about the credit boom. It is not optimal to produce information every period, and the credit boom increases output and consumption. There is a problem, however, because private agents, using short-term debt, do not care about the future, which is increasingly fragile. A social planner arrives at a different solution because his cost of producing information is effectively lower. For the planner, acquiring information today has benefits tomorrow, which are not taken into account by private agents. When choosing an optimal policy to manage the fragile economy, the planner weights the costs and benefits of fragility. Fragility is an inherent outcome of using the short-term collateralized debt, and so the planner chooses an optimal level of fragility. This is often discussed in terms of whether the planner should "take the punch bowl away" at the (credit boom) party. The optimal policy may be interpreted as reducing the amount of punch in the bowl, but not taking it away.

We are certainly not the first to explain crises based on a fragility mechanism. Allen

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and Gale (2004) define fragility as the degree to which "...small shocks have disproportionately large effects." Some of the literature focuses on the magnification of shocks, that is, small shocks always generate large effects, while other literature focuses on the sudden collapse of the economy in which small shocks sometimes generate large effects, and sometimes do not. Our work tackles both aspects of fragility.

Among papers that highlight the magnification type of fragility, Kiyotaki and Moore (1997) show that leverage can have a large amplification effect. In their setting, the amount that can be borrowed is also limited by the available collateral. A fundamental shock causes asset cash-flows to fall, which causes the borrower's equity to fall more, due to the high leverage. Then, going forward, the borrower's investment capacity falls because the collateral is worth less. This in turn leads more of the asset to be owned by a second-best user. But, the value of the asset to the second-best user is less than that of the constrained borrower, causing asset values to fall, reinforcing the spiral. This mechanism relies on the feedback effects over time to collateral value, while our mechanism is about a sudden informational regime switch. In our setting, there is a sudden change in the information environment; agents produce information and some collateral turns out to be worthless, or firms cut back on their borrowing to prevent information production.

Krishnamurthy (2009) outlines two amplification mechanisms which can explain how a small shock could have a large effect. The first mechanism is a feedback effect to agents' balance sheets from fire sales prices: a small negative shock causes agents to sell assets, which depresses asset prices, requiring further asset sales, and so on. The initial asset sales may be required due to leverage, capital requirements or margin requirements. This is similar to Kiyotaki and Moore, as the asset values decline due to the feedback effect. The second mechanism concerns Knightian uncertainty which can increase when unexpected events occur, especially in the context of financial innovation that is perhaps not very well understood. Agents may respond by withdrawing from these investments and seek safe assets. In our setting, leverage and complexity in the economy are endogenous (complexity corresponds to a higher cost of producing information). Agents withdraw in a way when there is a negative shock, but this is because of the endogenous credit constraint or because information is produced and firms with bad collateral cannot borrow. In our setting, complexity corresponds to the choice of collateral, where desirable collateral has a high cost of information production. When a shock causes information to be produced, it is the

realization that much collateral is bad that reduce output.

Papers that focus on the sudden collapse type of fragility are based on multiplicity of equilibria. Diamond and Dybvig (1983) show that banks are vulnerable to random external events (sunspots) when beliefs about the solvency of banks are self-fulfilling. Lagunoff and Schreft (1999) show that a wave of pessimism about future conditions may trigger a collapse in the presence of interconnected banks. A critique of sunspots is their lack of predictive power and the irrelevance of payoff relevant fundamentals in selecting among equilibria. In this respect Ordonez (2011) use a global game refinement to show that small changes in fundamentals may suddenly move the financial system towards regions where reputation concerns and market discipline collapse, leading to excessive risk-taking; Allen and Gale (2004) show that the only equilibria that are robust to the introduction of small liquidity shocks are those with non-trivial sunspot activity. Our work departs from this literature because fragility evolves endogenously over time and it is not based on equilibria multiplicity but by switches between uniquely determined information regimes.

Our paper is also related to the literature on leverage cycles developed by Geanakoplos (1997, 2010) and Geanakoplos and Zame (2010). Their work relies on low volatility and innovation for the buildup of leverage, and a jump in uncertainty for the sudden decline. In our paper, crises are generated by a negative aggregate shock in the expected value of collateral, which generates a jump in uncertainty. Furthermore, we explicitly derive real effects and welfare implications from endogenous changes in information regimes.

Finally, there are a number of papers in which agents choose not to produce information ex ante and then may regret this ex post. Examples are the work of Hanson and Sunderam (2010) and Pagano and Volpin (2010), who study ex ante incentives to become informed or provide information versus ex post needs for information when a bad state of the world is realized. Once the bad state of the world occurs it is too late to become informed and there can be a market shut-down.[3] Like us these models have endogenous information production, but we endogenously obtain the "bad state of the world" in the sense that the aggregate shock in our setting can be small, but the credit boom can create fragility that turns the small shock into a "bad state."

In the next Section we present the model and study debt decisions by a single firm.

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[3]See also Andolfatto (2010) and Andolfatto, Berensten, and Waller (2011)

In Section 3 we study the aggregate and dynamic implications of information sensitiveness. In Section 4 we illustrate the results with a numerical example. We consider policy implications in Section 5 and the choice of collateral in Section 6. In Section 7 we present some brief empirical evidence. In Section 8, we conclude.

2 Model

2.1 Setting

We consider an economy where two overlapping generations coexist each period. Each generation is composed by a mass 1 of risk neutral individuals who live for two periods: "young" and "old". We interpret the "young" generation as "households", with income and no managerial labor or entrepreneurial ideas, and the "old" generation as potential "firms", with no income of their own but with managerial labor.

There are two types of goods in the economy. A numeraire good K, which is perishable (cannot be stored for future consumption) and reproducible (can be used to produce more of the same good), and a mass 1 endowment of land X, which is non-perishable and non-reproducible.

Each household is born with an endowment of the numeraire good, $\overline{K}$. When getting "old", each household develops a fixed amount of managerial labor L^*. We interpret L^* as entrepreneurial ideas or managerial abilities, which does not generate any disutility. A firm is defined as a combination of a unit of land X, labor L^* and numeraire good K used as capital, which are combined with a stochastic Leontief production function to produce Y units of numeraire good.

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Y = \begin{cases} A \min\{K, L\} & \text{with prob. } q \\ 0 & \text{with prob. } (1-q) \end{cases}
$$

We assume that the expected marginal product of capital is higher than its marginal cost $qA > 1$, hence production is efficient. Under this technology, $K^* = L^*$ is the level of capital that maximizes profits. Since firms do not have any endowment of K, they need to borrow such capital. We also assume $\overline{K} > K^*$, hence households have enough endowment to finance efficient production.

The land has an alternative use, besides production. If land is "good", it is possible to extract C units of K from a unit, but only once. If land is "bad", it is not possible to extract anything from the land. Land cannot sustain firms' production anymore if it is used at least once in this alternative activity. We assume a fraction $\hat{p}$ of land is good. There is a perception p_i, shared by everybody in the economy, about the probability an individual unit i of land is good. Knowing whether an individual unit of land is good or bad is costly, and requires spending γ units of numeraire.[4]

Having discussed the technology, preferences and objectives that agents face, we need to discuss the characteristics of the market for land and the market for loans. On the one hand, households lend K to firms at the beginning of the period and buy land from firms at the end of the period to be used when becoming a firm in the next period. On the other hand, firms which acquired land when young, borrow K at the beginnings of the period to produce and sell the land at the end of the period to the next cohort of firms.

With respect to the market for land, we assume that each buyer matches with one seller and has the bargaining power (makes a take-it-or-leave-it offer). This implies that sellers will be indifferent between selling the piece of land or not, in which case they just obtain the expected output from the alternative activity.[5] Hence the price of a unit of land which is good with probability p is pC, the expected consumption of using the land in the alternative activity.[6]

With respect to loans, we assume lenders cannot observe or seize the output of the firms they finance, which means there is no lending unless there is some form of collateral than can be liquidated in case of no repayment. We assume the firm can use a fraction x of land as collateral. We also assume that firms have all the bargaining power when borrowing; then lenders are indifferent between lending or not.[7]

In every period, the expected consumption of a household ("young" generation) that

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[4]We abstract from asymmetric information, in which firms know more about the collateral than lenders. This introduces the complication of signaling without adding any additional insight with respect to information production.

[5]It is simple to modify the model to sustain this assumption. For example, if a small fraction of households inherit an endowment of new land, there will be more firms selling land than households buying land. Since sellers who do not sell just deplete their unsold land, the mass of land sustaining production in the economy is invariant.

[6]In Appendix A.1 we extend the model to allow for different levels of sellers' negotiation power. We discuss in that case that additional effects of multiplicity.

[7]It is simple to modify the model to sustain this assumption. For example if only a fraction of households develops L^* when becoming firms there will be more lenders than borrowers every period.

lends and buys land that is good with probability p is $\overline{K} - K(p) + E(repay|p) - pC$. The expected consumption of a firm ("old" generation) that borrows and sells land that is good with probability p is $E(Y|p) - E(repay|p) + pC$. Aggregate consumption in each period is the sum of aggregate consumption of households and firms.

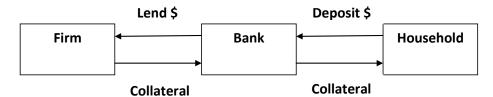$$W_t = \overline{K} + \int_0^1 [E(Y|p) - K(p)]f(p)dp$$

where $f(p)$ is the distribution of beliefs about collateral types in the economy. In the unconstrained first best all firms borrow and operate with K^*, regardless of beliefs p about the collateral. This implies that the unconstrained first best aggregate consumption in every period is

$$W^* = \overline{K} + K^*(qA - 1)$$

since $E(Y) = qAK^*$ in the first best.

Remark: The model captures the economic function of short-term debt, issued by financial intermediaries, e.g., demand deposits, sale and repurchase agreements, private bank notes, etc, in a completely self-contained macroeconomic model. The setting we have in mind is shown below in Figure 1.

Proposed subsection at the end of Section 2 on Model.

The model is intended to capture the economic function of short-term debt, issued by financial intermediaries, e.g., demand deposits, sale and repurchase agreements, private bank notes. The setting we have in mind is shown below in Figure #.

Figure 1: Economic Function of Short-Term Debt

Figure #

It is clear that our model has abstracted from the bank as we have the households lending directly to the firms. Furthermore, for simplicity, we have not modeled the transaction role of the short-term debt for the households, which is the focus of Dang, Gorton, and Holmström (2011). Instead we focus on the information dynamics. But, in so doing we do not want to be viewed as taking a stand on the role of the debt in lending, as opposed to its function as a transaction medium. When we look at some empirical tests, the model will be closer to the figure. But, for exposition in what follows we omit the banks.

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We will proceed in three steps. First we analyze the borrowing decision of a single firm that has collateral which is good with probability p. Then, we study the aggregate output when the collateral suffers idiosyncratic shocks (some good land becomes bad, and the opposite), but maintaining the fraction of good land constant at $\hat{p}$. Finally, we introduce aggregate shocks that affect all collateral in the economy, in addition to the idiosyncratic shocks, and discuss the dynamics of booms and crises.

2.2 Optimal loan from a single firm

In this section we study the optimal short-term debt contract between a single lender and a single firm, considering the possibility that the lender may want to produce information about the collateral type. The firm decides whether to issue debt that triggers information production or not. Triggering information production (information-sensitive debt) is potentially costly for the firm because it may raise the cost of borrowing. However, not triggering information production (information-insensitive debt) may also be costly because it may reduce the possible size of the loan. This trade-off determines the information-sensitiveness of the debt and, ultimately the amount of information in the economy and the information dynamics.

2.2.1 Information-Sensitive Debt

Lenders can learn the true type of the land by paying an amount γ of numeraire. When information is generated, it becomes public at the end of the period. This introduces incentives for lenders to obtain this information before lending. Since lenders are competitive and risk neutral, they break even based on the face value of the debt $R_{IS}(p)$ and the fraction $x_{IS}(p)$ of land with expected price pC posted by the firm as collateral. That is, lenders should be indifferent ex-ante between producing information or not:

$$p(qR_{IS} + (1-q)x_{IS}C - K) = \gamma \qquad \Rightarrow \qquad R_{IS} = \frac{pK + \gamma - (1-q)px_{IS}C}{pq}.$$

This equality shows the relation between R_{IS} and x_{IS}. However there is an additional condition, debt is risk free because the firm should pay the same in case of success or failure, $R_{IS} = x_{IS}C$. It is not possible that $R_{IS} > x_{IS}C$ because in that case the firm

would always prefer to hand in the collateral rather than paying in case of success. Similarly, it is not possible that $R_{IS} < x_{IS}C$ because then the firm would always prefer to sell the collateral directly in the market at a price C and give lenders R_{IS} rather than $x_{IS}C$ in case of failure. This condition pins down the fraction of collateral a firm with land that is good with probability p will post in equilibrium:

$$R_{IS} = x_{IS}C \qquad \Rightarrow \qquad x_{IS} = \frac{pK + \gamma}{pC} \leq 1$$

This implies the firm is able to borrow the optimal K^* when $\frac{pK^* + \gamma}{pC} \leq 1$ (this is, for all collateral with $p \geq \frac{\gamma}{C - K^*}$). Otherwise the firm will be able to borrow less than K^*, even posting the whole unit of good land as collateral. In this case $\frac{pK + \gamma}{pC} = 1$ (this is $K = \frac{pC - \gamma}{p}$). Naturally, there is no lending, even if the firm posts all the good collateral if $\frac{p0 + \gamma}{pC} > 1$ (that is, for $p < \frac{\gamma}{C}$).

The expected profits from issuing information-sensitive debt is

$$E(\pi|p, IS) = p(qAK - x_{IS}C) + pC.$$

Considering x_{IS} in equilibrium, expected profit are

$$E(\pi|p, IS) = pK^*(qA - 1) - \gamma + pC.$$

The firm decides to borrow rather than just selling the land if $pK^*(qA - 1) \geq \gamma$, or $p \geq \frac{\gamma}{K^*(qA - 1)}$. If $\frac{\gamma}{K^*(qA - 1)} > \frac{\gamma}{C - K^*}$ (or $qA < C/K^*$) the firm can always borrow K^* when willing to borrow. Based on this assumption, expected profits are

$$E(\pi|p, IS) = \begin{cases} pK^*(qA - 1) - \gamma + pC & \text{if } p \geq \frac{\gamma}{K^*(qA - 1)} \\ pC & \text{if } p < \frac{\gamma}{K^*(qA - 1)}. \end{cases}$$

2.2.2 Information-Insensitive Debt

Another possibility for firms is to borrow without triggering information acquisition by lenders. Still it should be the case that lenders break even in equilibrium

$$qR_{II} + (1 - q)px_{II}C = K \qquad \Rightarrow \qquad R_{II} = \frac{K - (1 - q)px_{II}C}{q}.$$

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As in the previous case, the condition $R_{II} = px_{II}C$ holds in equilibrium. Then we can obtain the optimal amount of collateral

$$R_{II} = x_{II}pC \qquad \Rightarrow \qquad x_{II} = \frac{K}{pC} \leq 1.$$

The problem the firm faces when issuing information-insensitive debt is that lenders may decide to deviate, check the value of the collateral and ex-post decide whether to lend or not at the specified fraction x_{II}, before the firm gets to know such an information. Lenders want to deviate if the expected profits from acquiring information, evaluated at x_{II} and R_{II}, are greater than the cost of acquiring information γ. Hence, there are no incentives to deviate and acquire information if

$$p(qR_{II} + (1-q)x_{II}C - K) < \gamma \qquad \Rightarrow \qquad (1-p)(1-q)K < \gamma,$$

that is, if the expected gains of producing information is smaller than the cost of producing information, γ. In essence, learning the collateral is good allows the lender to sell it a higher price later $x_{II}C$ in case the firm defaults, which occurs with probability $(1-q)$, while learning that the collateral is bad allows the lender not to lend.

It is clear from the previous condition that the firm can discourage information production about collateral by reducing borrowing and output. If the condition is not binding at $K = K^*$, then there are no strong incentives for lenders to produce information. If the condition is binding, the firm will borrow as much as possible given the restrictions of not triggering information acquisition,

$$K = \frac{\gamma}{(1-p)(1-q)}.$$

Hence, information-insensitive borrowing is characterized by the following debt size:

$$E(K|p, II) = \min\left\{K^*, \frac{\gamma}{(1-p)(1-q)}, pC\right\}. \tag{1}$$

We focus on the case in which information-insensitive borrowing is characterized by

three regions.[8]

$$K(p) = \begin{cases} K^* & \text{if } K^* \leq \frac{\gamma}{(1-p)(1-q)} & \texttt{(no credit constraint)} \\ \frac{\gamma}{(1-p)(1-q)} & \text{if } K^* > \frac{\gamma}{(1-p)(1-q)} & \texttt{(credit constraint)} \\ pC & \text{if } pC < \frac{\gamma}{(1-p)(1-q)} & \texttt{(collateral selling)} \end{cases}$$

The first kink is generated by the point at which the constraint to avoid information production is binding when evaluated at the optimal loan size K^*; this occurred when financial constraints start binding more than technological constraints. The second kink is generated by the constraint $x_{II} \leq 1$, below which the firm is able to borrow up to the expected value of the collateral pC without triggering information production.

Expected profits under information-insensitive borrowing are:

$$qAK - x_{II}pC + pC,$$

that is, with probability q production is successful, the firm always pays back $x_{II}pC$, and the collateral has an expected value of pC. Then:

$$E(\pi|p, II) = E(K|p, II)(qA - 1) + pC. \tag{2}$$

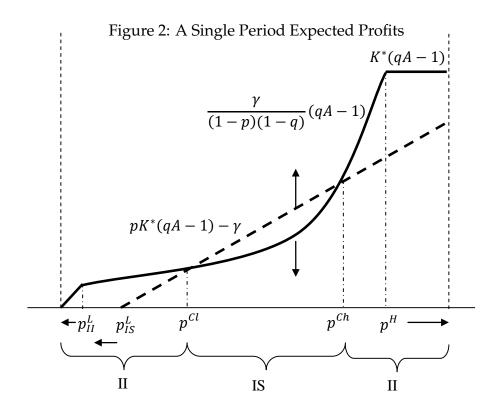In the case we are focusing on, explicitly considering the kinks, expected profits are:

$$E(\pi|p, II) = \begin{cases} K^*(qA - 1) + pC & \text{if } K^* \leq \frac{\gamma}{(1-p)(1-q)} \\ \frac{\gamma}{(1-p)(1-q)}(qA - 1) + pC & \text{if } K^* > \frac{\gamma}{(1-p)(1-q)} \\ pC(qA - 1) + pC & \text{if } pC < \frac{\gamma}{(1-p)(1-q)}. \end{cases}$$

2.2.3 Optimal Debt

Figure 2 shows the profits under these two information regimes for each possible p (after deducting the expected value of the collateral pC in all expressions). From comparing which one is larger we can obtain the values of p for which the firm prefers

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[8]This is the more natural case, when $C > K^*$ and γ is not large (specifically $\gamma < \frac{K^*}{C}(C - K^*)$). If $C > K^*$ and $\gamma > \frac{K^*}{C}(C - K^*)$, then there are only two regions, where the middle region disappears. If $C < K^*$, then the first region is given by pC and not K^*, since pC is always smaller than K^*. In all cases the main conclusions we derive are the same.

to borrow with an information-insensitive loan (II) or with an information-sensitive loan (IS).

Figure 2: A Single Period Expected Profits

The cutoffs highlighted in Figure 2 are determined in the following way:

1. The cutoff p^H is the belief that generates the first kink of information-insensitive profits, below which firms have to reduce borrowing to prevent information production:

$$p^H = 1 - \frac{\gamma}{K^*(1-q)}. \tag{3}$$

2. The cutoff p^L_{II} is obtained from the second kink of the information-insensitive profits,[9]

$$p^L_{II} = \frac{1}{2} - \sqrt{\frac{1}{4} - \frac{\gamma}{C(1-q)}}. \tag{4}$$

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[9]The positive root for the solution of $pC = \gamma/(1-p)(1-q)$ is irrelevant since it is greater than p^H, and then it is not binding given all firms with a collateral that is good with probability $p > p^H$ can borrow the optimal level of capital K^* without triggering information production.

3. The cutoff p_{IS}^L is obtained from the kink of information-sensitive profits

$$p_{IS}^L = \frac{\gamma}{K^*(qA - 1)}.\tag{5}$$

with the natural restriction that $p_{IS}^L = 1$ if $\gamma > K^*(qA - 1)$.

4. Cutoffs p^{Ch} and p^{Cl} are obtained from equalizing the profit functions of information-sensitive and insensitive loans and solving for the quadratic roots of:

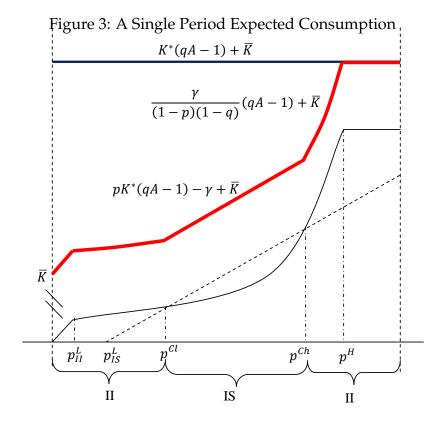$$\frac{\gamma}{(1 - p)(1 - q)} = pK^* - \frac{\gamma}{(qA - 1)}.\tag{6}$$

There are only three regions of financing. Information-insensitive loans are chosen by firms with collateral with high and low values of p, while information-sensitive loans are chosen by firms with collateral with intermediate values of p.

To understand how these regions depend on the information cost γ, the four arrows in the figure show how the different cutoffs and functions move as we reduce γ. In an extreme, if $\gamma = 0$ and information is free, all collateral is information-sensitive (i.e., the IS region is $p \in [0, 1]$). Contrarily, as γ increases, the two cutoffs p^{Ch} and p^{Cl} converge and the IS region shrinks until it disappears (i.e., the II region is $p \in [0, 1]$) when γ is large enough (specifically, when $\gamma > \frac{K^*}{C}(C - K^*)$).

Having characterized how the information-sensitivity of debt depends on collateral beliefs p, we can analyze expected consumption, which is our measure of welfare in the aggregate at a given period. By construction, at the cutoffs p^{Cl} and p^{Ch}, where the system changes from information-insensitive debt to information-sensitive debt, the expected consumption between the two regimes is the same. This is because, at these cutoffs

$$W_t^{IS} \equiv pK^*(qA - 1) - \gamma + \overline{K} = K(qA - 1) + \overline{K} \equiv W_t^{II}.$$

In Figure 3 we show how financial constraints reduce aggregate consumption when the perceived quality of the collateral p declines. Efficient consumption is the solid horizontal wide line on the top of the picture and the financially constrained aggregate consumption is the solid wide line increasing in p.

Figure 3: A Single Period Expected Consumption

$$K^*(qA - 1) + \bar{K}$$

$$\frac{\gamma}{(1-p)(1-q)}(qA - 1) + \bar{K}$$

$$pK^*(qA - 1) - \gamma + \bar{K}$$

$\bar{K}$

$p_{II}^L \quad p_{IS}^L \quad p^{Cl} \qquad p^{Ch} \quad p^H$

II   IS   II

3 Aggregate Results

In this section we characterize the evolution of information about collateral in the whole economy, and its impact on aggregate consumption. We study an environment in which each unit of collateral changes quality over time, mean reverting towards the average quality of collateral in the economy. These changes and their realization are not observable unless information is acquired about them. First, we study the case without aggregate shocks to collateral, in which the average quality of collateral in the economy does not change, and discuss the effects of endogenous information production on the dynamics of credit booms. Then, we introduce aggregate shocks that modify the average quality of collateral in the economy, and study the effects of endogenous information on the size of crises and the speed of recoveries.

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3.1 No Aggregate Shocks

In this section we impose a specific process of idiosyncratic mean reverting shocks that are useful in characterizing analytically the dynamic effects of information production on aggregate consumption. First, we assume idiosyncratic shocks are observable, but their realization are not unless information is acquired. Second, we assume the probability a piece of land faces an idiosyncratic shock is independent of its type. Finally, we assume the probability a piece of land becomes good, conditional on having an idiosyncratic shock, is also independent of its type. These assumptions are just imposed to simplify the exposition. The main results of the paper are robust to different processes, as long as there is mean reversion of collateral in the economy.

Specifically, assume that initially (at period 0) there is perfect information about which collateral is good and which is bad. In every period, with probability λ the true quality of each unit of land remains unchanged and with probability $(1 - \lambda)$ there is an idiosyncratic shock that changes its type. In this last case, land becomes good with a probability $\hat{p}$, independent of its current type. We assume the shock is observable. But, even when the shock is observable, the realization of the new quality is not, unless a certain amount of the numeraire good γ is used to learn about it. The idiosyncratic shock and the realization are assumed independent of the idiosyncratic production shock q.

In what follows we study aggregate consumption in this economy as time evolves, for different values of $\hat{p}$, and we show that, as long as $\hat{p}$ is large enough consumption is growing with time since there is no information production about the collateral.

First, for notational simplicity, we define borrowing depending on p, based on the analysis of Section 2.2:

$$K(p|\gamma) = \begin{cases} K^* & \text{if } p^H < p \\ \frac{\gamma}{(1-p)(1-q)} & \text{if } p^{Ch} < p < p^H \\ pK^* - \frac{\gamma}{(qA-1)} & \text{if } p^{Cl} < p < p^{Ch} \\ \frac{\gamma}{(1-p)(1-q)} & \text{if } p^L_{II} < p < p^{Cl} \\ pC & \text{if } \quad p < p^L_{II} \end{cases}$$

From the definition of the cutoffs, we know $K(p)$ is monotonically increasing in p.

The aggregate consumption of the economy at period t is defined by:

$$W_t = \int_0^1 K(p)(qA - 1)f(p)dp + \bar{K},$$

where $f(p)$ is the distribution of beliefs about all the collateral in the economy. In the simple stochastic process for idiosyncratic shocks we assume, and in the absence of aggregate shocks, this distribution has a three-point support: 0, $\hat{p}$ and 1. We can analyze the evolution of aggregate consumption when $\hat{p}$ is either in the information-sensitive or insensitive region.

- $\hat{p}$ **is information-insensitive ($\hat{p} > p^{Ch}$ or $\hat{p} < p^{Cl}$)**

  In this case, information is not reacquired and at period t, $f(1) = \lambda^t \hat{p}$, $f(\hat{p}) = (1 - \lambda^t)$ and $f(0) = \lambda^t(1 - \hat{p})$. Since $K(0) = 0$,

  $$W_t^{II} = \left[\lambda^t \hat{p} K(1) + (1 - \lambda^t)K(\hat{p})\right](qA - 1) + \bar{K}. \tag{7}$$

  Since $W_0^{II} = \hat{p}K(1)(qA - 1) + \bar{K}$ and $\lim_{t\to\infty} W_t^{II} = K(\hat{p})(qA - 1) + \bar{K}$, the evolution of aggregate consumption depends on $\hat{p}$. If $\hat{p}K(1) = K(\hat{p})$, aggregate consumption is constant over time, which occurs for the value $\hat{p}^*$ when:

  $$\frac{\gamma}{(1 - \hat{p}^*)(1 - q)} = \hat{p}^* K^*,$$

  which is fulfilled for $p^{Ch} < \hat{p}^* < p^H$.

  If $\hat{p} > \hat{p}^*$, more and more firms borrow, a credit boom ensues and aggregate consumption grows over time.

- $\hat{p}$ **is information-sensitive ($\hat{p} \in [p^{Cl}, p^{Ch}]$)**

  In this case, information about the fraction $(1 - \lambda)$ of collateral that gets an idiosyncratic shock is reacquired every period t. Then $f(1) = \lambda \hat{p}$, $f(\hat{p}) = (1 - \lambda)$ and $f(0) = \lambda(1 - \hat{p})$. Considering $K(0) = 0$,

  $$W_t^{IS} = \left[\lambda \hat{p} K(1) + (1 - \lambda)K(\hat{p})\right](qA - 1) + \bar{K}. \tag{8}$$

  Aggregate consumption W_t^{IS} does not depend on t; it is constant at the level at which information is reacquired every period.

3.2 Aggregate Shocks

In this section we introduce negative aggregate shocks that transform a fraction $(1-\eta)$ of good collateral into bad collateral. As with idiosyncratic shocks, the aggregate shock is observable, but which good collateral changes type is not observable. When the shock hits, there is a downward revision of the perception about all collateral quality. For example, collateral that was $p = 1$, gets a new belief $p' = \eta$ after the shock. Similarly, all collateral with $p = \hat{p}$ gets revised downwards to $p' = \eta\hat{p}$.

We also consider positive aggregate policy shocks that transform a fraction α of bad collateral into good collateral. In this case beliefs are revised upwards for all collateral. Collateral with $p = 0$ get revised to $p' = \alpha$ and collateral with $p = \hat{p}$ is revised to $p' = \hat{p} + \alpha(1 - \hat{p})$. In this section we focus on negative aggregate shocks and in the policy section we will discuss how policies that look like positive aggregate shocks can be constructed to deal with economic crises.

We will focus on the case where prior to the negative aggregate shock, the average quality of the collateral is good enough such that there are no financial constraints (that is, $\hat{p} > p^H$). Later we will justify this, allowing for endogenous choice of collateral, showing that this case is in fact the situation that arises naturally.

The next Proposition shows that the longer the economy did not face a negative aggregate shock, the larger the consumption loss when such a shock does occur.

Proposition 1 *Assume $\hat{p} > p^H$ and a negative aggregate shock η in period t. The reduction in consumption $\Delta(t|\eta) \equiv W_t - W_{t|\eta}$ is non-decreasing in shock size η and non -decreasing in the time t elapsed previously without a shock.*

Proof Assume a negative aggregate shock of size η. Since we assume $\hat{p} > p^H$, the average collateral does not generate information production. The aggregate consumption before the shock is given by equation 7 and after the shock aggregate consumption is:

$$W_{t|\eta} = \left[\lambda^t \hat{p} K(\eta) + (1 - \lambda^t) K(\eta\hat{p}) \right] (qA - 1) + \bar{K}.$$

Then we can define the reduction in aggregate consumption as $\Delta(t|\eta) = W_t - W_{t|\eta}$

$$\Delta(t|\eta) = [\lambda^t \hat{p}[K(1) - K(\eta)] + (1 - \lambda^t)[K(\hat{p}) - K(\eta\hat{p})]](qA - 1).$$

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That $\Delta(t|\eta)$ is non-decreasing in η is straightforward to check. Furthermore, $\Delta(t|\eta)$ is non-decreasing in t if the following condition holds

$$\hat{p}[K(1) - K(\eta)] \leq [K(\hat{p}) - K(\eta\hat{p})]$$

Since we assumed $\hat{p} > p^H$, $K(\hat{p}) = K(1)$. The condition is fulfilled because $K(p)$ is monotonically decreasing in p and $\hat{p} \leq 1$.   Q.E.D.

The intuition for this Proposition is the following. If there is little information about collateral in the economy (that is, there is a small fraction of collateral with either $p = 0$ or $p = 1$), a negative aggregate shock affects a high fraction of collateral in the economy. Pooling bad collateral with good collateral allows for the credit boom because firms with bad collateral gets credit that they would not obtain otherwise. The reason is that firms with good collateral are effectively subsidizing firms with bad collateral since pooling does not reduce the borrowing of firms with good collateral, but increases the borrowing of firms with bad collateral.

However, pooling with bad collateral puts good collateral in a weaker position to face aggregate shocks of a given size. When pooling, firms with good collateral may see their credit decrease in the presence of aggregate shocks to levels below those achievable if no pooling would have happened. Without pooling, the borrowing of firms with good collateral decreases starting from an original belief $p = 1$. Contrarily, with pooling, the borrowing of firms with good collateral decreases starting from an original belief $p = \hat{p}$, an hence is more exposed to suffer a larger reduction. Furthermore, after a negative shock to collateral, either a higher amount of the numeraire is used to produce information or borrowing is excessively restricted to avoid such information production, having a larger aggregate effect.

If we define *"fragility"* as the probability aggregate consumption declines more than a certain value, then the following corollary follows immediately from the previous Proposition.

Corollary 1 *Given a structure of negative aggregate shocks, the fragility of an economy increases with the number of periods the debt in the economy has been informationally-insensitive, and then increases with the fraction of collateral that is of unknown quality.*

The next Proposition shows that under a negative shock, information production speeds up the recovery.

Proposition 2 *Assume $\hat{p} > p^H$ and a negative aggregate shock η in period t. The recovery is faster when information is produced after the shock when $\eta\hat{p} < \overline{\eta\hat{p}} \equiv \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\gamma}{K^*(1-q)}}$, where $p^{Ch} < \overline{\eta\hat{p}} < p^H$. This is, $W_{t+1}^{IS} > W_{t+1}^{II}$ for all $\eta\hat{p} < \overline{\eta\hat{p}}$.*

Proof If the negative shock happens in period t, the distribution in period t is: $f(\eta) = \lambda^t\hat{p}$, $f(\eta\hat{p}) = (1 - \lambda^t)$ and $f(0) = \lambda^t(1 - \hat{p})$.

In period $t + 1$, if information has been produced (IS case), after the idiosyncratic shocks the distribution of beliefs is $f_{IS}(1) = \lambda\eta\hat{p}(1 - \lambda^t)$, $f_{IS}(\eta) = \lambda^{t+1}\hat{p}$, $f_{IS}(\hat{p}) = (1 - \lambda)$, $f_{IS}(0) = \lambda[(1 - \lambda^t\hat{p}) - \eta\hat{p}(1 - \lambda^t)]$. Hence, aggregate consumption at $t + 1$ if information is acquired is,

$$W_{t+1}^{IS} = [\lambda\eta\hat{p}(1 - \lambda^t)K^* + \lambda^{t+1}\hat{p}K(\eta) + (1 - \lambda)K(\hat{p})](qA - 1) + \overline{K} \tag{9}$$

In period $t + 1$, if information has not been produced (II case), after the idiosyncratic shocks the distribution of beliefs is $f_{II}(\eta) = \lambda^{t+1}\hat{p}$, $f_{II}(\hat{p}) = (1 - \lambda)$, $f_{II}(\eta\hat{p}) = \lambda(1 - \lambda^t)$, $f_{II}(0) = \lambda^{t+1}(1 - \hat{p})$. Hence, aggregate consumption at $t + 1$ if information is not acquired is,

$$W_{t+1}^{II} = [\lambda^{t+1}\hat{p}K(\eta) + \lambda(1 - \lambda^t)K(\eta\hat{p}) + (1 - \lambda)K(\hat{p})](qA - 1) + \overline{K}. \tag{10}$$

Taking the difference between aggregate consumption at $t+1$ between the two regimes of information production:

$$W_{t+1}^{IS} - W_{t+1}^{II} = \lambda(1 - \lambda^t)(qA - 1)[\eta\hat{p}K^* - K(\eta\hat{p})]. \tag{11}$$

This expression is non-negative for all $\eta\hat{p}K^* \geq K(\eta\hat{p})$, or alternatively, for all $\eta\hat{p} < \overline{\eta\hat{p}} \equiv \frac{1}{2} + \sqrt{\frac{1}{4} - \frac{\gamma}{K^*(1-q)}}$. From equation (6), $p^{Ch} < \overline{\eta\hat{p}} < p^H$. $\qquad$ Q.E.D.

The intuition for this Proposition is the following. When information is produced after a shock η that constrains credit a lot, information costs are spent at the time of the shock, and then only a fraction $\eta\hat{p}$ of collateral can sustain the maximum borrowing K^*. When information is not produced after a shock η that constrains credit, collateral that remains with belief $\eta\hat{p}$ will restrict credit in the following periods, until beliefs move back to $\hat{p}$. This is equivalent to restricting credit proportional to monitoring costs in all following periods as well. Not producing information causes a kind of debt overhang going forward. The Proposition generates the following Corollary.

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Corollary 2 *There exists a range of negative aggregate shocks (η such that $\eta\hat{p} \in [p^{Ch}, \overline{\eta\hat{p}}]$) in which agents do not acquire information, but recovery would be faster if they did.*

The next Proposition describes the evolution of the standard deviation of beliefs in the economy during a credit boom.

Proposition 3 *During a credit boom, the standard deviation of beliefs declines.*

Proof If at period 0 beliefs start from $f(0) = 1 - \hat{p}$ and $f(1) = \hat{p}$, the original variance of beliefs is

$$Var_0(p) = \hat{p}^2(1 - \hat{p}) + (1 - \hat{p})^2\hat{p} = \hat{p}(1 - \hat{p}).$$

At period t, during a credit boom, the distribution of beliefs is $f(0) = \lambda^t(1 - \hat{p})$, $f(\hat{p}) = 1 - \lambda^t$ and $f(1) = \lambda^t\hat{p}$. Then, at period t the variance of beliefs is

$$Var_t(p|II) = \lambda^t[\hat{p}^2(1 - \hat{p}) + (1 - \hat{p})^2\hat{p}] = \lambda^t\hat{p}(1 - \hat{p}),$$

decreasing in the length of the boom t.   Q.E.D.

Finally, the next Proposition describes the evolution of the standard deviation of beliefs in the economy during a crisis.

Proposition 4 *For a given negative aggregate shock η that triggers information production about collateral with new belief $\eta\hat{p}$, the increase of the standard deviation of beliefs is increasing in the length of the preceding credit boom.*

Proof Assume a shock η at period t that triggers information acquisition about collateral with new belief $\eta\hat{p}$. The shock η can be such that $\eta > p^{Ch}$ and there is no information production for collateral *known to be good before the shock* (with new belief η) or such that $\eta < p^{Ch}$ and there is information production also for collateral *known to be good before the shock*. We study these two cases next after a shock that happens after a credit boom of length t.

- $\eta > p^{Ch}$. The distribution of beliefs in case information is produced is given by $f(0) = \lambda^t(1 - \hat{p}) + (1 - \lambda^t)(1 - \eta\hat{p})$, $f(\eta) = \lambda^t\hat{p}$ and $f(1) = (1 - \lambda^t)\eta\hat{p}$. Then, at period t the variance of beliefs with information production is

$$Var_t(p|IS) = \lambda^t\hat{p}(1 - \hat{p})\eta^2 + (1 - \lambda^t)\eta\hat{p}(1 - \eta\hat{p}),$$

Then

$$Var_t(p|IS) - Var_t(p|II) = (1 - \lambda^t)\eta\hat{p}(1 - \eta\hat{p}) - \lambda^t\hat{p}(1 - \hat{p})(1 - \eta^2),$$

increasing in the length of the boom t.

- $\eta < p^{Ch}$, The distribution of beliefs in case information is produced is given by $f(0) = \lambda^t(1 - \hat{p}) + (1 - \lambda^t(1 - \hat{p}))(1 - \eta\hat{p})$, and $f(1) = (1 - \lambda^t(1 - \hat{p}))\eta\hat{p}$. Then, at period t the variance of beliefs with information production is

$$Var_t(p|IS) = \lambda^t\hat{p}(1 - \hat{p})\eta^2\hat{p} + (1 - \lambda^t(1 - \hat{p}))\eta\hat{p}(1 - \eta\hat{p}),$$

Then

$$Var_t(p|IS) - Var_t(p|II) = (1 - \lambda^t(1 - \hat{p}))\eta\hat{p}(1 - \eta\hat{p}) - \lambda^t\hat{p}(1 - \hat{p})(1 - \eta^2\hat{p}),$$

also increasing in the length of the boom t.

The change in the variance of beliefs also depends on the size of the shock. Naturally, for very large shocks $\eta \to 0$ the variance can decrease, but this reduction is lower the larger is t. $\hfill$ Q.E.D.
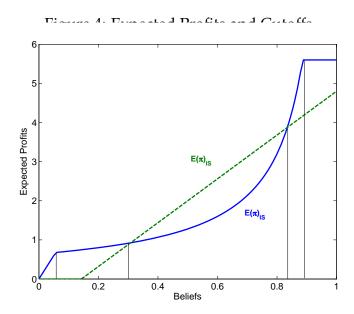
Finally it is important to highlight that shocks in real activity, in particular a reduction in the probability of success q, may trigger a credit crunch in the economy. This is clear from equation (3). Assume $\hat{p} > p^H$, so that initially many firms were borrowing K^*. A decline in q that increases p^H, may lead to a situation where $\hat{p} < p^H$, and these firms are then credit constrained. The reason is that a higher probability of default by firms increases the incentives of lenders to acquire information about the type of collateral. Hence firms have to restrict borrowing to discourage such information acquisition.

4 Numerical Illustration

We illustrate our main results with the following numerical exercise. We assume idiosyncratic shocks happen with probability $(1-\lambda) = 0.1$, in which case the collateral becomes good with probability $\hat{p} = 0.92$. Other parameters are $q = 0.6$, $A = 3$ (these two assumption imply that investing in the project generates a return of 80%), $\bar{K} = 10$,

$L^* = K^* = 7$ (which means the endowment is enough to invest in the optimal project size), $C = 15$ and $\gamma = 0.35$.[10]

Given these parameters we can obtain the relevant cutoffs for our analysis. Specifically, $p^H = 0.89$, $p_{II}^L = 0.06$ and the sensitive information region is in the values $p \in [0.31, 0.83]$. As discussed above, these cutoffs are obtained from comparing expected profits from taking a loan producing information with one without producing information. Figure 4 plots these functions and the respective cutoffs.

Figure 4: Expected Profits and Cutoffs

Using these cutoffs we simulate the model for 100 periods. As before, we assume that at period 0 there is perfect information about the true quality of all collateral in the economy. Over time there are idiosyncratic shocks that make this information vanish unless there is costly information acquisition about the realizations after idiosyncratic shocks.

We introduce a negative aggregate shock that transforms a fraction $(1 - \eta)$ of good collateral into bad collateral in periods 5 and 50. We also introduce a positive aggregate shock that transforms a fraction $\alpha = 0.25$ of bad collateral into good collateral in period 30. We compute the dynamic reaction of consumption in the economy for different sizes of negative aggregate shocks, $\eta = 0.97$, $\eta = 0.91$ and $\eta = 0.90$. We will

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[10]These parameters fulfill the assumptions $qA < C/K^*$ and $\gamma < \frac{K^*}{C}(C - K^*)$ in the text.

see that small differences in the size of a negative shock can have important dynamic consequences in the economy.

Figure 5 shows the average probability that collateral is good in the economy for the three possible negative aggregate shocks (this is the real collateral quality existing in the economy). While aggregate shocks have a temporary effect on the quality of collateral, after aggregate shocks occur the average quality converges back to $\hat{p} = 0.92$. As can be seen, the negative aggregate shocks were constructed such that $\eta\bar{p}$ is above p^H when $\eta = 0.97$, is between p^{Ch} and p^H when $\eta = 0.91$ and is less than p^{Ch} when $\eta = 0.90$.
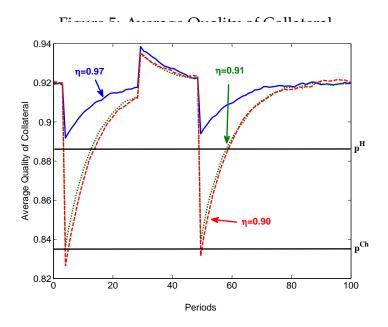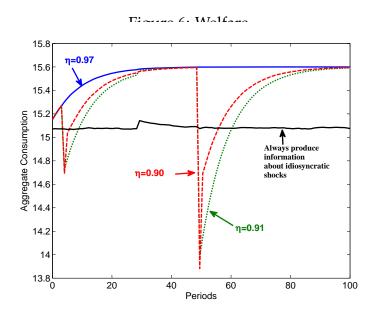

Figure 5: Average Quality of Collateral

Figure 6 shows the evolution of aggregate consumption for the three negative aggregate shocks. The first result to highlight is that when $\eta = 0.97$, aggregate shocks do not affect the evolution of consumption at all. The reason is that shocks do not introduce financial constraints. The second result is that positive shocks do not affect the evolution of consumption; the reason is that $\hat{p} > p^H$, and hence improvements in the belief distribution do not relax the financial constraints even more. This introduces an asymmetry into how shocks affect aggregate consumption.
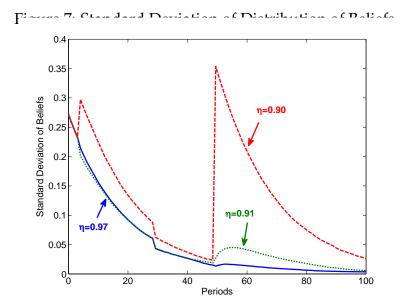
The third result is that the reduction in consumption from the negative aggregate shock in period 5, when not much information has vanished yet, is much lower than the reduction in consumption from the same size negative aggregate shock in period 50. The reason is that the shock reduces financing for a larger fraction of collateral

which information has vanished over time but was good enough to finance projects successfully. This is the result proved in Proposition 1.

Figure 6: Welfare

In Figure 7 we illustrate that small differences in the size of shocks have very different consequences for the variance of beliefs about the collateral. A shock $\eta = 0.91$ does not trigger information production, but a shock $\eta = 0.90$ does. Given that after many periods without a shock most collateral looks the same, these differences in information production imply that these differences have large consequences on the variance of beliefs and the information available about most collateral.

This effect of information acquisition implies that, even when the real quality of collateral is the same under the two shocks, a slightly larger shock that induces information acquisition implies a faster recovery, which is the result from Proposition 2.

Figure 7: Standard Deviation of Distribution of Beliefs

5 Policy Implications

In this section we discuss optimal information production when a planner cares about the discounted consumption of all generations, such that welfare is measured by

$$U_t = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} W_t.$$

We assume the planner faces the same information restrictions that households and firms face. This implies the planner also faces the problem of spending resources to obtain information.

First we study the economy without aggregate shocks, and show that a planner would like to produce information for a wider range of collateral p. Then, we study the economy with negative aggregate shocks, and show that, if a negative shock is very large or very likely then information production by the planner is more likely to be triggered compared to private agents.

5.1 No Aggregate Shock

We denote the expected discounted profits sustained by a unit of collateral with belief p if producing information as

$$V^{IS}(p) = p\pi(1) - \gamma + \beta[\lambda(pV(1) + (1-p)V(0)) + (1-\lambda)V(\hat{p})] + pC$$

and expected discounted profits sustained by a unit of collateral with belief p if not producing information as

$$V^{II}(p) = \pi(p) + \beta[\lambda V(p) + (1-\lambda)V(\hat{p})] + pC$$

where $\pi(p) = K(p)(qA - 1)$.

We can solve for

$$V^{IS}(p) = \frac{p\pi(1)}{1 - \beta\lambda} - \gamma + Z(p, \hat{p})$$

and

$$V^{II}(p) = \frac{\pi(p)}{1 - \beta\lambda} + Z(p, \hat{p}),$$

with $Z(p, \hat{p}) = \beta\left[\lambda\frac{\beta(1-\lambda)}{1-\beta\lambda} + (1-\lambda)\right]V(\hat{p}) + pC$.

The planner decides to acquire information if $V^{IS}(p) > V^{II}(p)$, or

$$\gamma(1 - \beta\lambda) < p\pi(1) - \pi(p),$$

while, as shown above, individuals decide to acquire information when

$$\gamma < p\pi(1) - \pi(p),$$

which effectively means individuals make their decisions the same way as the planner, with $\beta = 0$.

So, $\beta > 0$ implies that the planner decides to acquire information for a wider range of beliefs p. The cost of information is effectively lower for the planner, since acquiring information has the additional gain of enjoying more borrowing in the future if it is found that the collateral is good. How important this effect is depends on the discount rate of the government and the probability the collateral remains unchanged.

Finally, the planner can align incentives, for example, by subsidizing information

production by an fraction $\beta\lambda$ from lump sum taxes on individuals, such that the after the subsidy, the cost of information production becomes $\gamma(1 - \beta\lambda)$.

5.2 Aggregate Shock

In this section we assume that the planner considers the possibility of a negative shock, in which a fraction $(1 - \eta)$ of good collateral becomes bad, and assigns a probability μ to such shocks happening the next period. For simplicity in showing as crisply as possible the forces affecting information production we assume the negative shock can only happen once.

Expected discounted profits sustained by a unit of collateral with belief p if producing information is

$$
\begin{aligned}
V^{IS}(p) &= p\pi(1) + \beta[(1 - \mu)[\lambda(pV(1) + (1 - p)V(0)) + (1 - \lambda)V(\hat{p}) \\
&\quad + \mu[\lambda(pV(\eta) + (1 - p)V(0)) + (1 - \lambda)V(\eta\hat{p})] + pC,
\end{aligned}
$$

and if not producing information

$$
V^{II}(p) = \pi(p) + \beta[(1 - \mu)[\lambda V(p) + (1 - \lambda)V(\hat{p}) + \mu[\lambda V(\eta p) + (1 - \lambda)V(\eta\hat{p})] + pC.
$$

We can solve for

$$
V^{IS}(p) = \frac{\pi(p)}{1 - \beta q\lambda} - \frac{\beta\lambda\mu}{1 - \beta\lambda}p[\pi(1) - \pi(\eta)] + Z(p, \hat{p})
$$

and

$$
V^{II}(p) = \frac{p\pi(1)}{1 - \beta\lambda} - \gamma - \frac{\beta\lambda\mu}{1 - \beta\lambda}[\pi(p) - \pi(\eta p)] + Z(p, \hat{p}).
$$

Naturally, these aggregate shocks reduce expected profits in both situations. The effect on information production depends on which one drops more. The next two propositions summarize how the incentives to acquire information change with the probability of a future aggregate shock and with the size of the aggregate shock.

Proposition 5 *The incentives to acquire information in the presence of aggregate shocks increases with the probability of the shock μ if $p[\pi(1) - \pi(\eta)] \leq [\pi(p) - \pi(\eta p)]$, and decreases otherwise.*

The proof is straightforward from comparing $V^{IS}(p)$ and $V^{II}(p)$. To build intuition, assume η is such that $\pi(\eta p) < \pi(p)$ and $\pi(1) = \pi(\eta)$, which happens with a small shock and $p = p^H$. In this case, the aggregate shock, regardless of its probability, does not affect the expected discounted profits from information acquisition (under its simplifying assumption that the aggregate shock only happens once). Conversely, the expected discounted profits from no information acquisition decreases. This implies that the range of beliefs under which a planner acquires information widens. In this case, producing information relaxes the borrowing constraint in case of a future negative shock, hence a higher ex-ante probability of such a shock generates more incentives to acquire information.

Proposition 6 *The incentives to acquire information in the presence of aggregate shocks increases with the size of the shock (decreases with η) if $\frac{\partial \pi(\eta p)}{\partial \eta} \leq p \frac{\partial \pi(\eta)}{\partial \eta}$, and decreases otherwise.*

Proof Define $DV(p) = V^{IS}(p) - V^{II}(p)$, which measures the incentives to acquire information. Taking derivatives with respect to η, incentives to acquire information increase with the size of the shock (decrease with η) if

$$\frac{\partial DV(\eta|p)}{\partial \eta} = \frac{\beta \lambda \mu}{1 - \beta \lambda} \left[\frac{\partial \pi(\eta p)}{\partial \eta} - p \frac{\partial \pi(\eta)}{\partial \eta} \right] \leq 0.$$

Q.E.D.

As can be seen, the effect is not monotonic in the size of the shock. For example, at the extreme of very large shocks ($\eta = 0$), in which all collateral becomes bad, the incentives to produce information in fact decline, since the condition in that case becomes

$$\gamma \frac{1 - \beta \lambda}{1 - \beta \lambda z} < p\pi(1) - \pi(p),$$

increasing the effective cost of acquiring information. In this extreme case, the planner still wants to acquire more information than individuals, but less than in the absence of an aggregate shock (since $(1 - \beta \lambda) \leq \frac{1 - \beta \lambda}{1 - \beta \lambda z} \leq 1$).

The previous two propositions show there are levels of p under which, a large probability of a negative shock induces information production, which in expectation reduces current output in order to provide insurance against potential future negative shocks. Similarly, there are levels of p under which, even in the presence of a potential

negative shock the planner prefers not producing information, hence it is efficient to maintain a high level of current output rather than avoiding a potential reduction in future consumption. This result is summarized in the following Corollary.

Corollary 3 *The possibility of a negative aggregate shock does not always justify acquiring information and reducing current output to insure against potential future reductions in output.*

This corollary suggests that there are conditions under which it is efficient to accept potential reductions in future consumption in order to obtain guaranteed increases in current consumption. This result is consistent with the findings of Ranciere, Tornell, and Westermann (2008) who show that "high growth paths are associated with the undertaking of systemic risk and with the occurrence of occasional crises." Our model suggests that it may be efficient for a planner to accept the possibility of large crises in order to maintain high current levels of consumption.

5.3   Ex-Post Policies

Now we analyze two types of ex-post policies, conditional on the aggregate shock: collateral and lending policies. Naturally these policies affect the results in the previous section, since if they are effective in helping the economy recover, they render ex-ante information acquisition to relax borrowing constraints less important in the case where aggregate shocks do occur.

5.3.1   Collateral policies

This set of policies is intended to boost the expected quality of collateral ($\hat{p}$). After a negative aggregate shock η, the natural and trivial reaction of the government should be to eliminate such a shock by improving $\hat{p}$. The effectiveness of collateral policies depends on how fast the government is able to react to the negative shock, for example guaranteeing the quality of the collateral. This policy manifests itself as an α positive aggregate shock, one period after the negative aggregate shock.

The next Proposition shows that, if there is a positive aggregate shock after a negative aggregate shock that takes the average collateral $\eta\hat{p}$ to a higher new level above p^H,

the recovery from the negative shock is faster if there was no information production as a response to the negative aggregate shocks.

Proposition 7 *Assume a negative aggregate shock η that induced information acquisition, immediately followed by a positive policy aggregate shock of size α, such that $p' = \eta\hat{p} + \alpha(1 - \eta\hat{p}) > p^H$ and firms can borrow K^* with p'. This policy is more effective in speeding recovery if information were not acquired. More specifically $\Delta^{II} > \Delta^{IS}$ (where $\Delta^{II} \equiv W^{II}_{t+1|\alpha} - W^{II}_{t+1}$ and $\Delta^{IS} \equiv W^{IS}_{t+1|\alpha} - W^{IS}_{t+1}$) for all $\eta\hat{p} \in [p^{Cl}, p^{Ch}]$.*

Proof As in Proposition 2, if the negative shock happens in period t, the distribution in period t is: $f(\eta) = \lambda^t\hat{p}$, $f(\eta\hat{p}) = (1 - \lambda^t)$ and $f(0) = \lambda^t(1 - \hat{p})$.

1. Without information production, in period $t + 1$, after the idiosyncratic shocks, the distribution of beliefs is $f_{II}(\eta) = \lambda^{t+1}\hat{p}$, $f_{II}(\eta\hat{p}) = \lambda(1 - \lambda^t)$, $f_{II}(\hat{p}) = (1 - \lambda)$ and $f_{II}(0) = \lambda^{t+1}(1 - \hat{p})$.

In case the government introduces a policy that transforms a fraction α of bad collateral into good, for example by guaranteeing they pay C even when the collateral is bad, in the period $t + 1$, following the negative shock that occurred in period t, beliefs change from η to $\alpha + \eta(1 - \alpha)$, from $\hat{p}$ to $\alpha + \hat{p}(1 - \alpha)$, from $\eta\hat{p}$ to $\alpha + \eta\hat{p}(1 - \alpha)$ and from 0 to α.[11] The distribution of beliefs becomes: $f_{II}(\alpha + \eta(1 - \alpha)) = \lambda^{t+1}\hat{p}$, $f_{II}(\alpha + \eta\hat{p}(1 - \alpha)) = \lambda(1 - \lambda^t)$, $f_{II}(\alpha + \hat{p}(1 - \alpha)) = (1 - \lambda)$ and $f_{II}(\alpha) = \lambda^{t+1}(1 - \hat{p})$.

Since we assume $\hat{p} > p^H$ and $\eta > p^H$, the positive shock does not affect the borrowing of those beliefs. Since we assume $\alpha + \eta\hat{p}(1 - \alpha) > p^H$, borrowing of these firms, that previously had collateral with beliefs $\eta\hat{p}$, increases from $K(\eta\hat{p})$ to K^*. Similarly, borrowing for firms that previously had collateral with beliefs 0 increases from 0 to $K(\alpha)$.

Since the distribution does not change, just the beliefs assigned to collateral, we can compute the aggregate consumption from the positive policy and compare it to the one without the positive policy, from equation 10. Then,

$$\Delta^{II} \equiv W^{II}_{t+1|\alpha} - W^{II}_{t+1} = \lambda(qA - 1)[(1 - \lambda^t)(K^* - K(\eta\hat{p})) + \lambda^t(1 - \hat{p})K(\alpha)]. \tag{12}$$

2. With information production, in period $t + 1$, after the idiosyncratic shocks, the

---

[11]The same results hold if the policy is introduced in subsequent periods.

distribution of beliefs is $f_{IS}(1) = \lambda\eta\hat{p}(1-\lambda^t)$, $f_{IS}(\eta) = \lambda^{t+1}\hat{p}$, $f_{IS}(\hat{p}) = (1-\lambda)$, $f_{IS}(0) = \lambda[(1-\lambda^t\hat{p}) - \eta\hat{p}(1-\lambda^t)]$.

With the positive policy, beliefs change from η to $\alpha + \eta(1-\alpha)$, from $\hat{p}$ to $\alpha + \hat{p}(1-\alpha)$, and from 0 to α. Also, beliefs 1 remain 1. Since we assume $\hat{p} > p^H$ and $\eta > p^H$, the positive shock does not affect the borrowing of those beliefs. Finally, borrowing for firms that previously had collateral with belief 0 increase borrowing from 0 to $K(\alpha)$. We can compute the aggregate consumption from the positive policy and compare it to the one without the positive policy, from equation 9. Then,

$$\Delta^{IS} \equiv W^{IS}_{t+1|\alpha} - W^{IS}_{t+1} = \lambda(qA-1)[(1-\lambda^t\hat{p}) - \eta\hat{p}(1-\lambda^t)]K(\alpha). \qquad (13)$$

Taking the difference between equations (12) and (13),

$$
\begin{aligned}
\Delta^{II} - \Delta^{IS} &= \lambda\left[(1-\lambda^t)[K^* - K(\eta\hat{p})] + [\lambda^t(1-\hat{p}) - (1-\lambda^t\hat{p}) + \eta\hat{p}(1-\lambda^t)]K(\alpha)\right] \\
&= \lambda(1-\lambda^t)\left[K^* - K(\eta\hat{p}) - (1-\eta\hat{p})K(\alpha)\right].
\end{aligned}
$$

In the range of interest, where $\eta\hat{p} < p^{Ch}$ and there are incentives for information production, avoiding information production would imply $K(\eta\hat{p}) \leq \eta\hat{p}K^* - \frac{\gamma}{(qA-1)}$. This implies that the government's imposition of the restriction of no information production lowers the borrowing level that induces information production. Using this upper bound to evaluate the expression above,
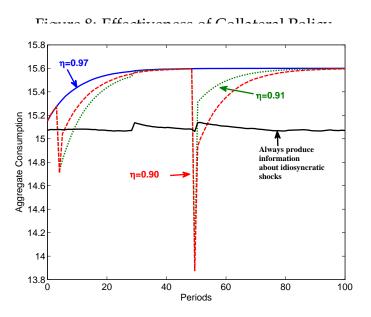
$$
\begin{aligned}
\Delta^{II} - \Delta^{IS} &\geq \lambda(1-\lambda^t)\left[K^* - \eta\hat{p}K^* + \frac{\gamma}{(qA-1)} - (1-\eta\hat{p})K(\alpha)\right] \\
&\geq \lambda(1-\lambda^t)(1-\eta\hat{p})\left[K^* - K(\alpha)\right] + \frac{\gamma}{(qA-1)(1-\eta\hat{p})} > 0.
\end{aligned}
$$

<div align="right">Q.E.D.</div>

The intuition for this Proposition relies on the speed of recovery of information. If an aggregate negative shock does not generate information production, when on average the collateral quality recovers, borrowing can recover fast for the high fraction of collateral without information about its true quality. If an aggregate negative shock generates information production, then, even when on average the collateral quality recovers, the fact that bad collateral has been identified, restricts lending to such collateral until it faces idiosyncratic shocks.

Figure 8 introduces a shock $\alpha = 0.25$ to the numerical simulation in period 51, right after the assumed negative shock. As can be seen, the collateral policy that replenishes confidence in the average collateral is more effective when the negative aggregate shock did not generate information than in the case in which the negative aggregate shock did generate information. This implies that, if the planner can use a collateral policy to deal with a crises, it will be more effective doing so if the shock is such that it just creates a credit crunch but no information is produced. This is the effect discussed in Proposition 7.

Figure 8: Effectiveness of Collateral Policy

5.3.2 Lending policies

Information production after the negative aggregate shock renders collateral policies that try to reintroduce confidence in the average value of collateral less effective. The planner may discourage information production by introducing lending policies.

Assume $\hat{p} < p^H$ such that the shock reduces efficient borrowing, or even worse, assume $\hat{p} < p^{Ch}$ such that firms face a credit crunch where borrowing also triggers information production. The government can tax households and transfer to firms an amount $K^* - \frac{\gamma}{(1-p)(1-q)}$ directly and let the firms borrow the remaining $\frac{\gamma}{(1-p)(1-q)}$ such that firms can efficiently get the optimal K^*, and no information is produced.

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6   The Choice of Collateral

In this Section we study an environment where collateral is heterogenous in two dimensions, the expected value of the collateral $\hat{p}$ and the cost of information acquisition γ. Firms can choose freely the characteristics of the collateral to use in order to maximize borrowing using such collateral.

In previous sections we analyzed the effects of p on borrowing for a given cost of information acquisition γ. In that environment we obtained that borrowing was increasing in p. The proof relies on the borrowing function $K(p|\gamma)$ being monotonically increasing. It is important to highlight at this point that λ does not enter into individuals' borrowing and information decisions, since they do not take into account the future quality of the collateral. For the planner, however, λ affects the effective cost of acquiring information. This implies λ is an additional dimension in the optimal choice of collateral for the planner, but not for the individuals.

Similarly, we can analyze borrowing for a given collateral with belief p, for different levels of information costs γ. In this case the amount borrowed critically depends on whether the collateral creates financial constraints or not and, in case it does, on whether the financial constraint locates the collateral in the information-sensitive or insensitive region. The next Proposition summarizes these results.

Proposition 8 *Consider collateral characterized by the pair (p, γ), the expected probability the collateral has value C and the cost of information acquisition when the collateral is hit by an idiosyncratic shock. Then:*

1. *Fix γ. After an idiosyncratic shock:*

    (a) *No financial constraint: Borrowing is independent of p.*

    (b) *Information-sensitive regime: Borrowing is increasing in p.*

    (c) *Information-insensitive regime: Borrowing is increasing in p.*

2. *Fix p.*

    (a) *No financial constraint: Borrowing is independent of γ.*

    (b) *Information-sensitive regime: Borrowing is decreasing in γ.*

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(c) *Information-insensitive regime: Borrowing is increasing in γ if higher than pC and independent of γ if pC.*

Proof Point 1 is a direct consequence of $K(p|\gamma)$ being monotonically increasing in p for $p < p^H$ and independent of p for $p > p^H$.

To prove point 2 we derive the function $\widetilde{K}(\gamma|p)$, which is the inverse of the $K(p|\gamma)$ and analyze its properties. Take a situation where information acquisition is not possible (or $\gamma = \infty$). In this case the limit to financial constraints is the point at which $K^* = pC$. This is because lenders will not acquire information but will not lend more than the expected value of the collateral pC. Then, the function $\widetilde{K}(\gamma|p)$ has two parts. One for $p \geq \frac{K^*}{C}$ and the other for $p < \frac{K^*}{C}$.

1. $p \geq \frac{K^*}{C}$:

$$\widetilde{K}(\gamma|p) = \begin{cases} K^* & \texttt{if } \gamma_1^H \leq \gamma \\ \frac{\gamma}{(1-p)(1-q)} & \texttt{if } \gamma^L \leq \gamma < \gamma_1^H \\ pK^* - \frac{\gamma}{(qA-1)} & \texttt{if } \gamma < \gamma^L \end{cases}$$
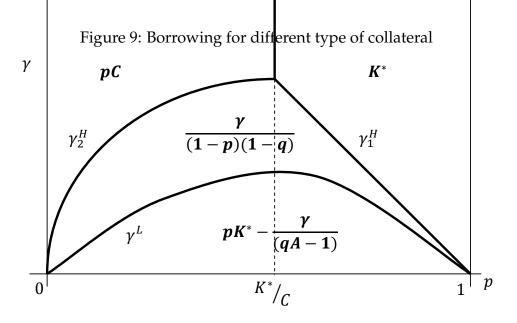
where γ_1^H comes from equation 3. Then

$$\gamma_1^H = K^*(1-p)(1-q) \tag{14}$$

and γ^L comes from equation 6. Then

$$\gamma^L = pK^* \frac{(1-p)(1-q)(qA-1)}{(1-p)(1-q) + (qA-1)} \tag{15}$$

2. $p < \frac{K^*}{C}$:

$$\widetilde{K}(\gamma|p) = \begin{cases} pC & \texttt{if } \gamma_2^H \leq \gamma \\ \frac{\gamma}{(1-p)(1-q)} & \texttt{if } \gamma^L \leq \gamma < \gamma_2^H \\ pK^* - \frac{\gamma}{(qA-1)} & \texttt{if } \gamma < \gamma^L \end{cases}$$

where γ_2^H in this region comes from equation 4. Then

$$\gamma_2^H = p(1-p)(1-q)C \tag{16}$$

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and γ^L is the same as above.

It is clear from the function $\widetilde{K}(\gamma|p)$ that, for a given p, borrowing is independent of γ in the first region, it is increasing in the second region (information-insensitive regime) and it is decreasing in the last region (information-sensitive regime).   Q.E.D.

Figure 9 shows the borrowing possibilities for all combinations (p, γ). As a further illustration of how borrowing is affected by these two dimensions, Figure 10 shows different levels of borrowing from high (dark red) to low (blue).[12]

Figure 9: Borrowing for different type of collateral

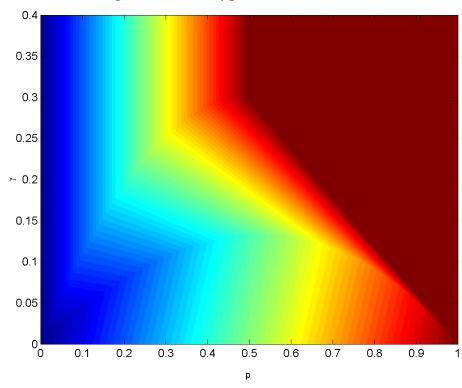[12]The numbers that created this Figure are $K^* = 2$, $C = 4$, $q = 0.7$ and $A = 3$.

Figure 10: Borrowing for different type of collateral - A numerical example

If we assume the price of collateral is the fair value pC, then firms would prefer to acquire collateral with the lowest possible price that maximizes the borrowing size. In this sense firms would start using collateral with $p = \frac{K^*}{C}$ and $\gamma > \gamma_1^H$ evaluated at that p. Then they will use collateral with a slightly higher p and $\gamma > \gamma_1^H$ for that p.

This implies that endogenously the collateral used for borrowing will be biased towards relatively high $\hat{p}$ and relatively high γ. This way the first collateral firms use to borrow are those that most likely allow the firm not to be financially constrained, either because the collateral is very likely to be of high quality, or because it is very expensive to acquire information about its quality.

7 Some Empirical Evidence (Very Preliminary and Incomplete)

In this section we examine some of the model's predictions using U.S. historical data. The model has a number of predictions. We focus on the prediction from Proposition

3, that during a credit boom, the standard deviation of beliefs declines. This is the central prediction of the model. If information about collateral decays, then lending should increases, and this translates into output.

There are a number of other predictions of the model as well. However, some are hard to operationalize since information production is not observable. Other predictions concern what happens after a shock. For example, the model predicts that the deeper the crash, the slower or more prolonged the recovery conditional on acquiring information. This requires pinning down the trough of a recession. But, as discussed below, the dating of the trough is somewhat noisy. Thus, we focus on the main prediction, which links the change in beliefs to the growth of credit.

7.1   The Pre-Federal Reserve Era

In order to examine the hypothesis, we need a long time series so that there are a sufficient number of crises. We also want to examine a period over which there is no central bank, so agents' beliefs and actions are not affected by expectations associated with possible central bank or government intervention, which could contaminate the empirical data. For this reason we first focus attention on the United States before the existence of the Federal Reserve System, that is, prior to 1915. We then examine the whole history of crises in the U.S. from 1815-2010, and the subperiod of 1915-2010, when the Federal Reserve is in existence.

To examine the pre-Fed period we will use the annual index of American industrial production, 1790-1915, produced by Davis (2004) and New York Stock Exchange stock price data for the period 1815-1925, collected by Goetzmann, Ibbotson, and Peng (2001). Davis (2004) uses annual physical-volume data on 43 manufacturing and mining industries to construct an index. We use the industrial production and stock price series through the year 1914, after which the Fed is in existence. We will proxy for the beliefs about collateral quality using the cross section of stock returns. This has been previously used as a measure of uncertainty by, e.g., Lougani, Rush, and Tave (1990), Brainard and Cutler (1993), and Bloom, Floetotto, and Jaimovich (2009). Here, however, the idea is that the standard deviation of the cross section of stock returns should decline during the credit boom, as more and more firms are borrowing based on collateral with a perceived value of $\hat{p}$. That is, the firms are increasingly viewed as being of the same quality. The previous work cited above takes

this measure of uncertainty as exogenous; we are trying to determine how it arises endogenously.

The focus of our empirical analysis is on the period prior a crisis, the time at which there is a negative shock. So, we examine business cycles. Davis's annual data results in a different business cycle chronology than the National Bureau of Economic Research (NBER); see Davis (2006). The NBER dating has not been revised since first announced (see the discussion in Davis (2004, 2006). There are some NBER cycles that Davis does not include. Some of Davis' cycles do not display much of a downturn.[13] Where the NBER and Davis agree on the cycle existence, there is also agreement on the date of the peaks. There is most disagreement about the trough dates. The differences concerning the trough dates make dating the start of the recovery somewhat problematic.

We focus on Davis's chronology, as it is the most current. This gives us a sample of nineteen cycles, omitting the wartime cycles, which were somewhat special as the shock was arguably the start of the war rather than anything else.[14] Our basic strategy is to examine the core hypothesis over the business cycle, taking the date of the cycle peak as the date that the negative shock arrives.

The period from 1790-1915 includes the National Banking Era, 1863-1914, which was followed by the Federal Reserve System, starting in 1914. It also includes the Civil War period, and the period prior to the Civil War where banks were overseen by the states and issued their own private money.

We will measure the credit boom in two ways. The first measure is the number of years from the last trough to the business cycle peak (BOOM1), and the second measure is cumulative output increase from the last trough to the peak (BOOM2). As mentioned, we proxy for agents' beliefs using the standard deviation of the cross section of stock returns, based on the monthly stock price data from Goetzmann, Ibbotson, and Peng (2001). Below, this variable is called BELIEFS. As they discuss, there are some missing values. Because Davis' data are annual, we convert the monthly standard deviations to annual buy simple averaging.[15] The stock price data starts in
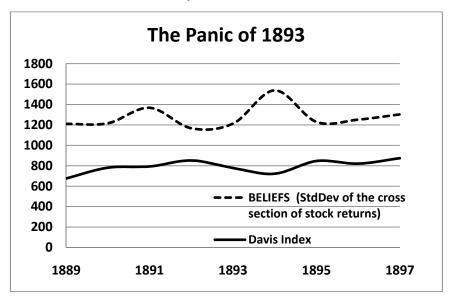
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[13]With regard to the cycles with peaks at 1811, 1822, and 1836, Davis (2004, p. 1203) states that these cycles had losses "that do not exceed the minimum postbellum loss."

[14]Davis (2004, p. 1203) says of the wartime cycles: "Two Civil War cycles (1861 and 1865 troughs) are omitted. Although their inclusion would not meaningfully affect calculations."

[15]When monthly values are missing, the annual average is the average over the remaining months. The entire year 1867 is missing; its annual value was interpolated.

1815, but there are only between eight and twenty stocks until 1833. The year 1837, following President Andrew Jackson's veto of the re-charter of the Second Bank of the United States, marks the beginning of the Free Banking Era, during which some states allowed free entry into banking. We will look at two periods, 1815-1914 and 1839-1914.

The Panic of 1893 was a major panic. The figure below illustrates the hypothesis that we will examine more closely below. Figure 11 shows the period 1889-1897, which includes the business cycle with peak in 1892, trough in 1897, and the widespread banking panic in 1893. For purposes of the figure, BELIEFS (the standard deviation of the cross-section of stock returns) has been multiplied by 10,000. The figure shows the rise in the industrial production index (the solid line) and the drop starting in 1892. BELIEFS falls, as predicted during the run-up to the shock, and then sharply rises, as predicted. This is followed by a decline.

We now turn to examining the main hypotheses. The prediction is that the cumulative change in the standard deviation of cross section of stock returns (BELIEFS) is negatively correlated with the rise in economic activity as more firms borrow BOOM. As the boom grows, the standard deviation of the cross section of stock returns (BELIEFS) should fall, as more firms are perceived to be of quality $\hat{p}$. The correlations are as predicted.

	BOOM1	BOOM2
BELIEFS1	-0.161	-0.190

B. The Post Federal Reserve Era

	BOOM1	BOOM2
BELIEFS1	-0.161	-0.190

[Section to be added.]

7.2 The Post-Federal Reserve Era

Section to be added.

8 Conclusions

Financial fragility is the susceptibility of the economy to small shocks having large effects. Such fragility is endogenous in market economies because they rely on collateralized, short-term, debt - private money for trade. It is not optimal for lenders to always produce information about the borrowers because it is costly. In that case, the information about the collateral degrades over time. Instead of knowing which borrowers have good collateral and which bad, all collateral starts to look alike. Agents choose collateral that has a high perceived quality when information is not produced. The result is that there is a credit boom in which firms with bad collateral start to borrow. During the credit boom, output and consumption rise, but also the fragility of the system to small shocks that induce information production. If information is produced, firms with bad collateral cannot access credit. Alternatively, firms are endogenously credit constrained to avoid information production. A social planner would not want to eliminate this fragility but would want to mitigate it.

Our analysis is simplified to highlight the central information channel, the dynamics of information production and the evolution of beliefs. There are clearly other reasons to produce information, for example, to learn about investment opportunities, and we did not incorporate this into the model. One can see that if the production of information about investment opportunities were to publicly reveal collateral type, then there would be an interesting interaction between these information production motives. This is a subject of future research.

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A   Appendix

A.1   Extension to Different Land Prices

In the main text we assumed the price of land was its outside option, since we assumed buyers have all the negotiation power and make take-it or leave-it offers. In this extension we generalize the results assuming Nash bargaining between buyers and sellers, where the sellers' negotiation power $\theta \in [0, 1]$ determines how much they can extract from the surplus of buyers (in the main text we assumed $\theta = 0$). To simplify the exposition in the main text we also assumed no discounting (i.e., $\beta = 1$). In this extension we assume a generic discount factor $\beta \in [0, 1]$

First we assume the case without aggregate shocks and then we discuss how the introduction of aggregate shocks just enter into prices as a an expectation. We denote the price of a unit of land with perceptions p as $Q(p)$.[16]

The surplus of land for the seller is just its outside option

$$J_S(p) = pC.$$

The surplus of land for the buyer is the expected profit from a firm plus the expected price of the land. If p is such that debt is information-sensitive, the surplus is

$$J_B(p|IS) = E(\pi|p, IS) + \lambda[pQ(1) + (1 - p)Q(0)] + (1 - \lambda)Q(\hat{p}),$$

where $E(\pi|p, IS) = [pK(1) + (1 - p)K(0)](qA - 1) - \gamma$.

If p is such that debt is information-insensitive, the surplus is

$$J_B(p|II) = E(\pi|p, II) + \lambda Q(p) + (1 - \lambda)Q(\hat{p}),$$

where $E(\pi|p, II) = K(p)(qA - 1)$.

Then

$$Q(p) = \beta[\theta J_B(p) + (1 - \theta)J_S(p)] \tag{17}$$

since $Q(p) = J_S(p) + \theta(J_B(p) - J_S(p))$.

1. Borrowing as a function of land price

Firms can compute the possible borrowing with both information-sensitive and insensitive debt and determine which one is higher. In the main text we impose the price of land as the sellers' outside option and we determine the optimal borrowing as a function of that price. Now the price of land also depends on the optimal borrowing, and then they should be determined simultaneously.

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[16]In the main text we did not need an explicit name since the price of land p was just pC.

In the case of information-sensitive debt, $R_{IS}(1) = x_{IS}(1)Q(1)$ and $R_{IS}(0) = x_{IS}(0)Q(0)$ because debt is risk-free. Lenders break even when,

$$p[x(1)Q(1) - K(1)] + (1-p)[x(0)Q(0) - K(0)] = \gamma$$

where $x(1)Q(1) \geq K(1)$ and $x(0)Q(0) \geq K(0)$.

In the case of information sensitive debt, $R_{II}(p) = x_{II}(p)Q(p)$ because debt is risk-free. Lenders break even when,
$$x(p)Q(p) = K(p).$$

with the constraint that

$$p[x(p)(qQ(p) + (1-q)Q(1)) - K(p)] \leq \gamma$$

or, which is the same as

$$K(p) \leq \frac{\gamma}{(p\frac{Q(1)}{Q(p)} - p)(1-q)}. \tag{18}$$

In the main text, where $\theta = 0$, this restriction was $K(p) \leq \frac{\gamma}{(1-p)(1-q)}$.

2. Solving Borrowing and Land Price Simultaneously

We now show how to solve simultaneously for optimal borrowing and the land price.

1. *When $\gamma > 0$, firms with collateral $p = 0$ and $p = 1$ prefer to borrow without producing information.*

   This is clear because knowing the type of the collateral (which is the case with $p = 0$ and $p = 1$), it does not make sense for the borrower to pay γ.

2. $K(1) = K^*$

   Since $K(1)$ is not financially constrained in the information-insensitive case, then $K(1) = K^*$.

3. *Determination of $K(\hat{p})$, $Q(\hat{p})$ and $Q(1)$.*

   (a) $\hat{p}$ is information-insensitive and $K^* \leq \frac{\gamma}{(\hat{p}\frac{Q(1)}{Q(\hat{p})} - \hat{p})(1-q)}$: This implies $K(\hat{p}) = K^*$ and
   $$Q(\hat{p}) = \frac{\beta(1-\theta)\hat{p}C + \beta\theta K^*(qA - 1)}{1 - \beta\theta}.$$

   (b) $\hat{p}$ is information-insensitive and $K^* > \frac{\gamma}{(\hat{p}\frac{Q(1)}{Q(\hat{p})} - \hat{p})(1-q)}$: Since $Q(\hat{p})$ and $Q(1)$ just depend on $K(\hat{p})$, it is obtained from equation 18.

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(c) $\hat{p}$ is information-sensitive: When information reveals the collateral is bad, and assuming the firm maximizes borrowing $x(0) = 1$. The following two equations jointly determine $K(0)$ and $K(\hat{p})$:

$$K(\hat{p}) = \hat{p}K^* + (1 - \hat{p})K(0) - \frac{\gamma}{(qA - 1)}, \tag{19}$$

$$K(0) = Q(0) = \frac{\beta\theta[K(0)(qA - 1) + (1 - \lambda)Q(\hat{p})]}{1 - \beta\theta\lambda}, \tag{20}$$

where $Q(\hat{p})$ just depends on $K(\hat{p})$.

In these three cases $K(\hat{p})$ is solvable, and the prices

$$Q(\hat{p}) = \frac{\beta(1 - \theta)\hat{p}C + \beta\theta K(\hat{p})(qA - 1)}{1 - \beta\theta},$$

and

$$Q(1) = \frac{\beta(1 - \theta)C + \beta\theta[K^*(qA - 1) + (1 - \lambda)Q(\hat{p})]}{1 - \beta\theta\lambda},$$

are well-defined. Similarly, expected profits for $\hat{p}$ in both the cases of information-sensitive and insensitive can be computed such that firms choose the highest possible amount of borrowing.

4. *Determination of $K(0)$ and $Q(0)$.*

These are determined by

$$K(0) = Q(0) = \frac{\beta\theta[K(0)(qA - 1) + (1 - \lambda)Q(\hat{p})]}{1 - \beta\theta\lambda}.$$

5. *Determination of $K(p)$ and $Q(p)$.*

There are two cases, from which the firm chooses the highest possible borrowing:

(a) p is information-insensitive:

$$K(p) = \frac{\gamma}{(p\frac{Q(1)}{Q(p)} - p)(1 - q)}.$$

(b) p is information-sensitive:

$$K(p) = pK^* + (1 - p)K(0) - \frac{\gamma}{(qA - 1)}.$$

where in both cases $Q(p)$ only depends on $K(p)$,

$$Q(p) = \frac{\beta(1-\theta)pC + \beta\theta[K(p)(qA-1) + (1-\lambda)Q(\hat{p})]}{1 - \beta\theta\lambda}.$$

The determination of which regions are information-sensitive and insensitive is similar to the case in the main text. Expected profits with information-sensitive debt is linear while expected profits with information-insensitive debt depend on the shape of the land prices.

3. Potential Multiplicity

In the previous steps we show how to solve the optimal borrowing when land prices are endogenous. However these steps do not guarantee uniqueness of the solution (for example under information-insensitiveness, equation (18) does not imply uniqueness). The intuition is the following: If there is no confidence that in the future low quality collateral can be used to sustain borrowing, this will reduce the price of the collateral, reinforcing the fact that it will not be able to sustain such a borrowing. This "complementarity" between the price of collateral and borrowing capabilities is what creates potential multiplicity.

An interesting example is the extreme opposite to the one assumed in the main text, this is $\theta = 1$. In this extreme case, the potential multiplicity takes a very clear form. Assume an equilibrium where all collateral sustain borrowing of K^* without producing any information, and regardless of the perception p that a land is good. If this is the case, the price for all collateral is independent of p,

$$Q(p) = \frac{\beta K^*(qA-1)}{1 - \beta}.$$

Given these prices, borrowing without information acquisition is not binding because $Q(1) = Q(p)$ and then $K^* < \frac{\gamma}{(p-p)(1-q)} = \infty$. Hence, as conjectured, all collateral can borrow K^* regardless of p. In general, a larger θ allows for the existence of an equilibrium that sustains a lot of credit without information acquisition, but fragile to beliefs about whether land with low p sustaining those levels of credit.