Information Dynamics and Macro Fluctuations

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March 2022

Abstract

The amount of information produced about firms' productivities and about the quality of collateral backing their loans varies over time. These information dynamics determine the evolution of credit, output and productivity, which feeds back into incentives to produce information. We characterize this intricate dynamic relation. A credit boom happens when information about collateral depreciates. A financial crisis happens when information about collateral is suddenly generated. Information about firms' individual productivities over credit booms can prevent or tame the crisis, acting as an endogenous macroprudential force.

Keywords: Business Cycles, Financial Markets and the Macroeconomy, Financial Crises
JEL Classification: E3, E32, E44, G01

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1 Introduction

Firms are multidimensional entities. How well a firm combines resources determines its profitability and the chances of success in its business activity. The quantity and quality of its assets determine the firm's value. Information about these two dimensions, what we call *productivity* and *collateral* jointly determine how easy and how cheap a firm can obtain credit. But total credit affects the output and average productivity in the economy, which feeds back on the incentives to produce information about firms' individual productivities and collateral. How information about these different firms' characteristics, total credit and average productivity interact dynamically?

We propose a model in which collateralized credit markets perform better when information production about firms' collateral is avoided – when debt is information-insensitive– as in Dang et al. (2019). While information about collateral depreciates the economy experiences a credit boom. A financial crisis is an event in which information about a large volume of collateral cannot be prevented, and credit disappears for many borrowers, as in Gorton and Ordoñez (2014). Credit booms and crashes have implications for the macroeconomy. During a credit boom more projects are financed and output grows, but new projects are marginally worse and average productivity falls. We study how an increase in output and a reduction in average productivity affects incentives to acquire information about individual collateral and about individual productivities.

We show that, as average productivity declines, lenders have more incentives to become informed about borrowers' collateral, then increasing the likelihood that the credit boom stops and a financial crisis ensues. When there is no information about individual productivities, this force affects all firms. If there is full information about each firm's productivity, this force only affects the least productive firms, the ones with higher chances of default. Hence, when the endogenous evolution of credit and collateral information puts the economy on a brink of a financial crisis, transparency about firms' individual productivities may prevent, or at least tame, the crisis. This is our first result. Transparency about firms' projects act as a macroprudential tool.

This result may suggest that it is always optimal that the economy is transparent about firm's productivities, as they relax incentives for lenders to investigate the collateral of firms with high productivity, insulating them from the forces that lead to a crisis. But there is another side of the coin. Transparency also tightens the incentives for lenders to investigate the collateral of firms with low productivity. If these firms' projects have still positive net present value, transparency inefficiently depresses credit booms and economic activity. When crises are not very likely (say because the cost of acquiring information about collateral in credit markets is large enough), transparency prevents credit to flow to firms that operate with low-quality, yet efficient, projects, avoiding funds flowing towards productive opportunities. Hence, when the endogenous evolution of credit and collateral information does not put the economy on a brink of a financial crisis, transparency about firms' individual productivities depresses credit and output. This is our second result: Transparency about firms' projects is a costly macroprudential tool, in terms of foregone credit and output.

But what determines information production about firms' individual productivities and the extent of project transparency? We explore the possibility that such information is generated either in stock markets and/or credit markets. In stock markets, agents buying a firm care about the quality of its projects, which determines buyers' expected returns. In credit markets, lenders do not only care about the collateral backing a firm's loan but also the likelihood that the firm defaults and lenders end up with such collateral, which is determined by the firm's quality of its projects.

For the case of stock markets, we propose a model in which the incentives to acquire information about the firm's productivity does not depend on exogenous noise trading, but instead by the average productivity in the economy. As a larger fraction of low quality projects are getting financed in credit markets as credit booms, stock buyers are more uncertain about the specific quality of the firms they buy and their incentives to acquire information increases. In other words, as credit booms the composition of firms' projects is more diverse, which strengthens information incentives. Stock markets act as an automatic macroprudential tool – by slowing down credit growth and so stabilizing the economy. This novel dynamic interaction between stock and credit markets through information acquisition highlights the delicate balance of their function in macroeconomics.

For the case of credit markets, lenders are not only interested in investigating the collateral that they may get in case of default but also the likelihood of default that is determined by the firm's productivity. We show that under certain conditions lenders may decide to acquire information about productivity before acquiring information about collateral, then also preventing a crisis. In other words, we show that credit market can have an intrinsic macroprudential force embedded in their activities, for instance if the cost of examining projects is relatively low.

While information about projects displays a credit-crisis trade-off, information about collateral is never beneficial in our setting. The losses from information production about collateral come from always depriving some, otherwise efficient, firms from operating. The gains or losses from information about firms' individual productivities, however, depends on how the information affects information acquisition about collateral in credit markets. Based on these results we provide normative insights about the optimal production of information in both dimensions. If a government could, for instance, affect the cost of information acquisition both about collateral and projects, it would be optimal to raise both. Examples include allowing complex and opaque securities to be used as collateral in credit markets, or tightening insider trading restrictions so it is more difficult to exploit information in stock markets.

But, if the government cannot target information production about collateral directly, so a crisis is a possibility once the credit boom becomes large enough, it may be optimal to encourage information about projects. If the cost is too large, stock and credit markets may not be able to prevent a crisis and the government would like to induce more information about projects, by, for example, loosening reporting standards for public firms so they are more transparent and easier to access by investors.

If information about projects is generated in stock markets, the model generates empirical counterparts of information acquisition, which can be proxied by the evolution of the cross-sectional dispersion of stock returns. Information in stock markets reduces future credit growth and tends to precede and predict financial crises. But not for good booms, those with relatively high TFP growth that do not end in crises. These implications are consistent with the results in Chousakos et al. (2018).

Related Literature: While in this paper we exploit the informational interpretation of financial crises that we proposed in Gorton and Ordonez (2014 and 2020), those models are just special cases of the setting we develop here. In those settings we focus on the functioning of credit markets in isolation. Here we propose an extended environment with both credit and stock markets and with potential information production both about collateral and projects. Our more comprehensive structure highlights a two-way information feedback between these two fundamental information dimensions and financial markets, revealing very rich dynamics. In contrast to most papers in the literature, which emphasize different elements of credit markets or stock markets separately, the contribution of this paper is to study their interactions, in particular through the production and flow of information. We uncover a novel role of transparency about firms' projects, besides the well-understood allocative and redistributive properties: a trade-off in which too much information production chokes off credit booms excessively but too little does not allow for the prevention of financial crises. Our work suggests that in the absence of well-developed stock markets or sophisticated financial intermediaries, we would have observed more crises in credit markets around the globe.

Our view of stock markets is consistent with a large literature on stock prices being informative and feeding back onto real variables (see, e.g., Dow and Gorton (1997)). In this literature, the information content in asset markets directs managers' investment decisions and allows for a better allocation of resources in the economy. In the work here, however, information in stock markets has another, previously unexplored, positive role in the economy beyond its pure allocative use – it endogenously acts as a macroprudential tool to reduce the likelihood of a financial crisis. While information about firms' collateral can be counterproductive by reducing aggregate credit in the economy, information in stock markets can be beneficial in allocating such credit, but also to costly asphyxiating of credit. Holmström (2015) and Dang et al. (2017) discuss these two markets as separate systems. Here we explore their interaction.

There is also a rich, and more recent, literature considering the conceptual link between information production and economic booms and busts, such as vanNieuwerburgh and Veldkamp (2006), Veldkamp (2006), Straub and Ulbricht (2017), Fajgelbaum et al. (2017), Farboodi and Kondor (2019), and Petriconi (2019). Perhaps the closest to our paper is Asriyan et al. (2019), who study a setting in which credit can be backed either by collateral (with perfect information) or by costly screening of projects, with this mix affecting macroeconomic dynamics and the probability and recovery from crises. Our setting considers both information about projects for trading in stock markets and information about collateral in credit markets, the effect of their interaction for macroeconomic dynamics, the likelihood of crises, and the optimal cost of information acquisition in both markets.

A scarcer literature explores the interaction between stock and credit markets. One branch is mostly empirical and focuses on pricing interactions, such as Beck and Levine (2004) and Gilchrist et al. (2009). Another branch is theoretical, such as Dow et al. (2017)), and studies how managers and creditors take actions based on information in stock markets, creating feedback effects on the determination of stock prices that magnify shocks. Our work differs by explicitly defining the concept of a crisis and on highlighting an informational interaction between these two markets. In our setting stock prices perfectly reveal information. The complementarity does not come from a feedback between choices and information about firms, but instead from a feedback between information acquisition about firms and about collateral. Furthermore, we explore this interaction through its impact on macroeconomics, providing a contribution to most standard macroeconomic models. While those models focus on the stock pricing implications of macro, we focus on the macro implications of the informational content of stock prices.

Finally, our paper displays endogenous cycles, such that shocks are not needed to trigger a crisis, just exhausted credit booms. A recent paper revives the discussion of endogenous cycles, as in our setting, is Beaudry et al. (2020). In their case, cycles are determined by complementarities between aggregate employment and consumption, which induce smooth deterministic cycles. In our case there are complementarities between the volume of credit and the incentives for information acquisition. Since this complementarity is not relevant unless information constraints bind, our model displays deterministic cycles that are not smooth: long booms that suddenly and dramatically end in crises. The sharp reversals after lending booms have been indeed documented by Gopinath (2004) and Ordoñez (2013) among others, but in our case it is generated by the evolution of information acquisition incentives and not from search frictions or learning inertia.

The paper proceeds as follows. In Section 2 we present the model. Section 3 analyzes the *costly* precautionary role of transparency about firms' individual productivities. Section 4 endogenizes this transparency allowing either stock markets or credit markets to produce information about productivities. Section 5 discusses normative insights. 6 concludes.

2 Model

This model explores how information about projects that are financed in credit markets (*project information*) affects the incentives to acquire information about the collateral backing those loans (*collateral information*). These *information dynamics* determine the evolution of credit and productivity, and the likelihood and magnitude of financial crises – *macroeconomic fluctuations*. We first analyze a setting in which project information is exogenous, highlighting its role in shaping credit booms and busts. Then we endogenize the production of project information, showing that credit booms and busts feed back into incentives to produce that information.

2.1 Environment

Agents and Goods: We assume a discrete time economy in which, in each calendar period t, two overlapping generations – young and old – coexist, each with *mass one* of a continuum of agents. There are two goods in the economy – *numeraire*, and *land*. Numeraire, denoted by K, is productive and reproducible (it can be used to produce more numeraire) but non-storable (it cannot be transferred across periods). Land, on the other hand, is storable but it is not productive, nor reproducible. Each generation is risk neutral and derives utility from consuming numeraire at the end of the period, without discounting.[1]

Technology: There is the potential for production in the economy. Old agents become *entrepreneurs* by coming up with an idea for a productive *project*, and can form *a firm* by combining the idea with a unit of land. A firm can operate only by additionally using K^* units of numeraire, in which case the firm produces AK^* units of numeraire with probability q, and nothing with probability $1 - q$.[2] There are two *project qualities* available: An exogenous fraction ψ has *high* probability of success, q_H, and the rest have a *low* probability of success, q_L. We assume *all projects are efficient*, i.e., $q_H A > q_L A > 1$, which implies that it is optimal for all firms to operate if they can get loans.

[1] No discounting and no concern about when to consume makes credit only useful for facilitating production and not for consumption smoothing.

[2] Here we assume a fixed project size K^*. We could assume a positive correlation between q and K^* without changing the main insights. Such correlation would increase the benefits of projects' information and increase the incentives for collateral information.

We say a firm is *active* if it has a chance (based on perceived collateral quality as we describe next) of obtaining a loan in credit markets. We denote by η the *mass of active firms*, which we will show later is endogenous. We assume that active firms are randomly assigned to a queue to choose their project quality. When a firm has its turn to choose according to its position in the queue, an active firm naturally picks the project with the highest available quality q of those remaining in the pool.[3] This protocol induces an average productivity of projects among active firms, which we denote by $\widehat{q}(\eta)$, that depends on two factors: the exogenous fraction of good projects in the economy, ψ, and the endogenous fraction of firms operating projects, η, as follows:

$$\widehat{q}(\eta|\psi) = \begin{cases} q_H & \texttt{if } \eta < \psi \\ z(\eta) q_H + (1 - z(\eta))\, q_L & \texttt{if } \eta \geq \psi. \end{cases} \tag{1}$$

where $z(\eta) \equiv Pr(q_H|\eta) = \frac{\psi}{\eta}$. This assumption about the protocol to assign project quality to active firms is a way to implement decreasing marginal returns of projects in the economy – the more firms operate, the lower their average quality.

We assume that an exogenous fraction y of firms are *transparent* in the sense that their q are known. Since transparency is independent of the realization of the project's quality, for the rest, or *opaque* projects, the best guess of quality is $\widehat{q}$. Later we discuss how y may be endogenous to the evolution of credit conditions.

An Agent's Lifetime: At the start of a period, say t, the individual is born young with endowment $\bar{K}$ of numeraire, which can be used to lend to a firm in credit markets. In period $t + 1$ the agent becomes old and forms a firm. Since the agent does not obtain any additional endowment, he needs to borrow numeraire K^* in credit markets to operate his project. Firms produce, loan contracts are settled, and land is sold to young agents at the end of the period so they can form their own firm in the next period. Consumption takes place at the end of each calendar period. This time line guarantees that resources are in the wrong hands and so there are gains from trade. At the beginning of each period old agents need numeraire they do not have (but the young do have) and at the end of the period they have land they do not need (but the young want).

[3] Notice that the project quality is not a function of an idea, which is just a precondition to have a project, but instead quality is only determined by the position on the queue. This assumption guarantees that, aside from the collateral, firms are identical for lenders absent additional project information.

Land as Collateral: We assume that $\overline{K} > K^*$ and since production is efficient, if output were verifiable it would be possible for all firms to borrow the required amount of numeraire K^* using state-contingent claims. In what follows, however, we assume *limited liability and a financial friction* – the output of the project is only observable by the borrower and non-verifiable by the lender. As the output could be hidden, firms would never repay their loans and young agents would never be willing to lend. While we assume that firms can hide the numeraire output, we also assume that firms cannot hide land, which makes land useful as *collateral* to relax the financial friction. Firms can credibly promise to transfer a fraction of land to households in the event of not repaying the loan, which relaxes the financing constraint from output non-verifiability.

Land comes in two *qualities*. If land is *"good"*, it can deliver C units of numeraire, but only once. If land is *"bad"*, it is worthless. We assume an exogenous fraction $\widehat{p}$ of land is good in every period. We denote the perception, or *belief*, about the quality of a particular unit of land as p. This belief is critical for the granting of loans. We assume that $C > K^*$ so that land that is known to be good can sustain the needed loan size, K^*. But land that is known to be bad is not able to sustain a loan. How many firms are able to use land as collateral will determine the mass of active firms, η.

Land's idiosyncratic quality is not permanent. This will induce dynamics in our setting absent any other shock. With probability λ the quality remains unchanged, but with probability $(1 - \lambda)$ it mean reverts and becomes good with a probability $\widehat{p}$, independent of its current type. Even when this idiosyncratic shock to land is observable, its realization is not. An implication of this process is that the distribution of beliefs about land quality will have just a three-point support: 0, $\widehat{p}$, 1, which simplifies the exposition that follows. It is, however, not restrictive. The only relevant assumption to trigger dynamics and information depreciation is mean reversion of collateral quality.

Remark on the interpretation of land as collateral: We have called the collateral "land", but this is a simplification for exposition. In the model there are no explicit financial intermediaries and no financial collateral, which can be introduced at the cost of more structure. Assume for instance that firms need intermediaries to borrow from households and that households cannot monitor intermediaries, so they require collateral. Households only know what firm (or type of firms) the bank lends to, but the household cannot see the firm's output realization. The bank can verifiably monitor the firm, determining its output, which is the bank's function. The bank takes the money deposited by households and lends it to the firm (or group of firms). Under this alternative with banks, the debt could be a repurchase agreement ("repo") or other money market instruments and collateral could be either a specific bond, a portfolio of bonds and loans or a mortgage-backed security (MBS) if the borrower were another household. Other than the specifics of these contracts, what is important is that, as "land", collateral does not trade in centralized markets where prices reveal the information that has been produced.

Credit Market Protocol: In credit markets firms can borrow numeraire from young agents. We assume random matching between a lender and a borrower, and that the borrower has the bargaining power. Before signing the loan, *the lender can privately acquire information about the firm's collateral quality* at a cost γ_C in terms of numeraire. We assume this information can be credibly certified and while the certification is private immediately after being obtained, it becomes public at the end of the period. Still, the agent can credibly disclose private information (the certificate) immediately if it is beneficial to do so.

This private information assumption gives rise to two possible collateralized loan contracts. The first, *information-sensitive debt* (IS), specifies that the lender produces information about the collateral quality before signing the contract. The second, *information-insensitive debt* (II), specifies a contract based on the expected value of collateral. This contract is only feasible if the lender does not have incentives to deviate and *privately* produce information (without the borrower knowing) before signing the contract.

Asset (Land) Market Protocol: In asset markets, at the end of the period, a young agent can buy a unit of land to combine with an idea and form a firm when becoming old in the subsequent period. Again we assume random matching between a buyer and a seller, with the buyer having all the bargaining power. This last assumption immediately implies that the buyer would never pay more than the expected value of the numeraire that the seller can obtain by extracting the intrinsic value from land, which determines the price of land as simply pC.[4]

[4]Assuming a different protocol would allow the price of land to incorporate its value as collateral, being higher than the fundamental price pC. While such possibility increases credit per unit of collateral (as in Martin and Ventura (2012)), we focus on the increase in credit by the use of more units of collateral. This possibility, however, would not change the qualitative information implications of the model. Gorton and Ordoñez (2014) explore this extension in detail.

2.2 Timing and Equilibrium

We have discussed the environment, preferences, technologies, market protocols, and information structures. Here we discuss the timing in a single period and define the equilibrium.

1. Credit Market: There is random matching between a young agent (the lender, l) and an old agent (the borrower, b). Both know the probability p that the borrower's land is good. A fraction y of projects are of publicly known quality q, and the rest are of unknown quality $\widehat{q}$. The borrower makes a take-it-or-leave-it offer for a loan K^*, the face value R to be repaid, and the fraction x of collateral that will be transferred to the lender in case of default. The loan contract also specifies whether the lender acquires information (IS contract) or not (II contract). The lender either accepts or rejects the offer.

2. Firms Production and Land Shocks: Production takes place and all information generated about land at the time of the loan (information privately acquired) gets revealed. Loan contracts are settled. Then, land realizes the mean-reverting idiosyncratic shocks.

3. Asset Market: After production, old agents who have not defaulted and handed their land over to their young lenders, want to sell their land, so they randomly match with young agents with no land who will need it to form a firm in the subsequent period.

4. Consumption: Numeraire goods are perishable and so are consumed.

We summarize this timeline of a single period t in Figure 1. As we will discuss, periods are only linked by the evolution of beliefs about land quality, p.

Figure 1: Timeline in period t

Credit Market	**Production and Shocks**	**Asset Market**	**Consumption**
Match: young - old. Info choice about C. Loan contract.	Firm production. Loan settlements Shocks to land type.	Match: young - old with no default Land traded at pC.	Consumption.

Now we can define the equilibrium. As the asset market is mechanical, with the price pinned down by the expected value of land, we focus on credit markets.

Definition 1. Equilibrium: *The credit market is in equilibrium if i) borrowers choose the loan contract type ($i \in \{IS, II\}$, R_i and x_i) to maximize expected profits conditional on the lender's participation constraint; ii) the borrower repays when the project succeeds and defaults when the project fails (truth-telling constraint); and iii) there are no private incentives to acquire information in the information-insensitive contract (incentive-compatibility constraint).*

2.3 The Credit Market

Here we solve for the optimal short-term collateralized debt contract for a single firm with arbitrary land quality belief p and arbitrary project quality belief q. Given our assumptions there are only three possible values of p (0, $\widehat{p}$ or 1) and three possible values of q (q_L, $\widehat{q}$ or q_H). While in both cases the extreme values represent information (bad and good respectively), the one in the middle represent no information (unknown collateral or project). We could, however, accommodate richer heterogeneity without changing the insights, but at the cost of more notation.

There are two possible loan contracts in terms of information processing. The first, an information-sensitive (IS) loan contract specifies information production about collateral. Lenders are willing to lend K^* only if they find out that the collateral is good (with probability p). Hence, from an ex-ante perspective, the participation constraint requires $p[qR_{IS} + (1-q)x_{IS}C - K^*] \geq \gamma_C$, where R_{IS} is the payment the borrower promises to repay and x_{IS} the fraction of land that goes to the lender if the borrower defaults. The truth-telling constraint requires $R_{IS} = x_{IS}C$, otherwise the firm always repays or defaults. This implies

$$R_{IS} = K^* + \frac{\gamma_C}{p} \qquad \text{and} \qquad x_{IS} = \frac{R_{IS}}{C} \leq 1.$$

Hence, this contract is feasible only when $p \geq \frac{\gamma_C}{C-K^*}$ (the cost of information is low enough vis-a-vis the expected collateral quality).[5]

The second kind of loan contract is an information-insensitive (II) loan contract, which specifies that no information about the collateral quality be produced. Then

[5]Note that, since the fraction of land posted as collateral does not depend on q, firms cannot signal their q by posting a different fraction of land as collateral (or similarly, by offering to pay a different interest rate). Intuitively, since collateral completely covers the loan value it prevents a loss due to default, so the loan cannot be used to signal the probability of default.

the contract is just based on the expected value of collateral. In this case, the lenders' participation constraint binds when $qR_{II} + (1-q)x_{II}pC = K^*$, and subject to the truth-telling constraint, $R_{II} = x_{II}pC$. We obtain,

$$R_{II} = K^* \qquad \text{and} \qquad x_{II} = \frac{R_{II}}{pC} \leq 1.$$

Hence, this contract is feasible only when: i) $p \geq \frac{K^*}{C}$ (the borrower has valuable enough collateral) and ii) the lender does not have incentives to deviate and check the value of collateral privately before signing the contract. Lenders may want to deviate because they can lend at beneficial contract terms if the collateral is good, and not lend at all if the collateral is bad. Formally, they do not deviate if the expected gains from acquiring information, evaluated at x_{II} and R_{II}, are lower than the private loss, γ_C. The incentive-compatibility constraint is then,

$$p[qR_{II} + (1-q)x_{II}C - K^*] < \gamma_C,$$

or in terms of the belief about the collateral quality, this contract is feasible if and only if

$$p > p^* \equiv 1 - \frac{\gamma_C}{(1-q)K^*}. \tag{2}$$

It is clear from this expression that the information-insensitive debt region widens with information costs p^* and shrinks with γ_C, with the project's expected probability of success p^*, and with q. Note that information about q will create greater heterogeneity about which firms will be examined in the credit market.

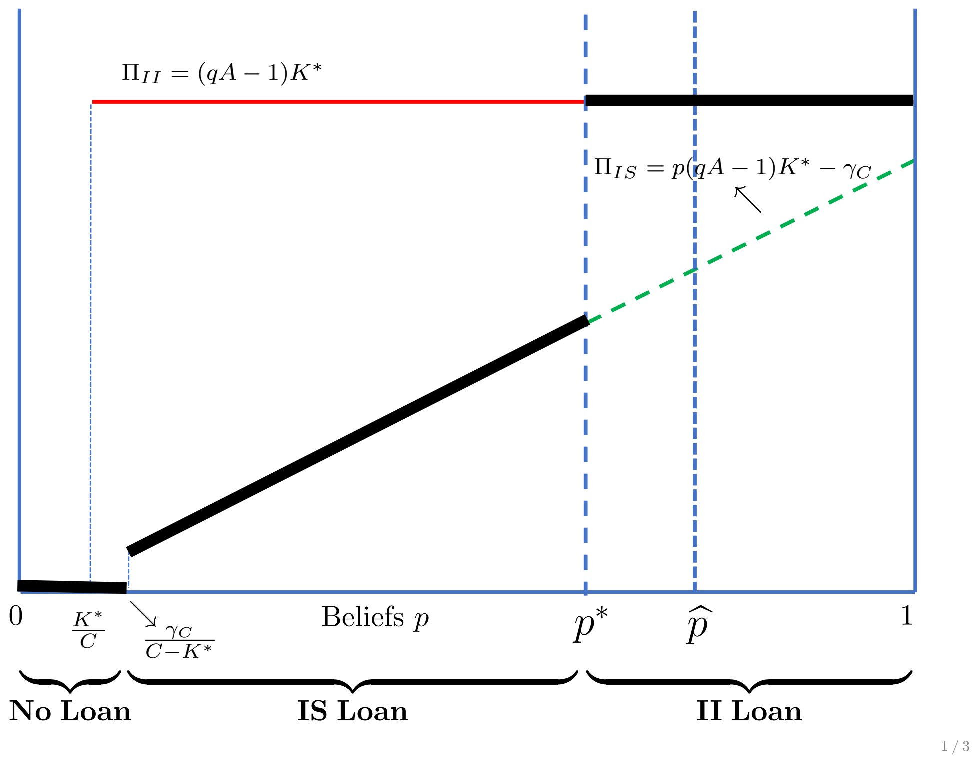
This threshold is depicted in Figure 2.[6] When the project is financed, the expected net production is $(qA-1)K^*$. It is clear that an information-insensitive loan is always preferred, as the project is always financed and there is no waste of resources on information. Firms that are unlikely to have good land (more specifically with $p < p^*$) cannot obtain information-insensitive loans because the lender has large incentives to deviate.

In the figure, firms with land that is expected to be good with probability $\widehat{p}$, for instance, can obtain information-insensitive loans. We will show later, when discussing

[6]The figure assumes a relatively high C, so the feasibility constraints of both contracts bind for low enough p.

dynamics, that as a credit boom proceeds η increases, expected q (i.e., $\widehat{q}$) declines and p^* increases for an average firm, eventually exceeding $\widehat{p}$. This is a crisis because of the discontinuous decline in expected production. Some firms that were getting loans suddenly cannot get loans. Output and consumption go down – a crisis.

Figure 2: Expected Net Production in Equilibrium



The operation of the credit market is a simplified version of Gorton and Ordoñez (2014) (where borrowers could affect information incentives by changing the loan amount) and of Gorton and Ordoñez (2020) (where both borrowers and lenders could acquire private information about the collateral). In this paper, the project is not scalable (the loan should be K^*), which eliminates the "size of the project" dimension of discouraging information, but allows a simpler emphasis on the "information about the project" dimension that is absent in those papers.

3 The Precautionary Role of Project Transparency

In this section we derive the dynamics of credit markets and productivity, in particular as a function of the share of projects that are transparent, this is the fraction y of projects of known quality q. We first characterize the evolution of beliefs and credit. Then we study a benchmark in which no project is transparent. Finally we show how those dynamics change as a function of project transparency.

3.1 Credit Booms, Busts and the Evolution of Beliefs

The idiosyncratic shock process for collateral generates depreciation of credit market collateral information. Given our assumed mean reverting process, a unit of land falls into one of three possible categories: it is either known to be good ($p = 1$), known to be bad ($p = 0$) or of uncertain quality ($p = \widehat{p}$). We denote the mass of land in each category $p \in \{0, \widehat{p}, 1\}$ at the beginning of period t as $m(p)_t$. Since the mass of *active firms* is given by all firms that may have good collateral,

$$\eta_t = m(\widehat{p})_t + m(1)_t. \tag{3}$$

If a fraction v_t of land of uncertain quality gets investigated by lenders in credit markets at time t, the mass of land in each belief category at the end of the period, which we denote by t' is

$$\begin{aligned} m(\widehat{p})_{t'} &= (1 - v_t)m(\widehat{p})_t \\ m(1)_{t'} &= m(1)_t + v_t\widehat{p}m(\widehat{p})_t \\ m(0)_{t'} &= m(0)_t + v_t(1 - \widehat{p})m(\widehat{p})_t. \end{aligned}$$

Idiosyncratic shocks happen between periods, so the mass of land in each belief category at the beginning of period $t + 1$ is

$$\begin{aligned} m(\widehat{p})_{t+1} &= \lambda m(\widehat{p})_{t'} + (1 - \lambda) \\ m(1)_{t+1} &= \lambda m(1)_{t'} \\ m(0)_{t+1} &= \lambda m(0)_{t'}. \end{aligned}$$

Putting these elements together, the mass of active firms in period $t+1$ is

$$\begin{aligned}\eta_{t+1} &= m(\widehat{p})_{t+1} + m(1)_{t+1} \\ &= \lambda[1 - v_t(1-\widehat{p})]m(\widehat{p})_t + \lambda m(1)_t + (1-\lambda). \qquad (4)\end{aligned}$$

The first term corresponds to land with $\widehat{p}$ that has not suffered an idiosyncratic shock, and that in the previous period either was not examined or was examined and was found to be good. The second term corresponds to land known to be good (i.e., $p = 1$) that has not suffered an idiosyncratic shock. The last term corresponds to all land that has suffered an idiosyncratic shock and is of uncertain quality at the beginning of $t+1$.

Combining equations (3) and (4) *a credit boom* is defined as *an expansion of credit on the extensive margin*, the change in the mass of firms that are actively participating in credit markets,

$$\begin{aligned}\eta_{t+1} - \eta_t &= (1-\lambda)(1-m(1)_t) - [1-\lambda(1-v_t(1-\widehat{p}))]m(\widehat{p})_t \\ &= (1-\lambda)m(0)_t - \lambda v_t(1-\widehat{p})m(\widehat{p})_t. \qquad (5)\end{aligned}$$

Since all firms obtain the same loan, more firms obtaining credit is the same as more aggregate credit. The credit boom is given by the old collateral known to be of bad quality that suffered an idiosyncratic shock and started in the pool of unknown collateral, minus the unknown collateral that was investigated and found to be bad collateral.

Now, we can put structure on the fraction of collateral v_t that is investigated in period t. In what follows we assume that parameters are in a range such that information about a firm's project quality makes a difference for information acquisition about its collateral. If this were not the case, information about projects would not affect the dynamics of credit markets. More precisely,

Assumption 1. *Assume $\widehat{p} < p^*(q_L)$ (there is information production about collateral of uncertain quality for firms known to operate with q_L-projects) and $\widehat{p} > p^*(q_H)$ (there is no information production about collateral of uncertain quality for firms known to operate with q_H-projects).*

Under this assumption, information acquisition about collateral and credit booms interact. First, the mass of active firms η_t reduces the fraction $z_t = \frac{\psi}{\eta_t}$ of q_H-projects in the economy. Among firms with collateral $\widehat{p}$, a fraction $y(1-z_t)$ are transparent q_L-firms, a fraction yz_t transparent q_H-firms, and a fraction $1-y$ are firms with opaque projects. Second, the mass of active firms η_t also reduces the average quality of opaque projects, $\widehat{q}_t$. If $p^*(\widehat{q}_t) \leq \widehat{p}$ there is no information production about the third group, just about the first group. If in contrast, $p^*(\widehat{q}_t) > \widehat{p}$ there is also information production about the third group, which we denote *a crisis*, and denote by $\mathbb{I}_{C,t+1}$ a crisis indicator function in period t, with $\mathbb{I}_{C,t} = 1$ in case of a crisis and 0 otherwise. Since $p^*(\widehat{q}_t)$ increases as $\widehat{q}_t$ declines, a higher η_t makes a crisis more likely. Hence, information about collateral in credit markets increases discontinuously upon a crisis.

$$v_t(\eta_t) = y(1 - z_t(\eta_t)) + \mathbb{I}_{C,t}(\eta_t)\,[1-y] \tag{6}$$

When $\mathbb{I}_{C,t} = 0$, there is no information acquisition about collateral of uncertain quality of a firm with an opaque project, $v_t = y(1-z_t)$ (only the collateral of q_L-projects are investigated). In contrast, during a crisis (this is $\mathbb{I}_{C,t} = 1$) only the collateral of known q_H-projects is not investigated, and then $v_t = 1 - yz_t$.

As the realized amount of credit depends on information acquisition about collateral, the next Lemma formally characterizes the evolution of credit in the economy.

Lemma 1. *The mass of active firms follows the following first-order difference equation.*

$$\eta_{t+1} = 1 - \lambda + \lambda[v_t(\eta_t)\widehat{p} + (1 - v_t(\eta_t))\eta_t] \tag{7}$$

and then

$$\frac{\partial \eta_{t+1}}{\partial \eta_t} = \lambda(1 - v_t(\eta_t)) - \lambda(\eta_t - \widehat{p})\frac{\partial v_t}{\partial \eta_t} \tag{8}$$

with $\frac{\partial v_t}{\partial \eta_t}$ *given by differentiation of equation (6).*

Proof Among collateral of known quality (i.e., $1 - m(\widehat{p})_t$), a fraction $\widehat{p}$ is of good quality. Then, $m(1)_t = \widehat{p}(1 - m(\widehat{p})_t)$. Substituting into equation (3), we can express $m(\widehat{p})_t$ as a function of η_t. This is,

$$\eta_t = \widehat{p} + (1-\widehat{p})m(\widehat{p})_t \qquad \Longrightarrow \qquad m(\widehat{p})_t = \frac{\eta_t - \widehat{p}}{1 - \widehat{p}},$$

and we can rewrite equation (4) as

$$\begin{aligned}\eta_{t+1} &= (1-\lambda) + \lambda(m(\widehat{p})_t + m(1)_t) - \lambda v_t(1-\widehat{p})m(\widehat{p})_t \\ &= (1-\lambda) + \lambda\eta_t - \lambda v_t(1-\widehat{p})m(\widehat{p})_t\end{aligned}$$

Replacing $m(\widehat{p})_t$ in this equation we obtain the equation (7) in the Lemma. Q.E.D.

3.2 Benchmark Without Any Transparent Projects

We use Lemma 1 to characterize the set of stationary equilibria. We start with a benchmark case without information about projects, this is $y_t = 0$ in all t. In the next Proposition we show the economy can be in a stationary *no boom* equilibrium (in which only a fraction of firms receive credit), a stationary *good boom* equilibrium (in which all firms receive credit), and a stationary *cyclical bad boom* equilibrium, with a deterministic sequence of booms and busts.

Proposition 1. *Assuming $y_t = 0$ for all t. From equation (6), $v_t = \mathbb{I}_C$ in all t. Then*

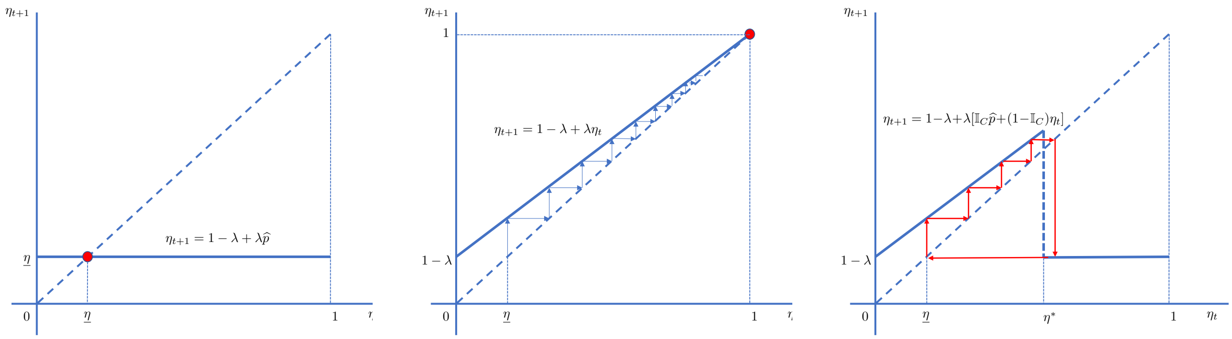
$$\eta_{t+1} = 1 - \lambda + \lambda[\mathbb{I}_C\widehat{p} + (1-\mathbb{I}_C)\eta_t]$$

where $\mathbb{I}_C = 1$ for all $\eta_t > \eta^*$ and 0 otherwise, with η^* given by $p^*(\widehat{q}(\eta^*)) = \widehat{p}$. Defining $\underline{\eta} \equiv 1 - \lambda + \lambda\widehat{p}$ as the lowest possible mass of active firms (all firms that suffer an idiosyncratic shock and all firms with good quality collateral that do not face an idiosyncratic shock), the stationary equilibria are:

1. *No Boom: If $\eta^* \leq \underline{\eta}$, information is replenished every period and $\eta_{SS} = \underline{\eta}$.*
2. *Good Booms: If $\eta^* \geq 1$, information is never generated and $\eta_{SS} = 1$.*
3. *Cycles of Bad Booms: If $\eta^* \in (\underline{\eta}, 1)$, information is generated only when $\eta_t > \eta^*$.*

The proof follows directly from the dynamics given by equations (7) and (8). When there is no crisis, (this is $\mathbb{I}_C = 0$), $\frac{\partial \eta_{t+1}}{\partial \eta_t} = \lambda$ and when there is a crisis, (this is $\mathbb{I}_C = 1$), $\frac{\partial \eta_{t+1}}{\partial \eta_t} = 0$. We illustrate this result using a phase diagram. The first panel of Figure 3 shows the first case of the proposition, in which the mass of active firms is constant and at the minimum, as information is replenished every period. The second panel shows the second case of the proposition, in which an economy with information transits to a steady state without information about any collateral and all firms are active (a *good boom*). The third panel shows the last case of the proposition, in which credit cycles between booms that end in crises once the mass of active firms (η^*) is high enough, just to restart the process again.

Figure 3: No Information in the Stock Market



(a) No Boom (b) Good Booms (c) Bad Booms

3.3 Transparent Projects as a Macroprudential Mechanism

In this section we present three results when some firms have transparent projects. First, in the extreme situation in which all projects are transparent, the economy displays just one stationary equilibrium with an intermediate level of active firms, and without crises. Second, when transparency is abundant crises are prevented, and even if they occur their magnitude is tamed when compared to a situation without any transparent projects. Finally, we consider a more flexible exercise in which we allow project transparency to move with the credit boom in an arbitrary way, this is $\frac{\partial y_t}{\partial \eta_t} \neq 0$. We show that if project transparency increases enough during a credit boom then it may endogenously serve as an automatic macroprudential tool. This possibility, however may induce *deterministic non-crisis cycles*.

The first result, based on full project transparency, is formally as follow,

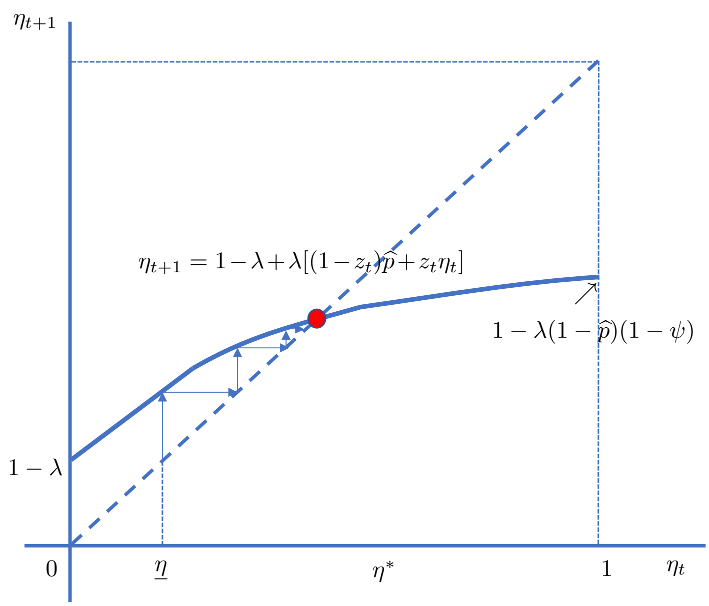
Proposition 2. *Assuming $y_t = 1$ in all t. From equation (6), $v_t = 1 - z_t$ in all t (i.e., there is never a crisis). Then*

$$\eta_{t+1} = 1 - \lambda + \lambda[(1 - z_t)\widehat{p} + z_t\eta_t] \qquad \textit{with } z_t = \min\left\{\frac{\psi}{\eta_t}, 1\right\}$$

There is a unique steady state in which $\eta_{SS} \in (\underline{\eta}, 1)$.

The proof follows directly from the dynamics given by equations (7) and (8) and from equation (6). When there is complete project transparency, collateral is only investigated if it is backing q_L-projects. This is why there are no crises (formally, from equation (6) the discontinuity generated at η^* disappears.), as there are only two possible thresholds for information acquisition, $p^*(q_L) > \widehat{p}$ and $p^*(q_H) < \widehat{p}$. The credit boom is continuous, strictly increasing at a decreasing rate, as there are more q_L-firms operating in the economy. Formally, from equation (8), $\frac{\partial \eta_{t+1}}{\partial \eta_t} = \frac{\lambda \widehat{p} \psi}{\eta_t^2}$ (positive and decreasing in η).

Figure 4: Full Information in the Stock Market



This benchmark, illustrated in Figure 4, provides a first indication of the role of project transparency in preventing crises. When information about projects reveals which firms are more likely to repay and which are more likely to default, credit markets react by investigating the relevant collateral. During a credit boom, there are more and more firms that are less likely to repay, hence there is more information acquisition in credit markets, preventing a sudden change – no crisis. Full project transparency generates a stationary equilibrium that is mediocre (i.e., with not all firms getting credit), but stable.

Now we assume project transparency is constant over time (this is, $y_t = y \in (0, 1)$) for all t. The next proposition shows that, even if this level of transparency is not enough to prevent a crisis (y is relatively low), the crisis is smaller than in an alternative scenario without project transparency.

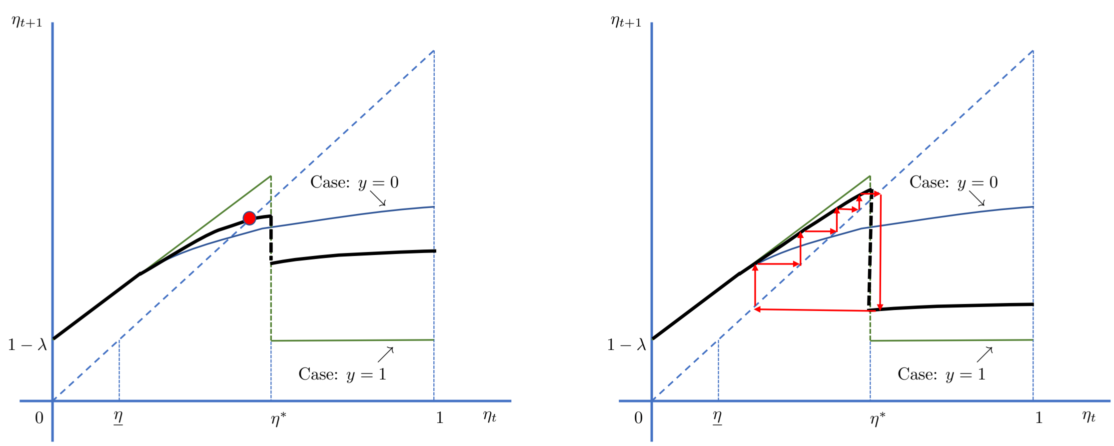
Proposition 3. *Assume bad booms in the absence of project transparency. There is a level of transparency $y > \bar{y}$ that prevents crises. If $y < \bar{y}$, crises occur but with a magnitude that decreases in transparency y.*

Proof From Lemma 1, the system reaches a steady state exactly at the point of crisis η^* when $\eta^* = 1 - \lambda + \lambda\eta^* - \lambda\bar{y}(1 - z(\eta^*))(\eta^* - \widehat{p})$. This implies that

$$\bar{y} = \frac{\lambda}{1-\lambda}\frac{1-\eta^*}{\eta^*}(\eta^* - \psi)(\eta^* - \widehat{p}) > 0,$$

and that for all levels of $y > \bar{y}$ the steady state happens at $\eta < \eta^*$, and a crisis is prevented. To show that, conditional on a crisis (this is $y < \bar{y}$), the crisis magnitude decreases with y, notice that, from equation (6) the affected mass of firms affected is $1 - y$. Hence the magnitude of a crisis, from equation (7) is $\eta^*|_{\mathbb{1}_C=1,y>0} > \eta^*|_{\mathbb{1}_C=1,y=0}$. This is the case because $\eta^*|_{\mathbb{1}_C=1,y>0} = 1 - \lambda + \lambda\widehat{p} + \lambda yz(\eta^*)(\eta^* - \widehat{p}) \equiv \underline{\eta} + \lambda yz(\eta^*)(\eta^* - \widehat{p}) > \underline{\eta}$. Q.E.D.

Figure 5: Some Information in the Stock Market



(a) High Info (Low y) (b) Low Info (High y)

Figure 5 is based on the parametric combination that generates bad booms in the absence of transparent projects (third panel of Figure 3). The first panel displays the case with relatively high transparency (that is, relatively high y). This information slows down the credit boom so much that the economy comes to a steady state without triggering a crisis. The second panel displays the case with relatively low project transparency (that is, relatively low y). This information slows down the credit boom, but not so much as to prevent a crisis. However, the collateral information about transparent projects allows some q_H-projects to avoid sudden collateral examination and decreases the magnitude of the crisis relative to the situation in which no project were transparent. In a few words, information about projects may prevent crises, and even if not, it reduces the volatility of deterministic boom-bust cycles.

Finally, we consider a more flexible situation in which project transparency changes over the credit boom, for instance increasing, $\frac{\partial y_t}{\partial \eta_t} > 0$. In the next section we discuss an extension in which information about projects is endogenously generated in credit and/or stock markets. The next Proposition shows that increasing transparency may prevent a crisis, but it may also generate *non-crisis cycles.*

Proposition 4. *When project transparency increases rapidly during the credit boom, it may prevent crises by creating non-crisis cycles.*

Proof From the proof of Proposition 3, $\frac{\partial \eta_{t+1}}{\partial \eta_t}|_{\mathbb{I}_C=0,y_t=y} > 0$. From equation (8), and depending on $\frac{\partial y_t}{\partial \eta_t}$ $\frac{\partial \eta_{t+1}}{\partial \eta_t}|_{\mathbb{I}_C=0,y^*}$ can be negative. The reason is that, as credit booms increase $\frac{\partial z_t}{\partial \eta_t} < 0$, and by assumption $\frac{\partial y_t}{\partial z_t} > 0$. If transparency changes quickly (large enough $\frac{\partial y_t}{\partial z_t} > 0$) the derivative is negative and can generate a cyclical steady state with a cycle with no crisis. Q.E.D.

Figure 6: No-Crisis Cycles

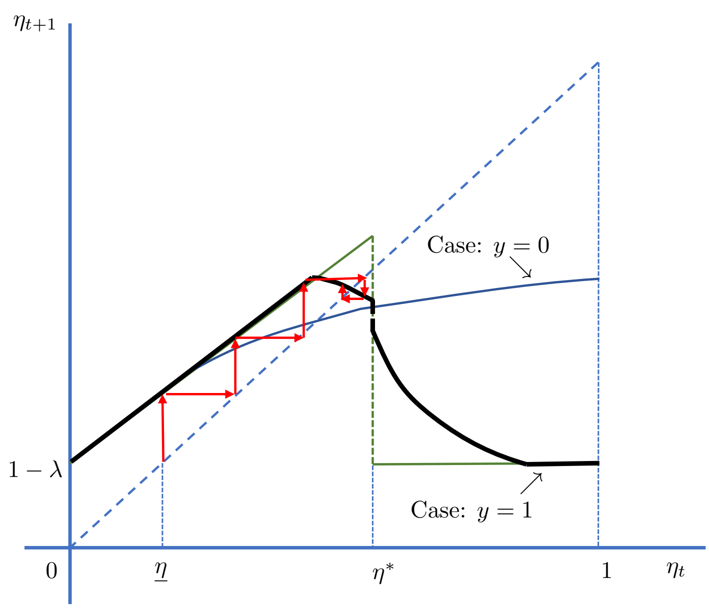


Figure 6 displays this possibility: the evolution of η_t bends as project information changes. Once project transparency increases, the difference equation transitions gradually from the case without information ($y = 0$) to the case of full information ($y = 1$). Once credit booms retract the difference equation transitions back to the case $y = 0$.

The shape of the difference equation critically depends on the assumptions about $\frac{\partial y_t}{\partial \eta_t}$, which we will endogenize later. In the case depicted, the economy cycles before suffering a crisis. The cycle still displays less volatility than the one involving crises. More in general, however, the phase diagram is contained between the benchmarks of $y = 0$ and $y = 1$ depending on how information about projects depend on the credit boom. The shape of the phase diagram determines whether the crisis is avoided with a non-crisis cycle, with a non-cyclical steady state or not avoided at all.

4 Endogenous Project Transparency

In the previous section we explored how incentives to acquire information about collateral during credit booms depends on the exogenous availability of information about the projects to be financed. Here we study how such information may endogenously depend on the extent of information about collateral and the magnitude of the credit boom. While it may be natural to think about information production about collateral happening in credit markets, information about projects can be generated in credit markets (when lenders try to assess the probability of loan defaults) but also in stock markets (when firm buyers try to assess the return of their investments). We will separately explore these two possibilities next.

4.1 Project Information Produced in Stock Markets

Capturing how information acquisition about a firm's earning possibilities depends on the magnitude of the credit boom is not straightforward in a standard model with noise traders. Such dependence would rely on introducing an arbitrary relation between noise trading and credit booms, as we did previously. Instead, in what follows, we take a more constructive approach that is internally consistent on linking information about projects to credit booms.

Assume an intermediate life-cycle stage, which we call *middle-aged*. This implies that in each calendar period t, three overlapping generations coexist: young, middle-aged and adult. Middle-aged agents generate ideas that turn into projects, and trade those ideas in *stock markets*. To be more precise about the operation of stock markets, we first re-normalize the mass of agents to three, and assume only a third are entrepreneurs and the rest managers. While entrepreneurs generate project ideas they cannot manage those ideas, while managers do not have their own ideas, but have the managerial skills necessary to run others' ideas. All middle-aged agents obtain an additional endowment $\bar{K}$, at the end of the period, which entrepreneurs can use to buy land from old agents to create a firm (a combination of land and an idea).[7] After an entrepreneur creates a firm, she sells it to a manager. The firm's operation still works as in the previous section.

Notice that under this extension, old agents do not obtain ideas randomly but instead are managers who bought those ideas from entrepreneurs before becoming old. Still, the average quality of ideas depreciates with a credit boom, since firms can only be sold when an idea is matched with a land that is either of good or uncertain quality (this is, a firm that can actively obtain credit).

Stock Market Protocol: In stock markets a middle-aged manager can buy a firm from a middle-aged entrepreneur. As there are twice as many buyers as sellers, we model the stock market as a random matching of two potential managers to one entrepreneur. Each buyer submits an individual bid in a sealed envelope to the seller, who then sells the firm to the highest bidder. Before submitting the bid, a bidder can privately acquire information about the firm's productivity at a cost γ_q in terms of numeraire. In the case of acquiring information we assume the bidder not only observes the project's quality q but also learns whether his competitor has acquired information. This last part is not relevant to the mechanism but greatly simplifies the formation of beliefs about what the other bidder knows, and then the exposition.

Take a firm with expected project quality $\widehat{q}$ and expected land quality p. A bidder's choice to acquire information about the realized q depends on the expected functioning of credit markets (how p maps into credit once the manager tries to obtain loans). At the same time, information about the project determines the informativeness of firms' stock

[7]Endowing numeraire to young agents at the beginning of the period and to middle-aged agents at the end of the period avoids a confusion of roles. While young agents are the only agents who can be lenders, middle aged agents are the only who can buy land.

prices about q, which is then used in credit markets to determine whether information about collateral will be generated. Here we explore this intricate relation, and how information about projects depends on the magnitude of the credit boom.

Both the seller and potential buyers agree on the belief about the firm's land quality (p). Buyers also know the fraction of active firms in credit markets (η) and then the probability of bidding for a firm with a q_H-project, which we define as $z(\eta) \equiv Pr(q_H) = \frac{\psi}{\eta}$. A firm's value is composed of two parts, one is the expected value of its collateral pC and the other is the expected profit generated by the project according to Figure 2.

We define $V_H(p|\eta)$ as the value of a q_H-project firm when its project quality is unknown at the moment of obtaining the loan (this is $\widehat{q}(\eta)$, and $V_L(p)$ as the corresponding value of a q_L-project firm. We also define $s(p|\eta)$ to be the fraction of informed bidders among firms with land p and project expected quality $\widehat{q}(\eta)$ and $P_U(p|\eta)$ be the *pooling price* of such firm. The first two values are determined in credit markets as discussed in Figure 2. The last two variables are jointly determined in equilibrium by the bidding and information production of potential buyers. The next proposition characterizes this endogenous information equilibrium.

Proposition 5. *For a given credit boom magnitude (mass of active firms η), define the fraction of q_H-firms that are available for the uninformed to buy as*

$$\omega(p|\eta) = \frac{z(1-s)}{z(1-s) + (1-z)(1+s)}. \tag{9}$$

The fraction of transparent projects is $y^*(p|\eta) = s^{*2}(p|\eta)$, where the fraction of informed investors of a firm with land p solves the equation

$$\omega^*(1-\omega^*)(V_H - V_L) = \gamma_q. \tag{10}$$

While $s^* < 1$, $s^* = 0$ if $z(1-z)(V_H - V_L) < \gamma_q$. The pooling price in equilibrium is,

$$P_U^* = \omega^* V_H + (1-\omega^*) V_L. \tag{11}$$

Proof In what follows, and unless there is risk of confusion, we dispense with explicit reference to the dependence of $z(\eta)$ on η, and of $V_H(p|\eta)$, $V_L(p|\eta)$, $s(p|\eta)$ and $P_U(p|\eta)$ on

p and η. The expected gains of an *informed bidder* are

$$\Pi^I = z(1-s)(V_H - P_U). \tag{12}$$

In words, an informed bidder always bids the value of the firm when facing another informed bidder (earning 0 with probability 1/2), a bit above the pooling price when facing an uninformed bidder and the firm is of high quality (buying the good firm at P_U), and less than the pooling price when facing an uninformed bidder and the firm is of low quality (not buying the bad firm). The expected gains of an *uninformed bidder* are:

$$\Pi^U = z\left[\frac{1-s}{2}(V_H - P_U)\right] + (1-z)\left[\left(s + \frac{1-s}{2}\right)(V_L - P_U)\right]. \tag{13}$$

In words, an uniformed bidder always bids a pooling, unconditional, price, P_U. When facing another uninformed bidder, he buys with a probability 1/2, regardless of the firm's project quality. When facing an informed bidder, he never buys a q_H-firm in equilibrium and always buys a q_L-firm. Notice that both Π^I and Π^U are both measured at the firm evaluated at $\widehat{q}(\eta)$, as gains and losses are only materialized when firms are traded at an uninformed price P_U.

Information about the project of a firm p is acquired in stock markets as long as

$$\mathcal{V}_{stock} \equiv \Pi^I(p) - \Pi^U(p) \geq \gamma_q.$$

First, $\Pi^U = 0$. Competition across uninformed bidders make them bid so their gains are zero, otherwise there are incentives to marginally increase the bid P_U and discretely raise the probability of buying the average quality firm. In other words, P_U, for a given s, balances the gains of buying a good firm and the losses of buying a bad one. Hence, equation (11) in the proposition.

Hence, information will then be acquired as long as $\Pi^I \geq \gamma_q$. Plugging equation (11) in (13) we obtain (10) in the proposition. Notice that, if all bidders for a firm p acquire information (this is, $s = 1$) then $\omega = 0$ and $P_U = V_L$, which implies that $\Pi^I(s = 1) = 0 < \gamma_q$, a contradiction. At the other extreme, if no bidder acquires information (this is, $s = 0$) then $\omega = z$ and $P_U = zV_H + (1-z)V_L$, which implies that $\Pi^I(s = 0) = z(1-z)(V_H - V_L) \equiv \overline{\gamma}_q$. This is an equilibrium as long as $\overline{\gamma}_q < \gamma_q$. Q.E.D.

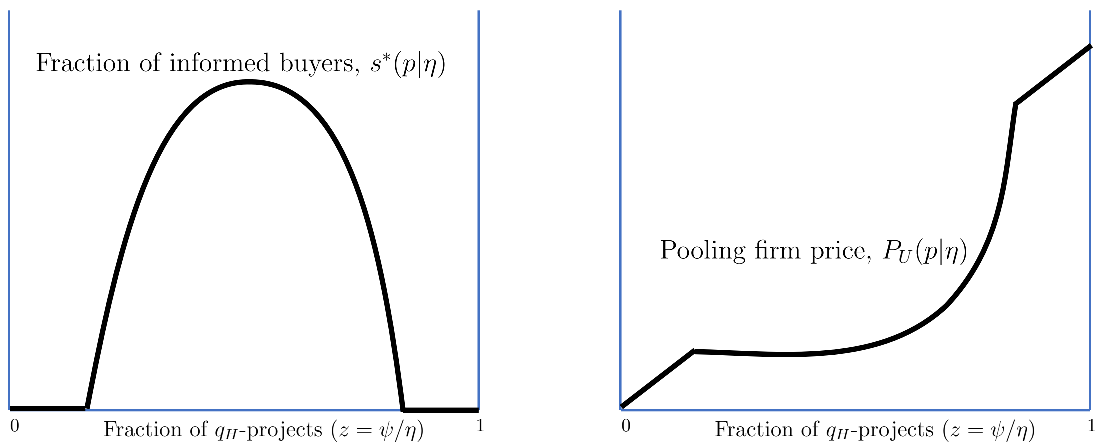
Intuitively, the pooling price is determined by the fraction of q_H-firms that are available for the uninformed to buy given the fraction of q_H-firms in the economy (this is, z) and the fraction of agents that are informed (this is s). When no bidder is informed (i.e., when $s = 0$), $P_U = zV_H + (1 - z)V_L$, the ex-ante value of the firm. When all bidders are informed (i.e., when $s = 1$), then $P_U = V_L$, as the only firms left for the uninformed to buy is a q_L-firm. The fraction of informed investors is pinned down by the benefits of information, which increases with the expected fraction of q_H-firms that can be identified and purchased (this is ω) and the fraction of q_L-firms that can be identified and avoid buying (this is $1 - \omega$). Not all investors can be informed (as there are no profits from competing with other informed agent), but all investors can be uninformed (when the cost of information is relative large).

The first panel of Figure 7 shows how the fraction of informed investors ($s^*(p|\eta)$) depends on the fraction of active firms with q_H-projects (this is $z = \psi/\eta$, on the x-axis). This has an inverted-U shape. When all firms have q_H-projects, bidders do not acquire information. As there are more and more active firms (during a credit boom, for instance) eventually more of the projects will be q_L firms and will attract information in stock markets. The incentives to acquire information are maximized when there is relatively large uncertainty about the composition of projects in the market.

The second panel shows the pooling price, $P_U(p|\eta)$, also as a function of the fraction of active firms with q_H-projects. Not surprisingly, as the composition of projects in the market worsens, $P_U(p)$ declines. As more informed bidders participate in the market they force a faster decline in the pooling price because those bidders "cream skim" the market. Note that the two kinks in the second panel correspond to the points at which no bidder becomes informed, because either almost all the projects are q_H (at the right end) or q_L (at the left end) so it does not pay to produce information.

Notice that the solution s^* determines *the information content of the stock market*. The distribution of observed prices in the economy determines beliefs about q. A fraction zs^{*2} of firms with land p trades at price V_H, which reveals that the firm has a q_H-project, a fraction $(1 - z)s^{*2}$ trade at price V_L, which reveals that the firm has a q_L-project, and a fraction $1 - y^{*2}$ trades at the pooling price P_U, which is uninformative about q. As can be seen, the higher is the fraction of informed bidders, the more information about q is revealed in stock markets, which affects the fraction of firms that are able to raise funds

Figure 7: Fraction of Informed Bidders and Pooling Price



with information-insensitive loans in credit markets.

In this endogenous information acquisition setting, the exogenous y assumed in the previous section would be replaced by s^{*2}, and then $\frac{\partial y}{\partial z} > 0$ in the initial phases of the credit boom, when the first panel of Figure 7 is in the increasing section. If it were in the decreasing section, then $\frac{\partial y}{\partial z} < 0$ and stock markets would not play a macroprudential role.

It is useful to highlight that, in case of endogenizing projects' information, there is a two-way feedback between credit and stock markets in each period. *Stock markets affects credit markets:* the availability of credit for a firm with collateral of quality p in a given period depends on the information about q that is revealed when the firm is traded, as is clear from equation (2) and Figure 2. *Credit markets also affect stock markets:* the trading price of a firm with project of quality q in a given period depends on the expected availability of credit for (and the information about) its collateral of quality p, included in the valuations of the firm $V_H(p)$ and $V_L(p)$ in equations (10) and (11), and Figure 7.

Remark on Information about Collateral in Stock Markets: Stock markets can also convey information about collateral, which can be used later in credit markets. Bidders' incentives to acquire information about collateral follow a similar logic than equation (10), but with a information cost γ_C, replacing $(V_H - V_L)$ by $(V_{p=1} - V_{p=0})$ and z by p in expression (9). Information about collateral in stock markets operates by reducing the extent of information-insensitive loans in credit markets, then endogenously affecting the net process λ of depreciation of collateral information. While this extension is interesting, it is beyond the scope of the paper.

4.2 Project Information Production in Credit Markets

Information about the quality of projects can also be potentially generated in credit markets. Philippon (2009), for instance, seems to suggest that bond markets convey information about cash flows in the economy. Here we show the conditions under which projects get investigated by lenders during a credit boom before a crisis happens. In this case credit markets both plant the seeds of a crisis but also provide an automatic macroprudential force.

Assume lenders not only can learn privately about collateral, at a cost γ_C, but also about the quality of the project at a cost γ_q in terms of numeraire. Since lenders are risk neutral and the truth-telling constraint implies expected payments are the same in both cases of repayment or default (this is $R = xE(C)$), they would not investigate the project's quality q just to learn about the default probability. Still, lenders are interested in knowing about projects' qualities to better target their decisions to acquire information about collateral. The next proposition shows how a credit boom affects information about projects in credit markets.

Proposition 6. *For a given credit boom magnitude (mass of active firms η), let $p_q^*(\eta)$ be the collateral belief below which the related project is investigated. The boom continues as*

$$p_q^*(\eta) \equiv 1 - \frac{\gamma_C + \frac{\gamma_q}{1-z(\eta)}}{(1-q_L)K^*} < \widehat{p} \tag{14}$$

and a crisis is prevented when $p^* < \widehat{p} < p_q^*$.

Proof During a credit boom lenders do not acquire information about unknown collateral given a project of expected quality $\widehat{q}$. Given Assumption 1, however, they would if knowing the project is of bad quality, q_L. This is

$$\widehat{p}\left[q_L K^* + (1-q_L)\frac{K^*}{\widehat{p}} - K^*\right] > \gamma_C > \widehat{p}\left[\widehat{q}K^* + (1-\widehat{q})\frac{K^*}{\widehat{p}} - K^*\right]$$

Since lenders change behavior upon learning the realized project's quality, such information is useful, and they would investigate projects' quality as long as

$$(1-z)\left[\widehat{p}\left(q_L K^* + (1-q_L)\frac{K^*}{\widehat{p}} - K^*\right) - \gamma_C\right] > \gamma_q$$

In words, lenders' expected gains from investigating the project comes from the expected benefit from investigating the collateral of a q_L-project times the probability of finding such a project. They investigate the project when those expected benefits are larger than the cost of information production. Rewriting this condition, we obtain equation (14). Q.E.D.

This proposition shows that lenders are induced to learn about the project's quality in order to privately investigate collateral that they are more likely to get if the project is very likely to default. As the credit boom increases the fraction of q_L-projects (an increase in $1-z$), makes this calculation more relevant, and the cutoff p^*_q increases. At some point during the boom, when its magnitude become η^* $p^*_q(\eta^*) = \widehat{p}$ there is sudden information acquisition about projects ($y(z)$ suddenly increases from 0 to 1). This sudden burst of projects' information prevents a crisis when $p^* < \widehat{p} < p^*_q(\eta^*)$.

5 Normative Insights

Our setting offers a clear characterization of the unconstrained first best: since we have assumed that all firms have a positive net present value project and their financing is feasible, the first best specifies that all firms operate in all periods, which would be achieved in the absence of financial frictions. Then, what makes our economy depart from the first best is the reliance on collateral of heterogeneous quality and the possibility of private information acquisition about projects and about collateral. While projects' information does not affect allocations directly, it does so by affecting collateral information and credit.

The first best is implemented in equilibrium in the situation we denoted as "good booms" in Proposition 1 (depicted in the second panel of Figure 3). In all other steady states the equilibrium implements lower welfare than in the first best, either because it displays recurrent crises (as in the case of bad booms) or because it displays less production than optimal (as in the case with full transparency about projects). What can a government do in those situations to bring the economy closer to the first best allocation? If the government could intervene in both dimensions, it would like to discourage information about collateral as much as possible, so to induce a credit boom without a crisis, and also to so discourage information about projects, which would impede the boom to benefit all firms. Hence, introducing opacity on both collateral and projects would allow for implementation of the first best allocation. The next proposition formalizes how large these taxes on information should be to implement the first best.

Proposition 7. *A policymaker can implement the first best allocation with a set of policies that i) induce a "shadow tax" to the cost of information about collateral such that* $1+\tau_C \geq \frac{(1-\widehat{p})(1-\widehat{q}_t(1))K^*}{\gamma_C}$ *(in credit markets) so to avoid a crisis when all firms obtain credit and ii) a "shadow tax" to the cost of information about projects such that* $1+\tau_q \geq \frac{\psi(1-\psi)}{\gamma_q}(q_H-q_L)AK^*$ *(if information is acquired in stock markets) or* $1+\tau_q \geq \frac{1-\psi}{\gamma_q}[(1-\widehat{p})(1-q_L)K^*-\gamma_C)]$ *(if information is acquired in stock markets) so to maximize the credit boom.*

Proof The government would like to implement a state in which all firms operate ($\eta^*=1$) but without crises. This can be done with policies that affect both information about collateral and projects: i) A shadow tax on the cost of information about collateral that avoids a crisis when all firms obtain credit, $p^*(\widehat{q}_t(\eta^*=1)) < \widehat{p}$, or using equation (2), $1-\frac{\gamma_C(1+\tau_C)}{(1-\widehat{q}_t(1))K^*} < \widehat{p}$. ii) A shadow tax on the cost of information about projects that maximizes the credit boom, this is $\eta^*=1$. Information in stock markets is avoided, from equation (10) when $\psi(1-\psi)(V_H-V_L) < \gamma_q(1+\tau_q)$, where $\widehat{q}(1)=\psi q_H+(1-\psi)q_L$ and evaluated at the situation in which all firms get credit, $V_H-V_L=(q_H-q_L)AK^*$. Information production in credit markets is avoided, from equation (14) when $(1-\widehat{p}) \leq \frac{\gamma_C+\frac{\gamma_q(1+\tau_q)}{1-\psi}}{(1-q_L)K^*}$. Q.E.D.

Notice that the desirability of discouraging information about projects arises from maximizing the credit boom, but this is conditional on avoiding a crisis when the boom is large by also discouraging information about collateral. If direct interventions in credit markets to avoid crises were not feasible, however, it is not optimal anymore to avoid information production about projects, and there is an optimal level of project transparency, which is formalized in the next proposition.

Proposition 8. *If the government cannot intervene in credit markets and there is a crisis at a credit boom* $\eta^*<1$*, the optimal amount of information about projects is given by,*

$$y=\left[\frac{(1-\lambda)(1-\eta^*)\eta^*}{(1-\psi)(\eta^*-\widehat{p})}\right]^{0.5},$$

which can be implemented with a "shadow tax/subsidy" such that equation (10) holds in stock markets and/or equation (14). *holds in credit markets.*

Proof If there is a mass of active firms $\eta^* < 1$ that triggers a crisis, it implies that the fraction of transparent projects with collateral $\widehat{p}$ is low enough to prevent it (as in the second panel of Figure 5. The maximum amount of information production that induces stability is then η^*. This credit volume is maintained in steady state when equation (7) in Lemma 1 holds when evaluated at η^* (which implies evaluating v_t as $(1-\frac{\psi}{\eta^*})y^*$, from equation (6). The equation in the proposition follows. The fraction y^* represents the minimum fraction of transparent projects that prevent a crisis. In stock markets, it can be implemented by reducing the cost of information to γ_q in equation (10) evaluated at the target y^* for $z=\frac{\psi}{\eta^*}$ and $V_H - V_L = (q_H - q_L)AK^*$. In credit markets, it can be implemented by reducing the cost of information production to γ_q in equation (14) evaluated at, also evaluated at the target y^* for $z=\frac{\psi}{\eta^*}$. Q.E.D.

Intuitively, there is a crisis once the credit boom reaches a mass η^* of active firms and there is not enough transparent projects to prevent it (as in the second panel of Figure 5). The proposition shows the minimum amount of information about projects that prevent a crisis exactly at that point. The government would not like to have more information than the volume characterized in the Proposition because it would just depress credit and production without further gains in terms of stability (as in the first panel of Figure 5). In other words, if the government cannot directly discourage information production about collateral in credit markets it may want to encourage information about projects in stock and/or credit markets to indirectly discourage information about collateral, and avoid a crisis. Still discouraging information directly in credit market is superior as it can avoid a crisis while at the same time increasing the feasible magnitude of the credit boom.

Remark on the Allocative Role of Stock Markets: Throughout the paper, and particularly in this section, we have assumed that all projects have positive NPV, and then the information production about the quality of projects does not have welfare implications in terms of resource allocation across projects. We have made this stark assumption to highlight the novel macroprudential benefit of project transparency. Allowing for a more standard allocative role would change the welfare implications in two important respects. First, if the planner could intervene in both markets, and directly prevent crises by discouraging information production about collateral in credit markets (as in Proposition

7) the presence of negative NPV projects would create a trade-off of information about projects. While still such information would restrict credit to flow into efficient projects, it would also prevent credit to flow into inefficient projects. Second, a planner who cannot intervene in credit markets to prevent crises (as in Proposition 8) would encourage project transparency even further, both for *macroprudential* and *allocative* reasons.

6 Conclusion

The dynamics of information production and the interaction of agents' information production decisions plays an important role in determining the evolving state of the macro economy. In this paper, we explored the interaction of information production in credit markets about collateral, which leads to credit booms and busts, and another market producing information about firms' individual productivities, like the stock market, but also possibly credit markets themselves.

Agents in both markets decide whether to acquire costly information about their respective firm characteristic, its projects and its collateral. While we conjecture stock markets scrutinize firms' projects more intensively and credit markets firms' collateral, we have allowed in the paper that these markets can produce information about both dimensions. The important property is that, as credit booms evolve and average projects' quality decline, not only are there more incentives to acquire information about collateral but also about firms' individual productivities. Once weaker firms are discovered and then possibly deprived of loans in credit markets, there is a relaxation of the incentives to acquire information about the collateral of remaining firms, potentially preventing a crisis.

By playing this macroprudential role in the economy, stock markets become an automatic stabilizer of credit markets, and/or credit markets have an automatic inhibitor of collapses. This cleansing effect of stock markets' information on credit markets' composition can prevent crises but comes at a cost. On the one hand, when stock markets do not convey too much information, we may observe more crises. On the other hand, when stock markets convey too much information, credit markets may not function at full capacity. We discussed normative implications that highlight the potential of designing policies to affect the information content and dynamics, both in credit and stock markets.

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