# Collateral Booms and Information Depletion

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# Collateral Booms and Information Depletion

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**Abstract**

We develop a new theory of information production during credit booms. Entrepreneurs need credit to undertake investment projects, some of which enable them to divert resources. Lenders can protect themselves from such diversion in two ways: collateralization and costly screening, which generates durable information about projects. In equilibrium, the collateralization-screening mix depends on the value of aggregate collateral. High collateral values make it possible to reallocate resources towards productive projects, but they also crowd out screening. This has important dynamic implications. During credit booms driven by high collateral values (e.g., real estate booms), economic activity expands but the economy's stock of information on existing projects gets depleted. As a result, collateral-driven booms end in deep crises and slow recoveries: when booms end, investment is constrained both by the lack of collateral and by the lack of information on existing projects, which takes time to rebuild. We provide empirical support for the mechanism using US firm-level data.

JEL: E32, E44, G01, D80.

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# 1 Introduction

Credit booms, defined as periods of rapid credit growth, are common phenomena in both advanced and emerging economies.[1] They are generally accompanied by a strong macroeconomic performance, including high asset prices, and high rates of investment and GDP growth.[2] Yet, the conventional wisdom is to view them with suspicion. First, credit booms are often perceived to fuel resource misallocation: high asset prices and a positive economic outlook may lead to the relaxation of lending standards and, consequently, to the funding of relatively inefficient activities.[3] As the old banker maxim goes, "bad loans are made in good times". Second, credit booms often end in crises that are followed by protracted periods of low growth.[4]

This conventional wisdom raises important questions. What determines the allocation of resources during credit booms? How does this allocation shape the macroeconomic effects of credit booms, and of their demise? And finally, are all credit booms alike? In this paper, we develop a new theory of information production during credit booms to address these questions and provide supporting new evidence of the theory's key prediction.

We study a stylized economy that is composed of a modern and a traditional sector. These sectors are meant to represent, in a simple way, productive and unproductive activities. Modern-sector output is produced through long-lived projects, which combine capital and labor and use a more productive technology than the traditional sector. Projects are operated by entrepreneurs, who have the necessary know-how but not the resources needed to acquire capital. Lenders, in turn, have the necessary resources but lack the know-how to operate modern-sector projects. Absent any friction, this would not be a problem, as lenders could simply provide enough credit for entrepreneurs to employ the economy's capital stock in the productive modern sector. We introduce a friction, however, by supposing that some projects enable entrepreneurs to divert their output for private consumption.

Lenders need to protect themselves against such diversion by entrepreneurs, and they have two ways of doing so. The first is through costly *screening*. Lenders may require experts to evaluate or screen the projects undertaken by entrepreneurs and make sure they do not permit resource diversion. The second is through *collateralization*. Entrepreneurs are endowed

[1]See Mendoza and Terrones (2008) and Bakker, Dell'Ariccia, Laeven, Vandenbussche, Igan and Tong (2012) for a brief discussion on the formal definition and empirical identification of credit booms. Claessens, Kose and Terrones (2011) use a different approach and study "credit cycles", but they also find them to be common among advanced economies.

[2]Mendoza and Terrones (2008) study empirically the macroeconomic conditions during credit booms.

[3]See, for example, García-Santana, Moral-Benito, Pijoan-Mas and Ramos (2016) and Gopinath, Kalemli-Özcan, Karabarbounis and Villegas-Sanchez (2017).

[4]See Schularick and Taylor (2012) and Krishnamurthy and Muir (2017).

with assets (e.g., real estate), and lenders may be willing to finance unscreened projects if entrepreneurs post these assets as collateral, effectively retaining some "skin in the game". We make three assumptions regarding screening. First, it requires the time and effort of experts, so that it is costly. Second, expertise is scarce, in the sense that experts are heterogeneous in their skills and their time is limited. This naturally implies that the cost of screening an individual project in any given period is increasing in the economy's aggregate amount of screening: as aggregate screening increases, it requires the use of less and less skilled experts thereby raising its cost.[5] Third, the information generated through screening is long-lived, and it accompanies the project throughout its life. At any point in time, therefore, the economy contains two types of projects being operated in the modern sector: unscreened projects, which obtain credit by pledging collateral, and screened projects, which can obtain credit even without pledging collateral. We think of the stock of screened projects as embedding the economy's stock of information at a given point in time.

A key insight of the model is that, in equilibrium, screened and unscreened projects are effectively substitutes because they provide alternative ways of organizing production in the modern sector. An expansion in the stock of unscreened projects, for instance, enables entrepreneurs to reallocate capital from the traditional to the modern sector. This raises aggregate output, but also labor demand and wages: all else equal, the result is a decline in the return to capital in the modern sector, which crowds-out screened projects. This general-equilibrium mechanism lies at the heart of our theory, and it has powerful implications for the dynamic effects of collateral booms, i.e., booms that are driven by high asset prices.

When the economy enters a collateral boom, the rise in the price of real estate enables entrepreneurs to expand the stock of unscreened projects. Output increases as capital is reallocated towards the modern sector, but – for the reasons outlined above – this crowds out screened projects. Thus, a collateral boom not only reallocates capital across sectors, from the traditional to the modern sector, but also within the modern sector, from screened to unscreened projects. Consequently, the economic expansion leads to a "depletion" of information, in the sense that it takes place against the backdrop of a falling stock of screened projects. When the boom ends and the price of real estate falls, there is an economic contraction for two reasons: (i) all else equal, the scarcity of collateral means that the economy requires information on entrepreneurs' projects in order to maintain production in the modern sector, and; (ii) since information has been depleted during the boom, it must be generated

[5] More broadly, this assumption captures the intuitive notion that the production of information is limited by factor scarcity. Screening borrowers, for instance, may require trained loan officers or experts, and information gathering and processing infrastructure, which are difficult to change in the short run. In the banking literature, it is common to assume that the screening cost function is increasing and convex due to capacity constraints (see, for instance, Ruckes (2004)).

anew through costly screening. Hence, the end of a collateral boom is accompanied by a large crash and a slow recovery, i.e., a transitory undershooting of output relative to its new long-run level.

We think of collateral booms as originating in high asset prices as opposed to high productivity. In this regard, the implications of the theory are highly relevant in a world of high and volatile asset values. Over the last three decades, for instance, Japan, the United States, and parts of the Eurozone (e.g., Spain, Ireland) have all exhibited large booms and busts in asset prices, which have had significant implications for economic activity despite having been often unrelated to productivity. Much has been written already on the possible origins of these asset price fluctuations, and we take them as given throughout most of the paper. Although we discuss different ways of interpreting collateral booms formally, including commodity booms and asset bubbles, our main focus is on their transmission and amplification through information depletion.

The theory sheds light on three key debates regarding credit booms and their macroeconomic effects. First, it shows that not all credit booms are alike. Richter, Schularick and Wachtel (2017) and Gorton and Ordoñez (2016) have recently referred to "good" and "bad" booms, depending on whether they end in crises or not. Through the lens of our model, the defining feature of booms lies in the underlying process that drives them. In particular, unlike collateral booms, we show that productivity booms do not generate information depletion: by raising the return to all modern-sector projects, an increase in productivity actually raises equilibrium screening and thus the economy's stock of information. Consequently, the end of productivity booms does not exhibit a deep crisis with an undershooting of economic activity. Second, the model speaks to the recent literature on asset price bubbles (e.g., Martin and Ventura (2018)). In essence, one can interpret collateral-driven booms as the result of bubbles, which raise asset prices and thus collateral but do not affect economic fundamentals. Under this interpretation, the model highlights a hitherto unexplored cost of bubbles that surfaces when they burst: while they last, bubbles deplete information. Third, the model also shows why credit booms can lead to resource or factor misallocation: by reducing information on entrepreneurial activity, collateral booms may raise the equilibrium dispersion of productivity across projects. However, the model also highlights that there is a positive counterpart to this increase in dispersion, as the economy saves on information costs.

Finally, we study the normative properties of our economy. Intuitively, it may seem that market participants produce too little information during booms. After all, if the economy's stock of information was somehow maintained during booms, the busts would be less severe and the recoveries faster. We show, however, that this intuition is incorrect. Since agents are rational, they correctly anticipate the value of information in future states of nature. Thus, even in the midst of a collateral boom, agents understand that – when the bust comes – screened projects will be very valuable and they will be able to appropriate this value. If anything, we find that information production is inefficiently high, because entrepreneurs fail to internalize the equilibrium crowding-out effect that screening has on unscreened projects. Our model in fact suggests that information production can be inefficiently low only if there are additional distortions that prevent agents from appropriating the social return to information, such as external economies in the screening technology and frictions in the market for projects.

Our theory is consistent with various strands of stylized evidence. First, there is ample evidence showing that investment is positively correlated with collateral values (Peek and Rosengren, 2000; Gan, 2007; Chaney, Sraer and Thesmar, 2012). Second, there is also evidence that lending standards, and in particular lenders' information on borrowers, deteriorates during booms (Asea and Blomberg, 1998; Keys, Mukherjee, Seru and Vig, 2010; Becker, Bos and Roszbach, 2018; Lisowsky, Minnis and Sutherland, 2017). Third, and focusing more specifically on collateral booms, Doerr (2018) finds that the US housing boom of the 2000s led to a reallocation of capital and labor to less productive firms. Fourth, there is evidence that credit booms that are accompanied by house price booms (Richter et al., 2017) and that are characterized by low productivity growth (Gorton and Ordoñez, 2016) are more likely to end in crises. All of these findings are consistent with the theory's main predictions.

But there is one prediction that is specific to our theory: an increase in collateral values leads to information depletion, i.e., to a decline in the economy's reliance on screening. We test this prediction on US firm-level data from COMPUSTAT. This is nontrivial for at least two reasons. First, assessing this in the data requires identifying changes in collateral values that are orthogonal to other economic conditions, such as productivity, which may affect screening intensity on their own. We deal with this by following Chaney et al. (2012) and estimating the impact of real estate prices on screening intensity using instrumental variables. Second, there is no universally accepted measure of screening intensity or, analogously, of the availability of information on existing projects. We rely throughout on one measure that has been widely used in the literature: the duration of the firm's main lending relationship in the syndicated loan market. Our empirical results are consistent with the key prediction of the model. The information generated on a firm, as measured through the duration of its main lending relationship, is decreasing in the value of its real estate.

We are not the first to consider the conceptual link between information production and economic booms and busts (Van Nieuwerburgh and Veldkamp, 2006; Ordoñez, 2013; Gorton and Ordoñez, 2014; Ambrocio, 2020; Gorton and Ordoñez, 2016; Fajgelbaum, Schaal and Taschereau-Dumouchel, 2017; Straub and Ulbricht, 2017; Farboodi and Kondor, 2019). Within this work, the closest to us are the papers by Gorton and Ordoñez. Like them, we focus on the interaction between information generation in the credit market and credit booms. Also like them, we predict that booms are characterized by a deterioration of information. There is a key difference between our framework and theirs, however. In their framework, information refers to the quality of entrepreneurs' collateral. Because of this, information production is detrimental for investment in their framework, and – in fact – it is information production that triggers a crisis: once lenders can distinguish between "good" and "bad" collateral, there is a fall in lending and investment. In our framework, instead, information refers to the quality of entrepreneurs' investment. Because of this, information production helps sustain investment. Differently from Gorton and Ordoñez, it is the crisis that triggers information production, as the lack of collateral makes it worthwhile for market participants to ramp up screening.

Our paper also speaks to the growing literature on the cost of credit booms and busts. On the one hand, we have already mentioned the evidence suggesting that credit booms raise misallocation (García-Santana et al., 2016; Gopinath et al., 2017; Doerr, 2018). Our model provides a possible cause of such misallocation: information depletion. Relatedly, our model contributes to the literature on rational bubbles (see Martin and Ventura (2018) for a recent survey) by identifying a hitherto unexplored cost of asset bubbles. By providing collateral, bubbles reduce incentives to generate information, making their collapse especially costly.

Conceptually, our theory is related to previous work that studies the optimal choice of technology in the presence of financial frictions. In our model, the equilibrium mix of screened and unscreened investment depends on the availability of collateral. This is reminiscent of Matsuyama (2007), where the lack of borrower net worth may induce a shift towards less productive but more pledgeable technologies. More recently, Diamond, Hu and Rajan (2020) also develop a model in which the equilibrium choice of technology depends on financial conditions: in particular, high expected asset prices in an industry prompt firms to adopt less pledgeable technologies, because they can obtain credit simply by collateralizing assets. This exacerbates the severity of downturns caused by a decline in asset prices, however, because firms' inability to pledge their cash flow prevents them from obtaining credit and leads to their liquidation.

Finally, our paper is also related to the literature studying the determinants of lending standards and their evolution over the business cycle (Manove, Padilla and Pagano, 2001; Ruckes, 2004; Martin, 2005; Dell'Ariccia and Marquez, 2006; Favara, 2012; Petriconi, 2015). Of these, we are closest to the influential paper by Manove et al. (2001). They study a contracting problem between banks and their borrowers in partial equilibrium, and find that collateral and screening may substitute for one another in the optimal contract. Although our work is clearly related to theirs, it also differs along key dimensions. First, we are interested in the general equilibrium effects of collateral on information production, whereas their analysis is

– as we mentioned – partial equilibrium. More precisely, our focus is on the interaction between aggregate scarcity of collateral and information production, while they focus on lenders' willingness to use collateral (which is always abundant) as part of the optimal contract.[6] Second, the role of collateral is different in both frameworks: while in their model collateral is partly used to separate between different types of borrowers, in our model it plays the more traditional role of protecting lenders against rent extraction by the borrower. In fact, by enabling lenders to "weed-out" bad borrowers, an increase in collateral may lead to a decline in aggregate investment in their framework (see, for instance, Martin (2008)). Finally, the normative implications of both models are different too. Whereas equilibrium screening in their framework may be inefficiently low, information production is inefficiently high in ours.

The paper is organized as follows. In Section 2, we present the model. In Sections 3 and 4, we characterize the equilibrium and derive our main results. In Section 5, we consider several extensions, and we provide supporting evidence in Section 6. We conclude in Section 7.

# 2 The Model

## 2.1 Description of the environment

We consider an economy populated by overlapping generations of individuals that live for two periods. Time is discrete and infinite, $t = 0, 1....$ As we explain shortly, this economy potentially experiences technology and collateral shocks. We define $h_t$ as the realization of these shocks in period $t$, and $h^t$ as the history of shocks until period $t$; that is, $h^t = \{h_0, h_1, ..., h_t\}$.

The objective of individual $i$ of generation $t$ is to maximize her utility:

$$U_{it} = E_t\{C_{it+1}\},$$

where $C_{it+1}$ is her old age consumption and $E_t\{\cdot\}$ is the expectations operator at time $t$. Each generation consists of two sets of individuals, entrepreneurs and households, each of mass one. We respectively use $I_t^e$ and $I_t^h$ to denote the set of entrepreneurs and households in generation $t$. Households work and provide expert services during youth, and they save their income to finance old-age consumption; they can also, as we will explain shortly, invest in a "traditional" low-productivity sector. Entrepreneurs borrow during youth to invest in a "modern" sector,

[6] Ruckes (2004), Gorton and He (2008) and Petriconi (2015) also study the evolution of screening over the cycle, but they stress the effect of bank competition on the equilibrium choice of screening. Instead, Martin (2005) and Favara (2012) study how the interplay between entrepreneurial net worth and lender incentives can give rise to endogenous lending cycles.

and they produce during old age. There is a risk-neutral international financial market willing to lend to and borrow from domestic agents at a (gross) expected return of $R$. Thus, we think of our economy as being small and open, and we refer to $R$ as the interest rate.

***Technology***. The economy is endowed with a fixed stock of capital, $\bar{K}$. Capital is traded in a competitive market at the end of each period, and it can be employed in the modern or the traditional sector. We think of the modern sector as being more productive, and the allocation of capital between sectors as being a key driver of the economy's overall productivity and output. Production in the modern sector is organized in projects or establishments, which are run by entrepreneurs. A project $j$ that employs $K_{jt}$ units of capital and $L_{jt}$ units of labor produces:

$$Y_{jt} = A_t \cdot K_{jt}^{\alpha} \cdot L_{jt}^{1-\alpha}, \tag{1}$$

units of output. We assume that each project is subject to a size constraint by which $K_{jt} \leq \kappa$, which is a simple way to capture diminishing returns at the project level. Alternatively, capital can also be employed in the traditional sector, which is run by households and produces:

$$Y_t^T = a \cdot K_t^T, \tag{2}$$

units of output, where $K_t^T$ denotes total capital employed in this sector. We impose the following parametric assumption throughout:

$$E_t A_{t+1} \cdot \alpha \cdot \bar{K}^{\alpha-1} < a, \tag{3}$$

in all periods $t$ and histories $h^t$. This condition guarantees that the traditional sector is always active in equilibrium.

***Endowments***. Households are endowed with one unit of labor during youth, which they supply inelastically in a competitive labor market. They are also endowed with expertise, which enables them to assess or "screen" the quality of modern-sector projects. Given their preferences, households save their entire income but they decide whether to do so through the international financial market at rate $R$, by lending to domestic entrepreneurs, or by purchasing capital to operate in the traditional sector.

Entrepreneurs operate the modern-sector projects, as we have said. During youth, entrepreneurs decide how many projects to operate: they can either start new projects at zero cost or purchase pre-existing ones from old entrepreneurs. All projects, regardless of their age, become obsolete with probability $\rho$ after production. Young entrepreneurs also purchase capital to run their projects. During old age, entrepreneurs hire labor for their projects in a competitive market. After production, they sell their capital and projects, and consume.

Each entrepreneur is also endowed with a "tree", whose period-$t$ market value is denoted by $q_t$. Trees play a crucial role in our environment: they can be fully pledged in the credit market and constitute the net worth or the collateral of entrepreneurs. In the main analysis, we take $q_t$ to be exogenous, but we endogenize it in Section 5.1. We think of these trees as assets distinct from projects or capital (e.g., real estate or land) so that their value affects entrepreneurs' net worth but is orthogonal to their investment opportunities. This distinction is of course stark, but it is helpful to clearly isolate the effects of fluctuations in collateral $q_t$ from those in productivity $A_t$.

***Information***. We now introduce a key aspect of the model: modern-sector projects differ in quality. When a new project is established, there is a probability $\mu$ that it is of good quality, which we denote with $G$; with probability $1-\mu$, the project is instead of bad quality, which we denote with $B$. The quality of each project established by an entrepreneur is independent of the rest and, once produced, persists throughout the project's lifetime. We assume that $G$- and $B$-quality projects are equally productive.[7] $B$-quality projects, however, suffer from an "agency" problem that enables the entrepreneur to abscond with their operating income. This assumption captures the intuitive notion that, although more productive, the modern technology is also more complex and thus potentially harder to verify by outside creditors, i.e., entrepreneurs can "hide" part of the income generated by these projects.

Crucially, entrepreneurs have the option of screening new projects before committing capital to them. Doing so requires the services of households, however, who have the expertise to screen. Each household $i \in I_t^h$ has the ability to screen up to $n > 0$ projects at a unit cost of $\psi_i$. We assume that this cost is heterogeneous across households, and it is distributed in the population according to cdf $\Gamma(\psi_i)$, which is continuous and has full support on $[0, \infty)$. Thus, the "best" experts in the economy can costlessly screen projects, while the "worst" face a prohibitive cost of doing so. If an expert screens a project, she produces a signal about its quality. For simplicity, we assume throughout that this signal is perfect. Moreover, any signal generated through screening is public information throughout the project's lifetime, although the history or past performance of the project is not.[8]

Thus, in the modern sector, there are potentially three "types" of projects being operated in any period $t$: projects that have been screened and are known to be of $G$-quality; projects that have been screened and are known to be of $B$-quality, and; projects that have not been screened, which we denote by $U$. We use $\varphi_{it}^m$ to denote the mass of type-$m \in \{G, B, U\}$ projects operated by entrepreneur $i \in I_{t-1}^e$, and $\varphi_t^m = \int_{i \in I_{t-1}^e} \varphi_{it}^m$ to denote the mass of all such

[7] We incorporate productivity heterogeneity in Section 5.2, where we study how credit booms affect measured factor misallocation.

[8] Thus, our results do not rely on information asymmetries, though we discuss their effects in Section 3.3.

projects. We use $K_{it}^m$ and $L_{it}^m$ to respectively denote capital and labor employed in type-$m$ projects by entrepreneur $i$, and $K_t^m = \int_{i \in I_{t-1}^e} K_{it}^m$ and $L_t^m = \int_{i \in I_{t-1}^e} L_{it}^m$ to denote the aggregate employment of capital and labor in such projects. Without loss of generality, and in order to economize on notation, we assume that projects of the same type employ the same amount of capital and labor.[9] Finally, the traditional sector employs all the capital owned by households, $K_t^T = \int_{i \in I_{t-1}^h} K_{it}$.

## 2.2 Markets

The timing in each period is as follows. At the beginning of the period, shocks $h_t = \{A_t, q_t\}$ are realized. Old entrepreneurs then hire labor for their modern-sector projects and young households supply it in the labor market. Production takes place. The old supply their non-obsolete projects and their capital inelastically to the young in the project and capital markets, respectively. Young entrepreneurs purchase existing projects and may also establish new ones, which they may screen by hiring screening services in the expertise market. To fund the purchase of projects and capital, as well as screening services, entrepreneurs borrow in the credit market. We describe each of these markets next.

***Project markets.*** Entrepreneurs buy and sell projects in a competitive market. We use $V_t^m$ to denote the market price of a project of type $m \in \{G, B, U\}$. Letting $\zeta_{it}^m$ denote the mass of new type-$m$ projects established by entrepreneur $i \in I_t^e$ and $\zeta_t^m = \int_{i \in I_t^e} \zeta_{it}^m$ to denote the aggregate mass of such projects, it follows that:

$$\varphi_{t+1}^m = \zeta_t^m + (1 - \rho) \cdot \varphi_t^m \text{ for } m \in \{G, B, U\}, \tag{4}$$

for all periods $t$ and histories $h^t$.

***Capital market.*** In each period, the old supply the entire capital stock $\bar{K}$ inelastically. Young entrepreneurs purchase capital to operate in modern-sector projects, while households purchase capital to operate in the traditional sector. We use $p_t$ to denote the market price of a unit of capital. Market clearing requires that the capital employed in the modern and the traditional sectors equal the total capital stock:

$$\sum_m K_{t+1}^m + K_{t+1}^T = \bar{K}, \tag{5}$$

for all periods $t$ and histories $h^t$.

[9] This allows us to drop project-specific subscript $j$ and only keep track of the total mass of type-$m$ projects run by entrepreneur $i$ and in the economy.

***Labor Market.*** Old entrepreneurs demand labor for their modern-sector projects in a competitive market at wage $w_t$, while young households supply their endowment of labor inelastically. Market clearing requires that:

$$\sum_m L_t^m = 1, \tag{6}$$

for all periods $t$ and histories $h^t$.

***Expertise market.*** Young entrepreneurs hire screening services, and young households supply them, in a competitive market for expertise at price $\psi_t$. Let $s_{it}$ denote the supply of screening services by household $i \in I_t^h$ and $s_t = \int_{i \in I_t^h} s_{it}$. Entrepreneur $i$ demands $\zeta_{it}^G + \zeta_{it}^B$ units of screening services, because screening is required to establish any project of known quality. Since there is a probability $\mu$ that a screened project turns out to be of $G$-quality, it must also hold that $\mu^{-1} \cdot \zeta_{it}^G = (1-\mu)^{-1} \cdot \zeta_{it}^B$ for $i \in I_t^e$. Market clearing thus requires that:

$$\zeta_t^G + \zeta_t^B = \frac{\zeta_t^G}{\mu} = \frac{\zeta_t^B}{1-\mu} = s_t, \tag{7}$$

for all periods $t$ and histories $h^t$.

***Credit market.*** Young individuals obtain financing in a competitive credit market, where they exchange credit contracts with domestic households or the international financial market at the interest rate $R$. We use $f_{it+1}$ to denote the (possibly state-contingent) promises of repayment issued by individual $i \in I_t^e \cup I_t^h$ against her modern- or traditional-sector income: thus, individual $i$ borrows $R^{-1} \cdot E_t f_{it+1}$ in the credit market against her income.

Entrepreneurs back their promises with their trees and the revenues from their projects. Whereas the value of trees $q_t$ can be fully pledged to outside creditors, the income generated from $B$-quality projects cannot.[10] This gives rise to the following set of financial constraints for entrepreneur $i \in I_t^e$:

$$\begin{aligned} f_{it+1} \leq & A_{t+1} \cdot \left(K_{it+1}^G\right)^\alpha \cdot \left(L_{it+1}^G\right)^{1-\alpha} - w_{t+1} \cdot L_{it+1}^G + \mu \cdot \left[A_{t+1} \cdot \left(K_{it+1}^U\right)^\alpha \cdot \left(L_{it+1}^U\right)^{1-\alpha} - w_{t+1} \cdot L_{it+1}^U\right] \\ & + \sum_m \left[p_{t+1} \cdot K_{it+1}^m + (1-\rho) \cdot V_{t+1}^m \cdot \varphi_{it+1}^m\right], \end{aligned} \tag{8}$$

for all $t+1$ and $h^{t+1}$.[11] This constraint reflects the fact that, in period $t+1$, the entrepreneur can (and will!) abscond with all the income generated by $B$-quality projects, i.e., she can only pledge the income generated by the projects that have been screened and are known to be

[10]Equivalently, entrepreneurs can sell a tree in the market for $q_t$ and use this amount to invest.

[11]Note that, since capital and labor that entrepreneur $i$ employs in all projects $j$ of type $m$ is the same, the total output that entrepreneur $i$ produces from type-$m$ projects is $A_{t+1} \cdot \left(K_{it+1}^m\right)^\alpha \cdot \left(L_{it+1}^m\right)^{1-\alpha}$.

$G$-quality, and by the share $\mu$ of the unscreened projects that are expected to be $G$-quality.

It is worth clarifying two issues regarding entrepreneurial borrowing. The first is that, when we refer to the value of trees $q_t$ as collateral, we do so in a broad sense. Specifically, we do not think of the real-world counterpart of our trees as being limited to *de jure* collateral, which is legally attached by firms to the repayment of specific loans. Rather, we think of them as *de facto* collateral, in the sense that they reflect the value of assets owned by firms that can be seized by creditors in the event of default. The second is that entrepreneurs in our model borrow both against the value of assets and against their future earnings, as indicated by Equation (8). Our model is thus consistent with the recent work of Lian and Ma (2018), which documents that US firms borrow both against assets and cash flows. Our model highlights, however, that lending against cash flows requires information about the firm's activities in a way that lending against assets may not. Thus, the value of firms' assets may affect the incentives to lend against – and thus to generate information on – cash flows.

Given an initial mass of projects $\{\varphi_0^m\}_m$ and allocation of capital $\{K_0^m\}_m$, a competitive equilibrium is a sequence of allocations $\left\{\{f_{it+1}\},\{\zeta_{it}^m\}_m,\{\varphi_{it+1}^m\}_m,\left\{K_{it+1}^m\right\}_m,\left\{L_{it+1}^m\right\}_m\right\}_{i\in I_t^e}$ and $\{\{f_{it+1}\},s_{it},K_{it+1}\}_{i\in I_t^h}$, and prices $\{\{V_t^m\}_m,p_t,\psi_t\}$ such that entrepreneurs and households optimize, and Equations (4)-(8) are satisfied for all periods $t$ and histories $h^t$.

## 2.3 Characterizing equilibria: preliminaries

We first characterize the equilibrium in the labor market, which is simple as it entails no inter-temporal choices. In any period $t$, profit maximization by old entrepreneurs implies:

$$L_t^m = \left[\frac{A_t\cdot(1-\alpha)}{w_t}\right]^{\frac{1}{\alpha}}\cdot K_t^m, \tag{9}$$

for $m\in\{G,B,U\}$. Equation (9) is the labor demand of projects of type-$m$, which results from hiring labor until its marginal product equals the wage. Together with market clearing in Equation (6), this implies that:

$$w_t = A_t\cdot(1-\alpha)\cdot\left(\sum_m K_t^m\right)^{\alpha}. \tag{10}$$

Thus, Equation (10) states that the wage equals the marginal product of labor in the modern sector evaluated at the aggregate capital-labor ratio in the modern sector.

Given the optimal demand for labor, if we use $r_t$ to denote the marginal product of capital in the modern sector, it follows that:

$$r_t = A_t \cdot \alpha \cdot \left( \sum_m K_t^m \right)^{\alpha - 1} . \tag{11}$$

Let us now consider the optimization problem of young households. Besides supplying their labor inelastically at wage $w_t$, young households decide whether or not to supply screening services at price $\psi_t$ and whether to save for old-age consumption by lending in the credit market or by purchasing capital. In short, household $i \in I_t^h$ chooses $\{\{f_{it+1}\}, s_{it}, K_{it+1}\}$ to maximize expected old-age consumption:

$$E_t \{(a + p_{t+1}) \cdot K_{it+1} - f_{it+1}\}, \tag{12}$$

subject to:

$$\begin{aligned} R^{-1} \cdot E_t f_{it+1} + w_t + \psi_t \cdot s_{it} &= p_t \cdot K_{it+1} + \psi_i \cdot s_{it}, \\ f_{it+1} &\leq (a + p_{t+1}) \cdot K_{it+1}, \\ s_{it} &\leq n. \end{aligned}$$

The household's old-age consumption is equal to her income, from production and sales of capital, minus promised repayments. Expected consumption is maximized subject to a set of constraints. The first one is the budget constraint, i.e., total spending on capital plus the costs of screening must equal the income the household earns in labor and expertize markets and its borrowing against traditional-sector output. The second constraint states that consumption must be non-negative. The third constraint reflects the upper bound on individual screening capacity, as each household can screen at most $n$ projects.

Household optimization gives rise to the following inverse supply of screening services:

$$\psi_t = \psi(s_t) \equiv \Gamma^{-1} \left( \frac{s_t}{n} \right), \tag{13}$$

since only households whose screening costs are below the price $\psi_t$ will choose to screen. Note that, since $\Gamma$ is a cdf, $\psi(0) = 0$ and $\psi'(\cdot) > 0$. Optimization also yields the following aggregate demand for capital by the traditional sector:

$$K_{t+1}^T \begin{cases} = 0 & \text{if } \frac{a + E_t p_{t+1}}{p_t} < R \\ \in [0, \infty) & \text{if } \frac{a + E_t p_{t+1}}{p_t} = R \\ = \infty & \text{if } \frac{a + E_t p_{t+1}}{p_t} > R \end{cases} . \tag{14}$$

That is, households save by investing in the traditional sector whenever the expected return it generates (weakly) exceeds the expected return on credit. Otherwise, households save all their income through the credit market.

We now turn to the problem of the entrepreneurs. A young entrepreneur $i \in I_t^e$ chooses $\left\{\{f_{it+1}\}, \{\zeta_{it}^m\}_m, \{\varphi_{it+1}^m\}_m, \left\{K_{it+1}^m\right\}_m\right\}$ to maximize expected old-age consumption:

$$E_t \left\{ \sum_m \left( (r_{t+1} + p_{t+1}) \cdot K_{it+1}^m + (1-\rho) \cdot V_{t+1}^m \cdot \varphi_{it+1}^m \right) - f_{it+1} \right\}, \tag{15}$$

subject to:

$$\begin{aligned}
q_{it} + R^{-1} \cdot E_t f_{it+1} &= \sum_m \left( p_t \cdot K_{it}^m + V_t^m \cdot \left( \varphi_{it+1}^m - \zeta_{it}^m \right) \right) + \psi_t \cdot \left( \zeta_{it}^G + \zeta_{it}^B \right), \\
f_{it+1} &\leq r_{t+1} \cdot \left( K_{it+1}^G + \mu \cdot K_{it+1}^U \right) + \sum_m \left( p_{t+1} \cdot K_{it+1}^m + (1-\rho) \cdot V_{t+1}^m \cdot \varphi_{it+1}^m \right), \\
\mu^{-1} \cdot \zeta_{it}^G &= (1-\mu)^{-1} \cdot \zeta_{it}^B, \\
K_{it+1}^m &\leq \kappa \cdot \varphi_{it+1}^m \text{ for } m \in \{G, B, U\}.
\end{aligned}$$

The entrepreneur's old-age consumption equals her income, from production and sales of capital and projects, minus promised repayments.[12] Expected consumption is maximized subject to a set of constraints. The first one is the budget constraint, i.e., total spending on capital, projects, and screening must equal the value of trees plus any additional borrowing against modern-sector projects. The second constraint is a restatement of the financial constraints in (8). The third constraint says that the establishment of $G$- and $B$-type projects are in proportion to one another. The fourth constraint reflects the upper bound on project size, as each project can employ at most $\kappa$ units of capital.

To streamline the solution to the entrepreneurs' problem, we conjecture that the equilibrium prices of projects are as follows:

$$V_t^G = \frac{\psi(s_t)}{\mu}; \quad V_t^U = V_t^B = 0. \tag{16}$$

for all $t$ and $h^t$. We will verify shortly that these prices are indeed part of equilibrium, i.e., at these prices entrepreneurs are indifferent between purchasing pre-existing projects or establishing new ones and the projects market clears.

Entrepreneurs' optimization gives rise to the following demand for capital and projects. First, no capital is allocated to $B$-type projects, i.e., $K_{t+1}^B = 0$ for all $t$ and $h^t$. The reason for this is simple. Suppose an entrepreneur purchases a unit of capital and assigns it to a

[12] Note that the expression in (15) already uses the entrepreneur's optimal demand for labor.

$B$-type project: she can always do better by assigning this unit to an unscreened project instead, where it is just as productive but is more pledgeable. Thus, $B$-type projects are never operated and we will not keep track of $\varphi_t^B$.

Second, the allocation of capital to $U$-type projects is never constrained by the stock of these projects because they can be created at zero cost. As a result, we will also not keep track of the evolution of $\varphi_t^U$ but only of $K_{t+1}^U$, which is given by:

$$K_{t+1}^U \begin{cases} = 0 & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} < R \\ \in \left[0, \frac{R}{p_t \cdot R - E_t\{\mu \cdot r_{t+1}+p_{t+1}\}} \cdot q_t\right] & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} = R \\ = \frac{R}{p_t \cdot R - E_t\{\mu \cdot r_{t+1}+p_{t+1}\}} \cdot q_t & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} > R > \frac{E_t\{\mu \cdot r_{t+1}+p_{t+1}\}}{p_t} \\ = \infty & \text{if } \frac{E_t\{\mu \cdot r_{t+1}+p_{t+1}\}}{p_t} \geq R \end{cases}, \tag{17}$$

for all $t$ and $h^t$. Equation (17) says that entrepreneurs are willing to allocate capital to unscreened projects as long as the return to operating capital in the modern sector exceeds the interest rate. Their ability to do so, however, may be constrained by the borrowing limit because the capital income generated by these projects cannot be fully pledged to creditors. Whenever the borrowing limit binds, the ability to allocate capital to unscreened projects is limited by the aggregate net worth of entrepreneurs, captured by $q_t$, times a financial multiplier that determines the extent to which this net worth can be leveraged in the credit market.

Finally, the entrepreneurs' demand for $G$-type projects, and for the capital to allocate to them, is governed by the following set of equations:

$$K_{t+1}^G \begin{cases} = 0 & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} < R \\ \in \left[0, \kappa \cdot \varphi_{t+1}^G\right] & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} = R \\ = \kappa \cdot \varphi_{t+1}^G & \text{if } \frac{E_t\{r_{t+1}+p_{t+1}\}}{p_t} > R \end{cases} \tag{18}$$

and

$$\varphi_{t+1}^G \begin{cases} = 0 & \text{if } \max\left\{\frac{E_t\{r_{t+1}+p_{t+1}\}}{R} - p_t, 0\right\} \cdot \kappa + \frac{(1-\rho) \cdot E_t \frac{\psi(s_{t+1})}{\mu}}{R} < \frac{\psi(s_t)}{\mu} \\ \in [0, \infty) & \text{if } \max\left\{\frac{E_t\{r_{t+1}+p_{t+1}\}}{R} - p_t, 0\right\} \cdot \kappa + \frac{(1-\rho) \cdot E_t \frac{\psi(s_{t+1})}{\mu}}{R} = \frac{\psi(s_t)}{\mu} \\ = \infty & \text{if } \max\left\{\frac{E_t\{r_{t+1}+p_{t+1}\}}{R} - p_t, 0\right\} \cdot \kappa + \frac{(1-\rho) \cdot E_t \frac{\psi(s_{t+1})}{\mu}}{R} > \frac{\psi(s_t)}{\mu} \end{cases}, \tag{19}$$

for all $t$ and $h^t$. Equation (18) says that entrepreneurs allocate capital to $G$-type projects whenever the expected return of doing so exceeds the interest rate. Equation (19) says that entrepreneurs demand $G$-type projects if the expected discounted payoff from operating them exceeds their price. This payoff consists of two parts: the expected profits generated by the employment of capital in these projects, and these projects' expected resale value.

Given these optimality conditions, we can determine the equilibrium price of capital. Condition (3) implies that the traditional sector is always active in equilibrium and that, as a result, the price of capital is pinned down by its productivity in the traditional sector:

$$p_t = \bar{p} = \sum_{t=1}^{\infty} \frac{a}{R^t} = \frac{a}{R-1}, \tag{20}$$

for all $t$ and $h^t$.[13] Intuitively, if $p_t < \bar{p}$, then the traditional sector would demand an infinite amount of capital (see Equation (14)). And, if $p_t > \bar{p}$, then the traditional sector would not demand capital at all, and the entire stock $\bar{K}$ would need to be employed in the modern sector. But given condition (3), Equations (17) and (18) imply that the modern sector would not demand capital at such a price either, contradicting market clearing.

## 2.4 Equilibrium

We are now ready to derive the equilibrium system that summarizes the evolution of the key aggregate variables of this economy. We have already established that:

$$K_{t+1}^{B} = 0, \tag{21}$$

for all $t$ and $h^t$, since no entrepreneur gains anything by assigning capital to $B$-type projects.

Equation (17) together with the equilibrium price of capital in Equation (20) imply:

$$K_{t+1}^{U} = \min\left\{\frac{R}{a - \mu \cdot E_t r_{t+1}} \cdot q_t,\ \left(\frac{\alpha \cdot E_t A_{t+1}}{a}\right)^{\frac{1}{1-\alpha}} - K_{t+1}^{G}\right\}, \tag{22}$$

for all $t$ and $h^t$, where $r_{t+1}$ is given by Equation (11). Equation (22) states that entrepreneurs lever up and borrow against their collateral to purchase capital for unscreened projects, as long as it is profitable to do so. Once the total capital employed in the modern sector reaches first-best, i.e., $E_t r_{t+1} = a$, there are no further incentives to allocate capital to it.

As for $G$-type projects, the market clearing condition in Equation (4), together with Equations (18) and (19) imply that $s_t$, $\varphi_t^G$ and $K_{t+1}^G$ evolve according to:

$$\frac{E_t\left\{r_{t+1} - a\right\} \cdot \kappa + (1-\rho) \cdot \frac{E_t \psi(s_{t+1})}{\mu}}{R} = \frac{\psi(s_t)}{\mu}, \tag{23}$$

[13] Throughout, we rule out rational bubbles on the price of capital, i.e., we impose that $\lim_{T\to\infty} R^{-(T-t)} \cdot E_t p_T$ for all $t$ and $h^t$.

$$\varphi_{t+1}^{G} = \mu \cdot s_t + (1-\rho) \cdot \varphi_t^{G}, \tag{24}$$

and

$$K_{t+1}^{G} = \min\left\{\kappa \cdot \varphi_{t+1}^{G},\ \left(\frac{\alpha \cdot E_t A_{t+1}}{a}\right)^{\frac{1}{1-\alpha}} - K_{t+1}^{U}\right\}, \tag{25}$$

for all $t$ and $h^t$. Equation (23) says that, in equilibrium, the net benefit of operating $G$-type projects must equal their cost of creation. Equation (24) draws on the relationship between the establishment of new projects and screening, i.e., $\zeta_t^G = \mu \cdot s_t$, to characterize the evolution of $G$-type projects as a function of screening. Finally, Equation (25) says that $G$-type projects are operated at capacity as long as the capital stock in the modern sector is no greater than the first-best level: once this threshold is reached, $E_t r_{t+1} = a$ and there are no further incentives to allocate capital to the modern sector.

Finally, as indicated by Equation (5), the traditional sector absorbs any capital that is not employed in the modern sector, which in turn implies that the economy's aggregate output is:

$$Y_t = A_t \cdot \left(\sum_m K_t^m\right)^{\alpha} + a \cdot \left(\bar{K} - \sum_m K_t^m\right), \tag{26}$$

for all $t$ and $h^t$.

The above equilibrium conditions were derived under conjecture (16) about equilibrium project prices. That these prices are part of equilibrium is straightforward to verify. At the conjectured prices, the old entrepreneurs supply all their projects inelastically as they are weakly better off selling them; young entrepreneurs in turn are indifferent between purchasing or establishing projects anew, thereby willing to absorb the project supply of the old.[14]

Given initial values for $\varphi_0^G$ and $\{K_0^m\}_m$, and a process for the shocks $\{A_t, q_t\}_{t\geq 0}$, we can summarize the competitive equilibrium of the economy by the sequence $\left\{K_{t+1}^T, \left\{K_{t+1}^m\right\}_m, \varphi_t^G, s_t\right\}_{t\geq 0}$ satisfying Equations (5), (11), and (21)-(26). The economy's only endogenous state variable is given by $\varphi_t^G$, which captures all the relevant information about existing projects that has been produced through screening in the past. We thus refer to $\varphi_t^G$ as the economy's *stock of information* and, consequently, to $V_t^G$ as the *price of information*.

[14] At the price $V_t^G = \mu^{-1} \cdot \psi(s_t)$, young entrepreneurs are indifferent between purchasing a pre-existing $G$-type project or establishing it anew by screening $\mu^{-1}$ projects at unit cost $\psi(s_t)$. At the price $V_t^U = 0$, young entrepreneurs are again indifferent between purchasing a $U$-type project from old entrepreneurs or establishing it anew at zero cost. Finally, $B$-type projects are weakly dominated by $U$-type projects, because capital is equally productive in both but its income cannot be pledged at all in the former: thus, entrepreneurs are only willing to absorb these projects at price equal to zero.

# 3 Collateral booms and busts

We are now ready to characterize the dynamic behavior of the economy. Our main objective is to analyze how the economy behaves during a collateral boom-bust cycle, i.e., an economic cycle driven by fluctuations in entrepreneurial collateral $q_t$. In the model, these reflect fluctuations in entrepreneurial net worth that are orthogonal to investment opportunities. Albeit stylized, they are meant to capture economic fluctuations that are driven largely by changes in wealth, e.g., fluctuations in land or real-estate values.[15] We contrast them with boom-bust cycles driven by fluctuations in productivity, $A_t$, which as we shall see have markedly different effects on information production and equilibrium dynamics.

To simplify the exposition, we gradually build up to the full dynamic analysis of the model. We begin by assuming that $\rho = 1$, so that projects become obsolete after one period. This means that information is short-lived, thereby eliminating its forward-looking nature and making the economy effectively static. We then set $\rho < 1$ and analyze the behavior of the economy in response to unanticipated shocks. This intermediate step enables us to use a simple phase diagram analysis to illustrate the "slow-moving" nature of information, and its interaction with investment and its composition. Finally, we allow for shocks to be anticipated and analyze the behavior of the economy in response to fluctuations in $q_t$ and $A_t$.

## 3.1 Building intuitions: short-lived information

When $\rho = 1$, projects become obsolete after production and thus must be created anew each period. Formally, the only equilibrium conditions that change are Equations (23) and (24), which now become:

$$\frac{E_t\left\{r_{t+1} - a\right\} \cdot \kappa}{R} = \frac{\psi(s_t)}{\mu}, \tag{27}$$

$$\varphi^G_{t+1} = \mu \cdot s_t. \tag{28}$$

Equation (27) says that, in equilibrium, the marginal benefit of information must equal its cost. Since information is short-lived and has no resale value, its marginal benefit equals the return of reallocating capital from the traditional to the modern sector for one period. Equation (28) says that the stock of information must be produced anew each period through screening. This economy has no state variables and hence no relevant dynamics. Albeit boring, it provides a useful benchmark to illustrate the key role played by entrepreneurial collateral.

Figure 1 shows how the equilibrium changes with $q_t$. For a given value of productivity $A$, it depicts the equilibrium output, $Y_t$, the allocation of capital within modern-sector projects,

[15] See Section 5.1 for a detailed discussion of alternative interpretations of fluctuations in $q_t$.

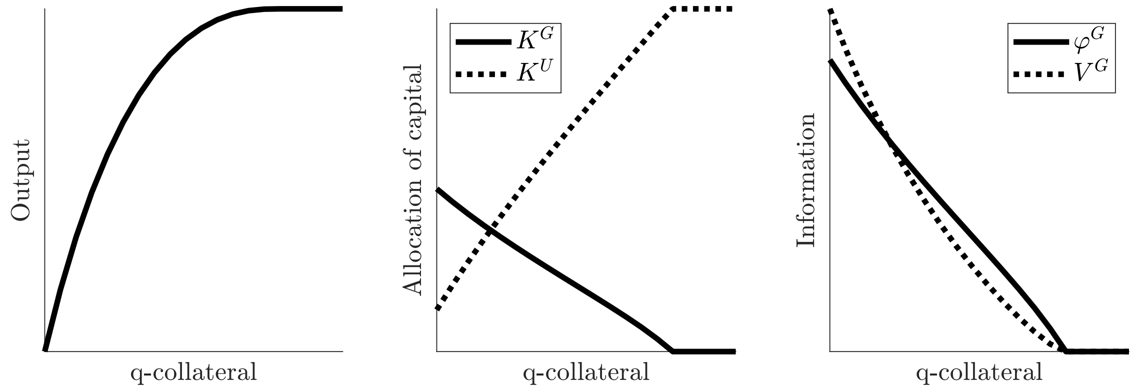


Figure 1: **Effects of collateral when $\rho = 1$.** The figure depicts the output, the allocation of capital in the modern-sector projects, and the stock and price of information as a function of collateral value $q$.

$K^G_{t+1}$ and $K^U_{t+1}$, and the stock and price of information, $\varphi^G_t$ and $V^G_t$, as a function of entrepreneurial collateral $q$.[16]

The left panel shows that output initially increases with $q_t$ but is constant after a critical value. The middle panel shows why this is the case: an increase in $q_t$ relaxes the financial constraint of entrepreneurs, enabling them to expand their purchases of capital to be employed in $U$-type projects. This enables the economy as a whole to reallocate capital from the traditional to the more productive modern sector, which increases output. This reallocation also raises the demand for labor and wages, however, which reduces the return to capital in the modern sector and weakens the incentives to screen projects, leading the stock and price of information to decline with $q_t$ (right panel). Thus, an increase in collateral values induces not only a reallocation of capital *across* sectors, from the traditional to the modern, but also *within* the modern sector, from $G$- to $U$-type projects. Once collateral is high enough to equalize the returns to capital across both sectors, it no longer affects the equilibrium.

Figure 1 summarizes the basic insight of our mechanism. There are two ways of allocating capital to the modern sector: one is information-intensive, in the sense that it relies on screening to identify $G$-type projects that can be used to obtain credit to fund capital purchases; the other one is not, in the sense that it relies on collateral to obtain credit to purchase capital that can be employed in $U$-type projects. Naturally, these two forms of reallocation are substitutes in equilibrium. Either one of them raises wages and thus reduces the return to the other. This is why an increase in collateral shifts the allocation of capital within the modern sector from $G$- to $U$-type projects. While enabling the economy to save on screening costs, this reallocation will turn out to have important dynamic implications.

[16]The parameter values used for all the illustrations are provided in Table 2 in Appendix A.6.

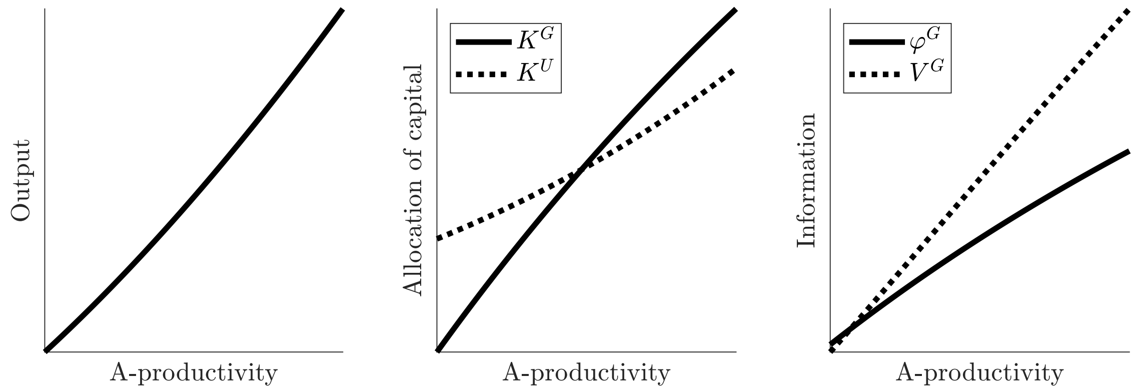


Figure 2: **Effects of productivity when $\rho = 1$.** The figure depicts the output, the allocation of capital in the modern-sector projects, and the stock and price of information as a function of productivity $A$.

Before turning to these implications, it is useful to contrast the effects of changes in entrepreneurial collateral to those of changes in modern-sector productivity. For a given value of $q$, Figure 2 depicts the equilibrium output, the allocation of capital within modern-sector projects, and the stock and price of information as a function of $A$. The left panel shows that, as expected, an increase in modern-sector productivity raises aggregate output. The middle panel shows, however, that this is not just due to the higher productivity but also to the reallocation of capital towards *both $G$- and $U$*-type projects. The reason is that higher productivity raises the expected return to all modern-sector projects, increasing both entrepreneurs' willingness to invest in screened projects and their ability to invest in unscreened projects. Finally, the right panel shows that the stock and price of information are both increasing in productivity: as the return of reallocating capital to the modern sector rises, so does the return of producing the information that makes this reallocation possible.

## 3.2 The dynamic model

We now set $\rho < 1$ and allow for fluctuations in entrepreneurial collateral and aggregate productivity. In particular, we assume that $q_t \in [\underline{q}, \bar{q}]$ and $A_t \in [\underline{A}, \bar{A}]$ for all $t$ and $h^t$, where $\underline{q} < \bar{q}$ and $\underline{A} < \bar{A}$. We will specify a precise stochastic process for $q_t$ and $A_t$ in the next section. Before doing so, we illustrate some dynamic properties of the economy by considering unanticipated changes in both variables.

We focus throughout on equilibria in which the stock of unscreened projects is always constrained by entrepreneurial net worth. In this case, the dynamics of the economy are fully characterized by the following system of equations:

$$K_{t+1}^U = \frac{R}{a - \mu \cdot E_t r_{t+1}} \cdot q_t, \tag{29}$$

$$\frac{E_t\left\{r_{t+1}-a\right\}\cdot\kappa+(1-\rho)\cdot\frac{E_t\psi(s_{t+1})}{\mu}}{R}=\frac{\psi(s_t)}{\mu}, \tag{30}$$

$$\varphi_{t+1}^G=\mu\cdot s_t+(1-\rho)\cdot\varphi_t^G, \tag{31}$$

and

$$K_{t+1}^G=\kappa\cdot\varphi_{t+1}^G, \tag{32}$$

for all $t$ and $h^t$, where $r_{t+1}$ is defined in Equation (11). The key difference with the "static" model is that the stock of information $\varphi_t^G$ now becomes a state variable.

### 3.2.1 Slow-moving information

Let us suppose for now that the economy does not experience shocks, i.e., $q_t=q$ and $A_t=A$ for all $t$ and $h^t$. Then, we can characterize both the steady state and the dynamic behavior of the economy with the help of a phase diagram in $\varphi_t^G$ and $s_t$, as shown in Figure 3. This figure depicts the following steady-state relationships:

$$\varphi^G=s\cdot\frac{\mu}{\rho}, \tag{33}$$

and

$$\left(\alpha\cdot A\cdot\left(\kappa\cdot\varphi^G+K^U(\varphi^G,q,A)\right)^{\alpha-1}-a\right)\cdot\kappa=(R+\rho-1)\cdot\frac{\psi(s)}{\mu}, \tag{34}$$

where $K^U(\varphi^G,q,A)$ is implicitly defined by Equation (29), with $K^U$ increasing in $q$ and $A$ but decreasing in $\varphi^G$. Equation (33) represents the rate of per-period screening $s$ necessary to maintain a stock of information $\varphi^G$ in steady state: clearly, $s$ is increasing in $\varphi^G$. Equation (34) represents instead the combinations of $s$ and $\varphi^G$ that are consistent with profit maximization by entrepreneurs and market clearing. Here, $s$ and $\varphi^G$ are negatively related because, intuitively, screening is less valuable if there is a high stock of information that already makes it possible to allocate much of the economy's capital to the modern sector.

The left panel of Figure 3 depicts both loci in the $\left(\varphi^G,s\right)$-space. Their intersection represents the steady state of the deterministic economy, which we denote by $\left(\bar{\varphi}^G,\bar{s}\right)$. This system can be shown to be saddle-path stable. The dynamics of the system along the saddle path is indicated by the arrows, which depict the slow-moving nature of information. To see this, suppose the economy starts with an initial value $\varphi_0^G<\bar{\varphi}^G$. In this case, the economy needs to build up its stock of information and therefore requires a high level of screening ($s_0>\bar{s}$): along the transition, $\varphi_t^G$ rises gradually towards $\bar{\varphi}^G$ and $s_t$ falls gradually towards $\bar{s}$. Analogously, given an initial value $\varphi_0^G>\bar{\varphi}^G$, the economy must instead run down its stock of

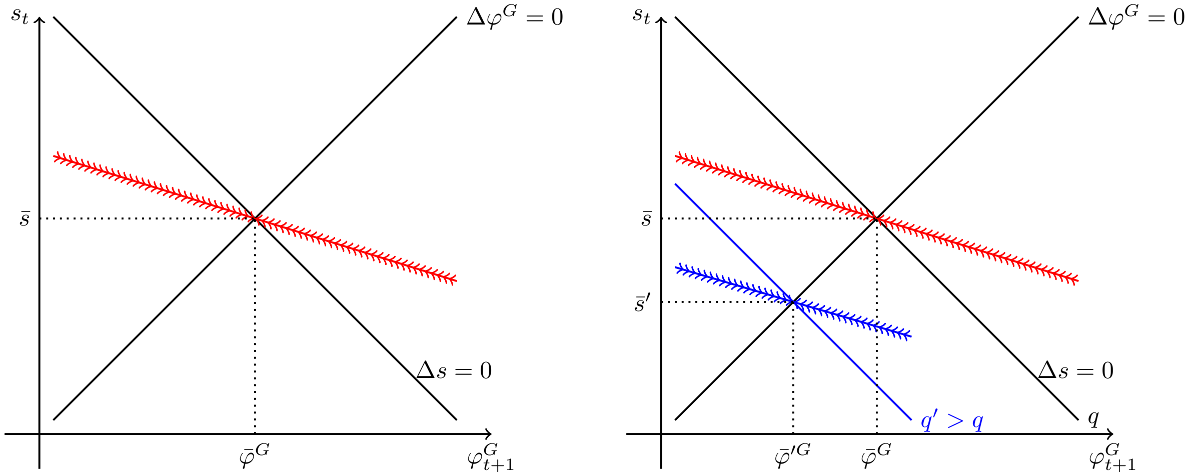


Figure 3: **Information dynamics.** The figure illustrates a phase diagram for the joint evolution of per period screening and stock of information. In the left panel, the saddle path of the system is depicted in red. In the right panel, the saddle path is depicted in red prior to the unexpected shock to $q$, and in blue thereafter.

information and it therefore requires a low level of screening ($s_0 < \bar{s}$): along the transition, $\varphi^G_t$ falls towards $\bar{\varphi}^G$ and $s_t$ rises towards $\bar{s}$.

The key takeaway of the dynamic model is that the economy cannot accumulate information instantaneously, as doing so would require drawing on inefficient experts to screen projects. Instead, information is accumulated gradually over time and is in this sense "slow-moving". To further illustrate this adjustment, the right panel of Figure 3 depicts the response of the economy to a permanent and unexpected increase in $q$. Whereas the locus of Equation (33) is unaffected by this change, the locus of Equation (34) shifts down. The reason is that a higher value of $q$ enables entrepreneurs to reallocate capital towards $U$-type projects, which reduces the return to capital in the modern sector and thus the benefits of screening. As a result, screening collapses on impact as the economy jumps to the new saddle path: at the new, higher level of entrepreneurial collateral, it is simply not worth maintaining the pre-existing stock of information. Along this new saddle path, the economy gradually transitions towards the new steady state, which entails both a lower stock of information $\varphi^G$ and a lower level of screening $s$ relative to the original steady state.

As in the "static" model, therefore, the dynamic economy responds to an increase in $q$ by reducing its information production. Crucially, however, this now leads to a gradual depletion of the stock of information over time. As we will see shortly, this behavior of information dynamics has important effects on the aggregate behavior of the economy during boom-bust cycles. Naturally, information also responds gradually to changes in productivity $A$, although the latter's effect on information is opposite to that of $q$. In particular, higher productivity induces an upward shift of the locus defined by Equation (34), thereby raising the steady-state

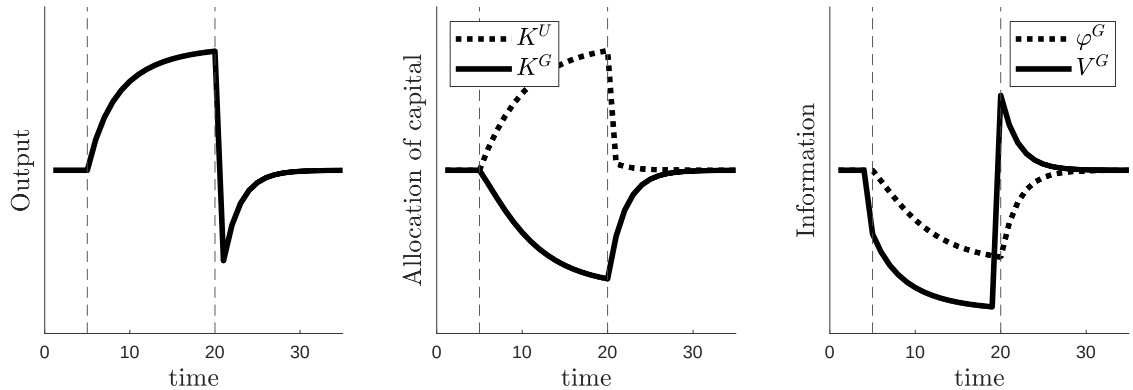


Figure 4: **Collateral boom-bust episode**. The figure depicts the equilibrium evolution of output, the allocation of capital within the modern-sector projects, and the stock and price of information. In this simulation, the state is $L$ before period 5 and after period 20, and the state is $H$ between periods 5 and 20. The variables are expressed in deviation from their steady-state value in state $L$.

stock of information $\varphi^G$ and screening $s$. Therefore, increases in entrepreneurial collateral deplete the stock of information whereas increases in productivity foster it.

### 3.2.2 Boom-bust episodes

We are now ready to study the behavior of the economy in response to fluctuations in collateral values, taking into account that agents are forward-looking and fully aware of the stochastic nature of these fluctuations. To do so, we assume that the economy fluctuates between low- and high-collateral states, denoted by $z_t \in \{L, H\}$, which are respectively meant to capture collateral busts and booms. Collateral evolves according to,

$$q_t = \begin{cases} \beta \cdot q_{t-1} + (1-\beta) \cdot \bar{q} & \text{if } z_t = H \\ \underline{q} & \text{if } z_t = L \end{cases}, \tag{35}$$

where $\beta \in (0, 1)$. We assume moreover that the states are persistent, so that the transition probabilities $P(z_t = H \,|z_{t-1} = L) = \lambda_L$ and $P(z_t = L \,|z_{t-1} = H) = \lambda_H$ satisfy $\lambda_L, \lambda_H \in \left(0, \frac{1}{2}\right)$. Finally, we assume that $\bar{q}$ is low enough for entrepreneurs to be constrained in both states.

According to the law of motion in Equation (35), collateral grows gradually during booms and eventually stabilizes at $\bar{q}$. The boom may end at any moment though, at which time collateral values drop to $\underline{q}$. Thus, this simple process captures in a very stylized way the asymmetric behavior of macroeconomic variables over credit cycles (e.g., Ordoñez (2013)), and it mimics similar processes used in the literature (e.g., Gorton and Ordoñez (2014, 2016)). The process is illustrative, however, as our theory is not designed to explain fluctuations in collateral values but rather to trace its effects through information production about investment opportunities.

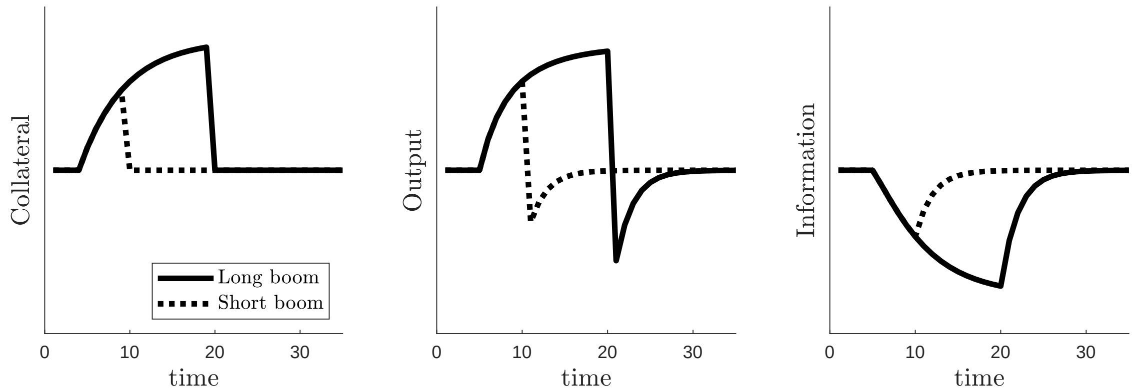


Figure 5: **Longer booms, larger busts**. The figure depicts the equilibrium evolution of output and the stock of information throughout collateral boom-bust episodes of two different durations: one lasts from period 5 to period 10, whereas the other lasts from period 5 to period 20. The variables are expressed in deviation from their steady-state value in state $L$.

Figure 4 illustrates the aggregate effects of fluctuations in collateral by depicting the evolution of the economy throughout a full boom-bust cycle. In particular, it depicts respectively the evolution of output, the allocation of capital within modern-sector projects, and the stock and price of information.

During the boom, aggregate output naturally rises (left panel) as high collateral values enable entrepreneurs to reallocate capital from the traditional to the more productive modern sector. Within the modern sector, moreover, capital is reallocated away from $G$- towards $U$-type projects (middle panel). The reason is that the return to capital in the modern sector falls during the boom, which reduces the value of information, disincentivizing screening and leading to a decline of the economy's stock of information (right panel). In a sense, the economic expansion during the boom conceals a depletion of information in the background.

When the boom ends, entrepreneurs are no longer able to maintain such a high level of capital employed in the modern sector. Lack of collateral directly limits the employment of capital in $U$-type projects, and lack of information – which was depleted during the boom – limits the employment of capital in $G$-type projects. The resulting scarcity of capital in the modern sector raises its productivity and thus the value of information, which spikes as collateral values fall. This provides incentives for the economy to rebuild its stock of information, which happens only gradually due to the high costs of screening. The key takeaway is that, throughout the transition, the economy temporarily undershoots its new steady-state level of output. In other words, the depletion of information prompted by the collateral boom amplifies the fall in output when the bust comes. Moreover, as Figure 5 shows, because longer booms lead to more information depletion, they also tend to end in deeper busts or "crises"

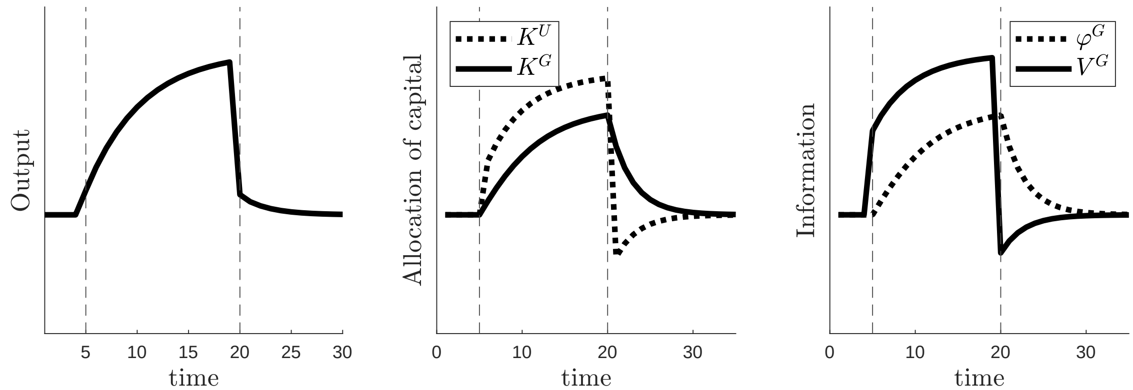


Figure 6: **Productivity boom-bust episode**. The figure depicts the equilibrium evolution of output, the allocation of capital within the modern-sector projects, and the stock and price of information. In this simulation, the state is $L$ before period 5 and after period 20, and the state is $H$ between periods 5 and 20. The variables are expressed in deviation from their steady-state value in state $L$.

and slower recoveries.

It is again instructive to contrast the boom-bust episodes driven by collateral values with those driven by productivity shocks. To this effect, Figure 6 depicts the evolution of an economy that undergoes a productivity boom.[17] In this case, output increases during the boom (left panel) as capital is reallocated towards *both* $G$-type *and* $U$-type projects (middle panel). The reason is that, since the value of information rises alongside the productivity of the modern sector, the stock of information now rises during the boom (right panel). As a result, the end of the productivity boom finds the economy with a relatively high stock of information, which "cushions" its transition to the new steady state.

## 3.3 Discussion

This section has outlined the key insight of our theory: namely, the economy's stock of information reacts to the availability of collateral. During collateral booms, the economy naturally relies less on information to reallocate capital to the modern sector. But this depletes the stock of information, which – given the slow-moving nature of information – amplifies the crises at the end of collateral booms and slows down the subsequent recoveries.

These results rely on two features of the environment. The first is that the productivity of capital in the modern sector is decreasing in the total capital stock allocated to the sector. This follows in our setting because the modern-sector technology combines capital and labor, and the latter is scarce. We capture this scarcity starkly through a fixed supply of labor, but nothing substantial would change if we assumed instead that the labor supply was increasing

[17] The process used for $A_t$ is identical to that for $q_t$ in Equation (35).

in the wage. What is key is that the equilibrium wage increases with modern-sector capital, as depicted by Equation (10). This means that, in equilibrium, all modern-sector projects are effectively substitutes because they compete for a common factor of production – labor.

The second feature of the environment is the scarcity of expertise, which is formally captured by the assumption that experts face a capacity constraint and have heterogeneous abilities to screen projects. These assumptions jointly imply that screening is costly and that screening costs are effectively convex. As a result, it is costly for the economy to produce a large amount of information all at once, which implies that it takes time to replenish the depleted stock of information in the wake of a collateral bust.[18] These features of the screening technology are standard in the banking literature (e.g., Ruckes (2004), Freixas and Rochet (2008)) and often motivated by the fact that screening borrowers may require trained loan officers and information gathering/processing infrastructure that are difficult to change in the short run.

Besides these two central features, we have made additional assumptions regarding the screening technology that are convenient but not central for the results. We comment on two of them here. The first assumption is that there is no asymmetric information, so that screening is equally informative for lenders and entrepreneurs. As we show in Appendix A.5, however, our model is equivalent to a setting with asymmetric information in which entrepreneurs can effectively choose whether to set up $G$-quality projects, which enable them to pledge the entire stream of revenues, or $B$-quality projects, which enable them to pledge only a fraction of these revenues.

The second assumption is that the information produced through screening is public. In the context of our OLG setting with two-period lifetimes, where only public information can act as a state-variable, it is important that the outcome of screening become public information with some positive probability.[19] However, we conjecture that the same relation between collateral and information depletion would arise in a more complex world, where creditors are long-lived (so that private information acts as a state-variable) and where screening produces private information for them that cannot be credibly disclosed to the market. The reason is that, even in such a world, creditors would face a trade-off between producing (costly) private information about their borrowers or lending to them against collateral. Once this trade-off exists, a collateral boom is bound to relax the constraints that restrict unscreened investment and – through the aforementioned effects – lead to information depletion.

[18] An equally compelling explanation is that generating information takes time. It is through repeated interaction that lenders learn about the characteristics and behavior of their borrowers. Clearly, in this case, there is a natural constraint on the speed at which information can be generated. Both of these narratives are realistic and lead to the same result, which lies at the heart of our mechanism: the economy cannot replenish its stock of information on a whim.

[19] This could be either because entrepreneurs are able to disclose the outcome of screening to the public, or because entrepreneurs' or lenders' equilibrium behavior partially reveals this outcome.

# 4 Is there too little information?

The main insight of the previous section is that, during collateral boom-bust cycles, the effects of the bust are magnified due to the depletion of information that takes place during the boom. It may therefore be tempting to conclude that this depletion of information is inefficient, in the sense that the amount of information produced in equilibrium is inefficiently low. We now show that such a conclusion is unwarranted in our baseline model. Since the asset market is undistorted and agents are forward-looking, market prices accurately reflect the value of information: thus, even at the peak of a collateral boom, agents effectively anticipate the benefits of owning screened projects in the event that the bust materializes. If anything, due to a general equilibrium crowding-out effect that screening generates, the information produced in equilibrium is inefficiently high!

To see this, consider the problem of a constrained social planner whose objective is to maximize the present value of aggregate consumption net of screening costs, discounted at the interest rate $R$. Since agents' preferences are linear, this is equivalent to the maximization of social welfare, where the welfare of future generations is discounted at rate $R$.[20] To focus on inefficiencies stemming from information production, we assume that the planner is constrained to only choose the sequence of screening choices $\{s_t\}$ on the agents' behalf; all the other decisions are made in a decentralized fashion as in the competitive equilibrium. Finally, we focus on parameter values for which borrowing constraints bind at the planner's solution: as in the competitive equilibrium, this requires $q_t$ to be low enough for all $t$ and $h^t$.

Formally, the social planner's problem can be expressed recursively as follows (see Appendix A.1 for detailed derivations):

$$\begin{aligned} V\left(\varphi_t^G, q_t, A_t\right) = \max_{s_t}\ & A_t \cdot \left(K_t^G + K_t^U\right)^\alpha + a \cdot \left(\bar{K} - K_t^G - K_t^U\right) - \int_0^{s_t} \psi(x)dx \\ & + q_t + R^{-1} \cdot E_t V\left(\varphi_{t+1}^G, q_{t+1}, A_{t+1}\right) \end{aligned} \tag{36}$$

where, as in the competitive equilibrium, we have that for all $t$ and $h^t$:

$$\varphi_{t+1}^G = \mu \cdot s_t + (1-\rho) \cdot \varphi_t^G, \tag{37}$$

$$K_{t+1}^G = \kappa \cdot \varphi_{t+1}^G, \tag{38}$$

$$K_{t+1}^U = \frac{R}{a - \mu \cdot E_t\{\alpha \cdot A_{t+1} \cdot (K_{t+1}^G + K_{t+1}^U)^{\alpha-1}\}} \cdot q_t. \tag{39}$$

The planner's value function depends on the economy's state variables: the stock of infor-

[20] For simplicity, we abstract from distributional effects within a given generation.

mation, the value of collateral and aggregate productivity. The planner's per period return is given by the total output of the economy net of the screening costs of the experts plus the value of collateral. Equations (37)-(39) respectively state that the aggregate stock of screened projects must be consistent with actual screening; that the allocation of capital to modern-sector $G$-type projects satisfies project capacity constraints; and that allocation of capital to modern-sector $U$-type projects satisfies the borrowing constraint.

The borrowing constraint in Equation (39) plays a key role. Combined with the project capacity constraint (38), it implicitly defines the stock of capital allocated to $U$-type projects as a decreasing function of the stock of information, i.e., $K^U_{t+1} = K^U(\varphi^G_{t+1}, q_t, A_t)$, with $\partial K^U(\varphi^G_{t+1}, q_t, A_t)/\partial \varphi^G_{t+1} < 0$. This reflects the fact that, in equilibrium, the resulting expansion in the stock of $G$-type projects increases the demand for labor and thus wages, which (by depressing the marginal product of capital in the modern sector) reduces the pledgeable output of $U$-type projects and thus crowds them out. In the laissez-faire equilibrium, entrepreneurs do not internalize this relationship because they take wages as given. But the planner does and the first-order conditions to her problem yield:

$$\frac{\psi(s_t)}{\mu} = \frac{E_t\left\{r_{t+1} - a\right\} \cdot \widehat{\kappa}_t + (1-\rho) \cdot \frac{E_t \psi(s_{t+1})}{\mu}}{R}, \tag{40}$$

where $r_{t+1} = \alpha \cdot A_{t+1} \cdot \left(K^G_{t+1} + K^U_{t+1}\right)^{\alpha - 1}$ and,

$$\widehat{\kappa}_t = \kappa - \left|\frac{\partial K^U(\varphi^G_{t+1}, q_t, A_t)}{\partial \varphi^G_{t+1}}\right| \in (0, \kappa) \tag{41}$$

for all $t$ and $h^t$. Together with Equations (37)-(39), these characterize the solution to the planner's problem.

Equations (40) and (41) illustrate the key difference between the planner's solution and the competitive equilibrium. In the latter, market clearing and optimization require that the market value of a screened project, i.e., $\frac{\psi(s_t)}{\mu}$, equals its expected discounted return. From the perspective of an individual entrepreneur, a key part of this return is that a screened project enables her to reallocate $\kappa$ units of capital from the traditional to the modern sector, generating a rent of $r_{t+1} - a$ per unit of capital. However, the entrepreneur fails to internalize the general equilibrium effects associated with this reallocation. Namely, as explained above, the ensuing expansion in the stock of modern-sector capital reduces the pledgeable income of $U$-type projects and thus crowds them out. At the margin, therefore, a $G$-type project enables the economy to transfer only $\widehat{\kappa}_t < \kappa$ units of capital from the traditional to the modern sector, where the difference between the two corresponds to the crowding-out effect on $U$-type projects.[21] Whereas individual entrepreneurs do not internalize this effect, the planner does and she thus chooses to produce less information.

Contrary to conventional wisdom, therefore, there is no shortage of information in the competitive equilibrium. Although this result may appear surprising given that entrepreneurs in our economy are short-lived, it is quite natural given that the market for projects is frictionless. This enables entrepreneurs to fully appropriate the value of information embedded in screened projects. Things would be clearly different in the presence of additional distortions that prevented this appropriation. We explore two examples of such distortions in Appendix A.2: (i) market power in the market for projects, and (ii) learning-by-doing externalities in the screening technology. In both cases, we show that – if the distortion is severe enough – information production may indeed be sub-optimally low in the competitive equilibrium.[22]

Finally, we note that the planner's allocation can be decentralized through a sequence of state-contingent Pigouvian taxes $\{\tau_t\}$ on the screening of projects, with revenues rebated in lump-sum fashion to the households. Using superscript $SP$ to denote the planner's optimal allocation, the sequence of taxes that implements it can be shown to satisfy:

$$\tau_t = \frac{E_t\{\alpha \cdot A_{t+1} \cdot (\kappa \cdot \varphi_{t+1}^{G,SP} + K_{t+1}^{U,SP})^{\alpha-1} - a\}}{R} \cdot (\kappa - \widehat{\kappa}_t^{SP}) + \frac{1-\rho}{R} \cdot E_t \tau_{t+1} \tag{42}$$

for all $t$ and $h^t$. The first term on the right-hand side of Equation (42) reflects the crowding-out effect that a project screened in period $t$ has on the allocation of capital to unscreened projects in that same period. The second term reflects the fact that projects are long-lived, so that this crowding-out effect will extend into the future. Jointly considered, these terms imply that the planner can decentralize the optimal allocation by setting a tax on the screening of projects that is equal to the crowding-out effect that a screened project imposes throughout its entire lifetime.

# 5 Bubbles and misallocation

We have developed a theory of information production during collateral booms and have derived its main implications. Now we turn to some lingering questions. What exactly is the origin of collateral booms? And what does the theory say about other phenomena that have

[21] This effect is quite general and it is present in a broad class of environments in which different technologies compete for common factors of production in the presence of financial frictions (see, for instance, Matsuyama (2007) and Broner, Martin and Ventura (2020)).

[22] Specifically, market power by buyers of screened projects depresses their price below the value of the information that they contain. This type of distortion is present in related papers in the literature that find information production to be suboptimally low in equilibrium (see, for instance, Gorton and Ordoñez (2014)).

been recently associated to credit booms, such as rising factor misallocation?

## 5.1 What is collateral?

Up to now, we have analysed the effects of fluctuations in the value of collateral $q_t$ without specifying their origin. Since $q_t$ is assumed to be exogenous to entrepreneurs' investment and production opportunities, it literally reflects the value of resources that are determined outside of the production process. If we think of the modern sector as manufacturing, for instance, $q_t$ could reflect an alternative source of wealth, such as natural resources (e.g., land or agricultural rents) or real estate, which is not directly related to manufacturing activity but nonetheless generates resources for the private sector.

Under this interpretation, fluctuations in $q_t$ would simply reflect economic shocks that have a large impact on wealth but little impact on productivity. There are many examples of such shocks in the macroeconomics literature. A traditional one is a boom in commodity prices, which is often driven by global factors – i.e., it is determined outside of the domestic economy – but nonetheless relaxes domestic financial conditions and leads to an increase in domestic investment and output.[23] Another example is a shift in preferences or beliefs, which raises the demand for real estate and thus boosts real estate prices and leverage.[24] In fact, such fluctuations in beliefs have been used to model asset price bubbles, which have received much attention lately.

Bubble-driven booms and busts are precisely characterized as episodes of large fluctuations in asset prices that seem largely unrelated to the underlying economy's productive opportunities.[25] As such, they provide a perfect interpretation of $q_t$ in the model. To see this formally, consider a slightly modified version of our economy in which projects are grouped into firms that are owned and managed by entrepreneurs. After production, young entrepreneurs can purchase pre-existing firms in the stock market or they can create new ones at zero cost. Entrepreneurs use credit to fund the purchase of firms and investment in them, but access to credit is limited by their inability to pledge entirely the operating income of the firm (since they cannot pledge the income generated by $B$-quality projects).

Given that ours is a small-open economy, it admits two types of equilibria: a fundamental equilibrium, in which the stock market value of all firms is equal to the cost of replacing their

[23]See Drechsel and Tenreyro (2018) for a recent model – and supporting evidence – of a small-open economy in which commodity booms raise output, consumption and investment.

[24]See Kaplan, Mitman and Violante (2017) for a formal argument that a major driver of the US housing boom of the early 2000's was a shift in preferences, and that the boom affected financial conditions. Chaney et al. (2012) provide empirical evidence that the US housing boom enabled firms with relatively large holdings of real estate to expand their investment.

[25]See Martin and Ventura (2018) for examples of "bubbly episodes" in Japan, the United States and the Euro area over the last few decades.

projects, and bubbly equilibria, in which the stock market value of some firms exceeds the cost of replacing their projects.[26] Formally, if we use $J_t$ to denote the set of firms that are active in period $t$, we can write the stock market value of firm $j \in J_t$ as:

$$\nu_{jt} = V_t^G \cdot \varphi_{jt}^G + V_t^U \cdot \varphi_{jt}^U + p_t \cdot K_{jt} + b_{jt}, \tag{43}$$

where $\varphi_{jt}^G$, $\varphi_{jt}^U$ and $K_{jt}$ respectively denote the stock of $G$-type projects, $U$-type projects, and the capital stock owned by firm $j$ after production, and $b_{jt}$ denotes the value of the bubble attached to firm $j$.

In a fundamental equilibrium, $b_{jt} = 0$ for all $j \in J_t$ and a firm's stock market value is exactly equal to the value of the projects and capital stock that it owns. In a bubbly equilibrium, instead, $b_{jt} > 0$ for some $j \in J_t$, and the stock market value of some firms exceeds the value of the projects and capital stock that they contain. Given the international interest rate $R$ and firm prices in Equation (43), $b_{jt} > 0$ in equilibrium if and only if:

$$R = \frac{E_t b_{jt+1}}{b_{jt}}. \tag{44}$$

Equation (44) says that the expected growth rate of bubbles must equal the interest rate. If this condition was not satisfied with equality for some firm $j$ for which $b_{jt} > 0$, the demand for the firm's stock by young entrepreneurs would be either infinite or zero, which could not be true in equilibrium. In any bubbly equilibrium, the evolution of $b_{jt}$ is driven by beliefs or "market psychology".

It can be shown that, together with a process of $b_{jt}$ that satisfies Equation (44), Equations (21)-(26) can be interpreted as a bubbly equilibrium in which $q_t$ reflects the value of bubbles attached to newly created firms at time $t$. According to this interpretation, fluctuations in $q_t$ reflect changes in the market psychology that drives market bubbles, which in turn affect entrepreneurial net worth, borrowing and investment. By boosting asset prices, bubbles create collateral without changing the economy's production possibilities. Our theory thus highlights a novel cost of bubbly episodes, which has been unexplored in the literature. Namely, they are likely to be accompanied by information depletion and, as a result, their demise is likely to be characterized by deep crises and slow recoveries.

Albeit realistic, these interpretations of $q_t$ as being completely unrelated to productivity are somewhat extreme. There are also alternative interpretations according to which fluctuations in $q_t$ would result from shocks that affect both entrepreneurial net worth or collateral and

[26] In a small-open economy, the rest of the world has unbounded resources and bubbles are always feasible. For a general discussion of existence conditions for bubbles in small-open and closed economies, see Martin and Ventura (2018).

productivity. One simple example of this, which we explore in Appendix A.4, corresponds to an economy in which entrepreneurs are endowed with a factor of production, such as labor. In this case, productivity booms enhance investment opportunities and also raise entrepreneurial collateral. Yet, our mechanism remains valid: relative to a world where productivity booms only enhance investment opportunities, they now also deplete information. The key takeaway is clear. Regardless of the origin of the underlying shock, increases in productivity boost information production, whereas increases in entrepreneurial collateral discourage it. Insofar as shocks in real economies combine both aspects, their net effect on the economy's stock of information will depend on their impact on collateral relative to productivity.

## 5.2 Credit booms and factor misallocation

There is a growing view among economists that credit booms are associated with a less efficient allocation of resources, i.e., with "misallocation". Following Hsieh and Klenow (2009), misallocation is typically measured as the dispersion of TFP (more precisely, revenue TFP) – normalized by average productivity – across plants or firms within a given industry or sector. In an ideal world, resources would flow from less to more productive firms/plants to eliminate any such dispersion. If this is not the case, the logic goes, there must be frictions that prevent the efficient allocation of resources. Recently, García-Santana et al. (2016) and Gopinath et al. (2017) have documented a significant increase in misallocation during the Spanish credit boom of the early 2000s, which has been broadly interpreted as an indication that the allocation of resources is somehow distorted during episodes of rapid credit growth.

Our theory offers an alternative, complementary interpretation of this evidence. To see this, it is best to focus on the "static" version of the model (i.e., $\rho = 1$) and modify it along one key dimension: besides their different pledgeability to outsiders, $G$- and $B$-quality projects also differ in their productivity. In particular, we focus here on the case in which $G$-quality projects are more productive: concretely, we assume that the productivity of $G$-quality projects is equal to $A_t > 0$, while the productivity of $B$-quality projects equals $\gamma \cdot A_t$ for $\gamma < 1$. We relegate the case of $\gamma > 1$ to Appendix A.3.[27]

Appendix A.3 contains the equilibrium conditions of the model when modern-sector projects differ in their productivity. In the traditional sector, this modification is irrelevant as all units of capital have productivity $a$ and there is no misallocation. In the modern sector,

[27] The arguments of this section require only that there be some correlation (positive or negative!) between productivity and pledgeability of projects. For instance, firms that invest in more intangible, research-intensive technologies may be more productive (Crass and Peters, 2014) but less pledgeable (Campello and Giambona, 2010; Dell'Ariccia, Kadyrzhanova, Minoiu and Ratnovski, 2017); alternatively, firms that suffer from poor corporate governance or management practices may be less productive (Tian and Twite, 2011; Bloom, Genakos, Sadun and Van Reenen, 2012) and also less able to access credit (Ashbaugh-Skaife, Collins and LaFond, 2006).

misallocation is instead given by the variance of TFP across projects, relative to average:

$$VAR_{TFP,t} = \frac{K_t^G + \mu \cdot K_t^U}{K_t^G + K_t^U} \cdot \left(\frac{A_t}{\bar{A}_t} - 1\right)^2 + \frac{(1-\mu) \cdot K_t^U}{K_t^G + K_t^U} \cdot \left(\gamma \cdot \frac{A_t}{\bar{A}_t} - 1\right)^2, \tag{45}$$

where $\bar{A}_t$ denotes the average TFP in modern-sector projects. This expression has a very natural interpretation. Of all the units of capital in the modern sector, $K_t^G + \mu \cdot K_t^U$ are employed in $G$-quality projects, for which TFP equals $A_t > \bar{A}_t$. The remaining $(1-\mu) \cdot K_t^U$ units are instead employed in $B$-quality projects, for which TFP equals $\gamma \cdot A_t < \bar{A}_t$.

As we show in the Appendix, misallocation in this economy depends only on the ratio $K_t^G/K_t^U$. Specifically, it is decreasing in this ratio (and thus increasing in $q_t$) whenever:

$$\frac{K_t^G}{K_t^U} > \gamma \cdot (1-\mu) - \mu. \tag{46}$$

Intuitively, an increase in $K_t^G/K_t^U$ reduces misallocation whenever the stock of capital employed in $G$-quality projects exceeds the (productivity weighted) stock of capital employed in $B$-quality projects. This requires $K_t^G/K_t^U$ to exceed a certain threshold, and if $\mu > \gamma/(1+\gamma)$, this threshold is negative and misallocation is always decreasing in $K_t^G/K_t^U$.

Figure 7 depicts measured misallocation as a function of $q_t$. In the parametrization used for the figure, condition (46) always holds. When $q_t = 0$, all capital in the modern sector is employed in $G$-type projects and there is no misallocation. As $q_t$ increases, capital is reallocated from the traditional to the modern sector. But capital is also reallocated within the modern sector, from $G$- to $U$-type projects, which raises measured misallocation. Simply put, agents reduce their screening and this leads to higher investment in $B$-quality projects. When $q_t$ is large enough, entrepreneurs become unconstrained, and their investment decisions and thus misallocation no longer depends on collateral values.

We could easily extend this static example to the fully dynamic economy to show how collateral booms can be accompanied by rising misallocation. In this way, the model can rationalize the empirical evidence outlined above. It is also consistent, moreover, with the narrative that is commonly invoked to account for this evidence: during booms, credit ends up being allocated to low-quality activities. Our model suggests that this is not necessarily inefficient, however. It is true that agents reduce their screening during collateral booms, and therefore make their investment decisions in a less informed manner. But generating this information is costly! In other words, the availability of collateral enables the economy to switch to a cheaper investment technology, albeit one that leads to more disperse outcomes.

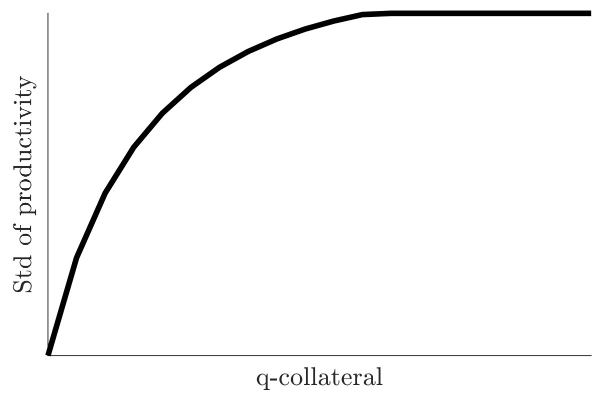


Figure 7: **Effects of collateral on misallocation when $\rho = 1$ and $\gamma < 1$.** The figure depicts the standard deviation of productivity in the modern-sector projects as a function of collateral $q$.

# 6 Supporting evidence

We have developed a theory based on a simple premise: in order to protect themselves from prospective losses, lenders can either generate information about the quality of their borrowers' projects or they can ask their borrowers to pledge collateral. The key insight of the theory is that, from a macroeconomic perspective, the relative appeal of these two strategies depends on aggregate conditions. In particular, information production depends negatively on the aggregate availability of collateral. During collateral booms, i.e., periods in which collateral is abundant, lenders naturally rely less on information. This depletes the economy's stock of information and, because information is slow-moving, it implies that the end of a collateral boom is accompanied by a deep bust and a slow recovery.

The main implications of the theory are broadly in line with several strands of stylized evidence. First, there is widely accepted evidence that investment is increasing in the value of collateral (Chaney et al., 2012). Second, there is also evidence that the quality of lenders' information on borrowers is lower in good times (Becker et al., 2018; Lisowsky et al., 2017), which is consistent with information depletion during booms.[28] At a more aggregate level, the theory is consistent with the finding that not all credit booms are alike: in particular, credit booms that are accompanied by house price booms (Richter et al., 2017) and that are characterized by low productivity growth (Gorton and Ordoñez, 2016) – both features of collateral booms according to our model – are more likely to end in crises.

Our goal here is to go beyond this stylized evidence and focus on the prediction that is at the core of our theory: namely, increases in collateral values lead to a decline in the economy's

[28] Using Swedish data, for instance, Becker et al. (2018) find that banks are less able to predict the credit quality of borrowers in good times. Lisowsky et al. (2017), in turn, show that banks significantly reduced their collection of audited financial statements from construction firms during the US housing boom before 2008.

reliance on screening (i.e., to less information production). We test this prediction on US firm-level data. Doing so is non-trivial for at least two reasons.

First, we need to identify changes in collateral that are orthogonal to other economic conditions, such as productivity, which may affect information production on their own. Previous research has dealt with this problem (i) by identifying exogenous shocks to the value of assets, e.g., real estate, and (ii) by tracing out the effects of these shocks on firm-level outcomes. We follow the same approach here. In particular, we build on the work of Chaney et al. (2012) and use the value of US firms' real estate holdings as a proxy for their collateral. We can then interpret local variations in real estate prices as shocks to the collateral value of firms that own real estate and use this variation to measure the impact of real estate prices on screening intensity (i.e., information generation). Relative to the original paper of Chaney et al. (2012), we extend the sample period to include the post-2007 housing bust and – crucially – we focus on the effect of real estate prices on firm-level information (as opposed to their effect on investment).

Second, there is no generally agreed-upon measure of information production or screening. We rely throughout on one firm-level measure of information that has been widely used in the literature: the duration of a firm's main lending relationship. The banking literature has shown that close relationships between banks and firms facilitate monitoring and screening, generating information about borrowers. Such information is gathered over time through multiple interactions (Slovin, Sushka and Polonchek, 1993; Petersen and Rajan, 1995; Berger and Udell, 1995). It has recently been shown that long-lasting relationships between firms and their banks "insulate" the firms and make their investment less sensitive to fluctuations in the value of collateral (Anderson, Bahaj, Chavaz, Foulis and Pinter, 2018).[29] But our theory predicts that the duration of firm-bank relationships is itself endogenous, and should be negatively affected by the value of collateral. We test this prediction by using data from the syndicated loan market.[30]

[29]This finding is consistent with our model's central mechanism that screening helps alleviate agency frictions and thereby mutes the dependence of investment on collateral values.

[30]In Appendix B, we show that our results remain valid under an alternative firm-level measure of information: the number of financial analysts that follow a particular firm. Similar to screening in our model, financial analysts produce and disseminate information by aggregating and consolidating it in a way that is more easily digestible for less sophisticated investors (Huang and Stoll, 1997; Chang, Dasgupta and Hilary, 2006). Through the lens of our theory, we should therefore expect the number of analysts that follow a firm to be decreasing in the value of the firm's collateral, which we confirm in the data.

## 6.1 Empirical specifications

Formally, we estimate – for firm $i$, at date $t$, with headquarters in location $k$ (or MSA) – the following equation:

$$Relationship_{it} = \alpha_i + \delta_t + \beta \cdot RE_{it} + \gamma \cdot P_{kt} + controls_{it} + \varepsilon_{it}, \tag{47}$$

where $Relationship_{it}$ is a measure of the duration of firm $i$'s main lending relationships, $RE_{it}$ is the ratio of the market value of real estate assets in year $t$ to lagged property, plant and equipment, and $P_{kt}$ controls for the level of (residential) real estate prices in location $k$ (at state or MSA level) in year $t$. The inclusion of $P_{kt}$ should allow us to disentangle the collateral effect of a firm's real estate from the general effect of house prices on the local economy, including their effect on banking conditions. Our prediction is that $\beta < 0$ and significant. In other words, increases in the value of collateral should be associated with a decline of information on firm $i$ as measured through the duration of its lending relationships.

There are two potential sources of endogeneity in the estimation of Equation (47): (i) real estate prices may be correlated with information, and; (ii) a firm's decision to own real estate may be correlated with information as measured through the duration of its lending relationships. To address the first, we estimate as a first stage – for MSA $k$, at date $t$ – the following regression predicting real estate prices $P_{kt}$:

$$P_{kt} = \alpha_k + \delta_t + \gamma \cdot Elasticity_k \times R_t + \upsilon_{kt}, \tag{48}$$

where $Elasticity_k$ measures constraints on land supply at the MSA level (taken from Saiz (2010)), $R_t$ is the nationwide real interest rate at which banks refinance their home loans, $\alpha_k$ is an MSA fixed effect, and $\delta_t$ captures macroeconomic fluctuations in real estate prices. Low values of local housing supply elasticity correspond to MSAs with relatively constrained land supply. We expect the coefficient $\gamma$ to be positive, indicating that the positive effect of declining interest rates on prices is stronger in MSAs with less elastic supply. To address the second source of endogeneity we follow Chaney et al. (2012), who use the same setup to study firm investment and control for initial characteristics of firm $i$, denoted by $X_i$, interacted with real estate prices $P_{kt}$. Vector $X_i$ includes controls that are likely to influence the decision to own real estate: five quintiles of age, assets, return on assets, two-digit industry dummies, and state dummies.

## 6.2 Data

Our analysis uses accounting data from COMPUSTAT on US listed firms, merged with real estate prices at the state and Metropolitan Statistical Area (MSA) level, and bank relationship information from LPC Dealscan. The sample period is 1993 to 2016. For a detailed description of the construction of the dataset and definitions of the control variables, see Appendix B.1.

Our measure of information is the duration of the firm's main lending relationships, expressed in years. To construct this measure, which captures the duration of the firm's lending relationships with its main banks, we use data from the syndicated loans market. Specifically, we obtain data on the characteristics of syndicated loan deals, the lead arranger, and the participant lenders from LPC's Dealscan.[31] Our relationship measure is volume-weighted by loan amount across all main-bank relationships of the firm. It is this measure that we denote by $Relationship_{it}$ in Equation (47), and we interpret it as a proxy for the stock of information on firm $i$ at time $t$.

Appendix B.2 Table 3 presents the descriptive statistics of our regression variables. In our sample, real estate is a sizable fraction of the tangible assets that corporations hold on their balance sheet. For the median firm in the sample, the market value of real estate represents 26 percent of the book value of Property, Plants and Equipment. As for relationship length, there is a significant variation across firms: the median main bank relationship is 1.8 years, with an interquartile range of 5.5 years.

## 6.3 Empirical results

Table 1 presents estimates of various specifications of Equation (47). The regression results support our central prediction that collateral price increases are associated with a decline in the duration of a firm's main banking relationships.

Column 1 reports the baseline results, which correspond to the specification in which real estate prices are measured at the state level. In this case, the coefficient of interest equals $-0.09$, which implies that each additional percentage-point increase in real estate collateral (relative to PPE) decreases the length of the firm's main banking relationship by 0.09 years, or 1.1 months. The effect is economically substantial: it suggests that a one-standard deviation increase in real estate collateral lowers the average duration of the banking relationship by 13.5 percent of its standard deviation.[32] Column 2 uses residential prices measured at the MSA level instead of at the state level. The results remain qualitatively similar. Column 3 shows

[31] This dataset on syndicated loans has been widely used in the academic literature; see, for example, Sufi (2007), Ivashina (2009) and Ivashina and Scharfstein (2010).

[32] The sample standard deviation of $RE_{it}$ is 1.44 and that of $ln(1 + Relationship_{it})$ is 0.96.

Table 1: **Information and collateral**

| VARIABLES | (1)<br>Relationship<br>OLS | (2)<br>Relationship<br>OLS | (3)<br>Relationship<br>IV |
|---|---|---|---|
| RE Value (State Prices) | -0.0897*** | | |
| | (0.00820) | | |
| RE Value (MSA Prices) | | -0.0750*** | -0.0811*** |
| | | (0.00802) | (0.00889) |
| State Prices | -1.122 | | |
| | (1.229) | | |
| MSA Prices | | 2.117 | -2.980*** |
| | | (3.527) | (0.983) |
| Cash | 0.00647** | 0.00483 | 0.00448 |
| | (0.00317) | (0.00330) | (0.00338) |
| Market/Book | -0.0230*** | -0.0242*** | -0.0208*** |
| | (0.00396) | (0.00425) | (0.00445) |
| Initial Controls x State Prices | Yes | No | No |
| Initial Controls x MSA Prices | No | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes |
| Observations | 23 950 | 20 502 | 17 632 |
| Adjusted R-squared | 0.656 | 0.652 | 0.656 |

Notes: The table reports the empirical link between the value of real estate assets and information at the firm level. The dependent variable is ln(1+R), where R is the volume-weighted duration of the firm's main bank relationship, expressed in number of years, computed using data from LPC Dealscan. RE Value is the ratio of the market value of real estate assets normalized by the lagged value of PPE. Column 1 uses state-level residential prices, while Columns 2 and 3 use MSA-level residential prices. All regressions control for Cash, previous year Market/Book, and firm-level initial characteristics (five quintiles of age, asset, and ROA, as well as two-digit industry and state of location) interacted with Real Estate Prices. Column 3 presents IV estimates where MSA residential prices are instrumented using the interaction of real mortgage rate interacted with the local elasticity of land supply taken from Saiz (2010) (see column 1 in Table 4 for the first-stage regressions). All specifications use year and firm fixed effects and cluster observations at the state-year or MSA-year level. Standard errors are in parentheses. Sample period is 1993 to 2016. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

results of the IV regression in which real estate prices are instrumented using the interaction of interest rates and local housing supply elasticity. More specifically, predicted prices from the estimation of Equation (48) are used as an explanatory variable in Equation (47). The IV estimate of the coefficient on real estate collateral is close to the OLS estimate and statistically significant at the 1 percent level. The first-stage regression estimates of Equation (48) are presented in Appendix B.2 Table 4 and confirm the findings of Chaney et al. (2012), even though the impact of local housing supply elasticity on housing prices is somewhat reduced in our extended sample period. As expected, we find that the positive effect of declining interest rates on real estate prices is stronger in MSAs with less elastic supply.

Results are robust to not weighting the relationship measure by the volume of loans and to dropping the initial three years from the sample to remove the influence of firms that start with an initial relationship value of zero (see Columns 1 and 2 of Appendix B.2 Table 5). Moreover, as expected, results are stronger for smaller firms (total assets below 1 billion US dollars) and for firms without a credit rating, for which information frictions are likely to be more pronounced (see Columns 3 and 4 of Appendix B.2 Table 5). Finally, our results are qualitatively unaltered when using the number of financial analysts that follow a particular firm as an alternative firm-level measure of information (see Appendix B.2 Table 6).

Taken together, these results suggest that the firm-level evidence from the US is consistent with the central prediction of the theory: increases in collateral are associated with a decline in firm-level information, as measured through the duration of firms' main banking relationships. Interpreted through the lens of our theory, these results imply that long-standing banking relationships – and the information that they generate – are less valuable for firms when they have abundant collateral, presumably because collateral enables them to obtain credit at favorable terms even from lenders who do not have much information about them.

# 7 Conclusions

This paper has developed a new theory of information production during credit booms. The main insight of the theory is that collateral-driven credit booms are likely to end in deep recessions. The reason is that the abundance of collateral reduces incentives to produce information, which proves costly when collateral values fall. The theory is consistent with existing stylized evidence on the relaxation of lending standards during credit booms, and on the increase and reallocation of investment during real estate booms. We have also provided supporting evidence for the theory's core mechanism using US firm-level data.

Crucially, the theory developed here implies that not all credit booms are alike: in particular, booms that are driven by high collateral values are more likely to end in deep recessions than those driven by productivity. And it suggests that, in order to understand the macroeconomic effects of credit booms, it is crucial to assess their effects on information production. We have taken a first step in this direction by analyzing different proxies for information at the firm level. But much more remains to be done. Constructing a reliable macroeconomic measure of information production, or – equivalently – of screening intensity, should be instrumental in understanding the nature of different credit booms and their effects. This is a promising and exciting line of research going forward.

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# A Appendix: Derivations for Sections 2-5

## A.1 The planner's problem

The planner's objective is to maximize the expected present discounted value of aggregate consumption net of screening costs, $E_0 \sum_{t=0}^{\infty} R^{-t} C_t$. Consider the consumption goods available to the planner at time $t$. First, there is total output, given by $A_t \cdot \left(K_t^G + K_t^U\right)^{\alpha} + a \cdot (\bar{K} - K_t^G - K_t^U)$. Second, the planner must devote $\int_0^{s_t} \psi(x)dx$ resources for screening if she is to screen $s_t$ projects. Finally, the planner can borrow $f_t$ consumption goods from the international market, and she must repay $R_t \cdot f_{t-1}$ if she has borrowed $f_{t-1}$ at time $t-1$, which has the property that $E_{t-1} R_t = R$, i.e., the international financial market breaks even. Therefore, the aggregate consumption at time $t$ is given by:

$$C_t = A_t \cdot \left(K_t^G + K_t^U\right)^{\alpha} + a \cdot (\bar{K} - K_t^G - K_t^U) - \int_0^{s_t} \psi(x)dx + f_t - R_t \cdot f_{t-1} + q_t. \quad (49)$$

We impose the transversality condition, $\lim_{t\to\infty} R^{-t} f_{t-1} = 0$, and suppose that $f_{-1} = 0$. This immediately implies that:

$$E_0 \sum_{t=0}^{\infty} R^{-t} C_t = E_0 \sum_{t=0}^{\infty} R^{-t} \cdot \left( A_t \cdot \left(K_t^G + K_t^U\right)^{\alpha} + a \cdot (\bar{K} - K_t^G - K_t^U) - \int_0^{s_t} \psi\left(x\right) dx + q_t \right). \quad (50)$$

The recursive formulation in the text is then obtained by simply defining the planner's value at time $t$ to be:

$$V_t \equiv E_t \sum_{\tau=t}^{\infty} R^{-(\tau-t)} \cdot \left( A_\tau \cdot \left(K_\tau^G + K_\tau^U\right)^{\alpha} + a \cdot (\bar{K} - K_\tau^G - K_\tau^U) - \int_0^{s_\tau} \psi\left(x\right) dx + q_\tau \right). \quad (51)$$

The first-order conditions to the planner's problem of maximizing (36) subject to the constraints (37)-(39) yield:

$$\frac{\psi\left(s_t\right)}{\mu} = R^{-1} \cdot E_t \frac{\partial V\left(\varphi_{t+1}^G, q_{t+1}, A_{t+1}\right)}{\partial \varphi_{t+1}^G} \quad (52)$$

and

$$\frac{\partial V\left(\varphi_t^G, q_t, A_t\right)}{\partial \varphi_t^G} = \left(\alpha \cdot A_t \cdot (\kappa \cdot \varphi_t^G + K_t^U)^{\alpha-1} - a\right) \cdot \widehat{\kappa}_t + (1-\rho) \cdot R^{-1} \cdot E_t \frac{\partial V\left(\varphi_{t+1}^G, q_{t+1}, A_{t+1}\right)}{\partial \varphi_{t+1}^G} \quad (53)$$

for all $t$ and $h^t$, where $\widehat{\kappa}_t$ is defined in Equation (41).

Combining these, we get Equation (40) in the main body of the paper, which together with

(37)-(39) and the transversality condition, $\lim_{t\to\infty} R^{-t}\psi(s_t) = 0$, characterizes the solution to the planner's problem.

## A.2 Frictional markets and learning-by-doing

In this section, we explore two distortions that prevent entrepreneurs from fully appropriating the benefits of information production.

A first set of distortions are those that directly affect the market for screened projects. Assume for instance that – instead of being perfectly competitive – trading in this market is attained by matching: every time an old entrepreneur goes to the market, she is matched with a young entrepreneur and they bargain over the price. The surplus from the transaction is $\frac{\psi(s_t)}{\mu}$, and let us assume that the buyer manages to extract a fraction $\beta$ of this surplus. In this setting, the zero-profit condition for screened projects becomes:

$$\frac{\psi\left(s_t\right)}{\mu} = \frac{E_t\left\{r_{t+1} - a\right\} \cdot \kappa + (1-\beta) \cdot (1-\rho) \cdot \frac{E_t \psi(s_{t+1})}{\mu}}{R}, \tag{54}$$

whereas the planner's solution, which depends only on total consumption regardless of its distribution, remains as in the baseline model. Because it prevents entrepreneurs from fully capturing the value of screening upon resale, the matching friction reduces screened investment in the decentralized equilibrium. And given that the planner's solution is unaffected, it is now possible (if $\beta$ is high enough) for information production to be inefficiently low in equilibrium.

A second set of distortions are those that directly affect the technology for screening, such as the presence of dynamic economies of scale. Namely, suppose that $\psi_t = \psi\left(s_t, \varphi_t^G\right)$ with $\psi_1 > 0 > \psi_2$ and $\psi_1 + \frac{\mu}{\rho}\psi_2 > 0$: relative to our baseline model, the assumption that $\psi_2 < 0$ can be interpreted as capturing economy-wide "learning-by-doing," so that the experts' cost of screening projects falls with the cumulative amount of screening done in the past. In this setting, it is the zero-profit condition of individual entrepreneurs that remains unchanged, whereas the planner's optimality condition becomes:

$$\frac{\psi\left(s_t, \varphi_t^G\right)}{\mu} = \frac{E_t\{r_{t+1} - a\} \cdot \widehat{\kappa}_t + (1-\rho) \cdot \frac{E_t \psi\left(s_{t+1}, \varphi_{t+1}^G\right)}{\mu}}{R} + \frac{E_t \int_0^{s_{t+1}} \psi_2(x, \varphi_{t+1}^G) dx}{R}. \tag{55}$$

Agents in the decentralized economy do not internalize the learning-by-doing externality, but the planner does. As reflected in the last term of Equation (55), the planner understands that, by raising screening today, she reduces the expected cost of screening in period $t+1$. Once again, if this effect is strong enough, it is possible for information production to be inefficiently low in equilibrium.

## A.3 Credit booms and factor misallocation

The system of equations that characterizes the equilibrium of this modified economy is as follows. First, using the fact that the marginal product of labor will be equalized across $G$- and $U$-type projects and combining this with market clearing for labor, we can express the aggregate output of the economy as follows:

$$Y_t = A_t \cdot \left( K_t^G + \bar{\gamma}^{\frac{1}{\alpha}} \cdot K_t^U \right)^{\alpha} + a \cdot \left( \bar{K} - K_t^G - K_t^U \right), \tag{56}$$

where $\bar{\gamma} \equiv \mu + (1-\mu) \cdot \gamma$. The stock of capital in unscreened projects is given by:

$$K_{t+1}^U = \min \left\{ \frac{R}{a - \mu \cdot \bar{\gamma}^{\frac{1-\alpha}{\alpha}} \cdot E_t r_{t+1}} \cdot q_t, \quad \left( \left[ \frac{\alpha \cdot E_t A_{t+1} \cdot \bar{\gamma}^{\frac{1}{\alpha}}}{a} \right]^{\frac{1}{1-\alpha}} - K_{t+1}^G \right) \cdot \frac{1}{\bar{\gamma}^{\frac{1}{\alpha}}} \right\}, \tag{57}$$

where $r_{t+1} \equiv \alpha \cdot A_{t+1} \cdot \left( K_{t+1}^G + \bar{\gamma}^{\frac{1}{\alpha}} \cdot K_{t+1}^U \right)^{\alpha - 1}$. The stock of capital in screened projects is:

$$K_{t+1}^G = \min \left\{ \kappa \cdot \varphi_{t+1}^G, \quad \left[ \frac{\alpha \cdot E_t A_{t+1}}{a} \right]^{\frac{1}{1-\alpha}} - \bar{\gamma}^{\frac{1}{\alpha}} \cdot K_{t+1}^U \right\}, \tag{58}$$

where the stock of information evolves according to:

$$\varphi_{t+1}^G = \mu \cdot s_t + (1-\rho) \cdot \varphi_t^G \tag{59}$$

and screening satisfies:

$$\frac{\psi(s_t)}{\mu} = \frac{(E_t r_{t+1} - a) \cdot \kappa + (1-\rho) \cdot \frac{E_t \psi(s_{t+1})}{\mu}}{R}. \tag{60}$$

The above system fully characterizes the evolution of capital within each sector, its allocation within the modern sector, as well as the evolution of screening and total output. Using these, the variance of TFP across modern-sector projects relative to the average is given by:

$$VAR_{TFP,t} = \frac{K_t^G + \mu \cdot K_t^U}{K_t^G + K_t^U} \cdot \left( \frac{A_t}{\bar{A}_t} - 1 \right)^2 + \frac{(1-\mu) \cdot K_t^U}{K_t^G + K_t^U} \cdot \left( \gamma \cdot \frac{A_t}{\bar{A}_t} - 1 \right)^2, \tag{61}$$

where $(1-\mu) \cdot K_t^U$ denotes the capital stock employed in $U$-type projects that are of $B$-quality, and $\bar{A}_t$ denotes the average productivity of projects in the modern sector:

$$\bar{A}_t = \frac{K_t^G + K_t^U \cdot \bar{\gamma}}{K_t^G + K_t^U} \cdot A_t. \tag{62}$$

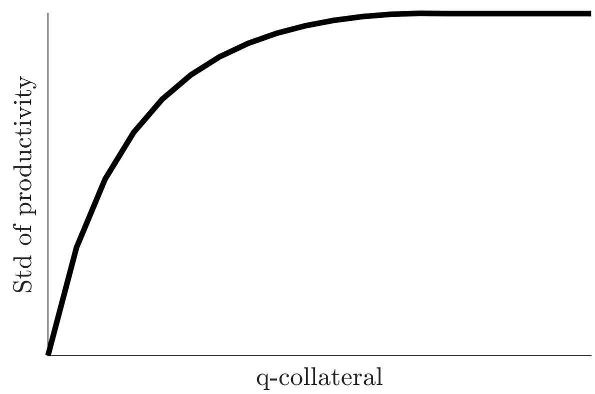


Figure 8: **Effects of collateral on misallocation when $\rho = 1$ and $\gamma > 1$.** The figure depicts the standard deviation of productivity in the modern-sector projects as a function of collateral $q$.

Noting that

$$\frac{A_t}{\bar{A}_t} - 1 = \frac{(1-\mu) \cdot K_t^U}{K_t^G + K_t^U \cdot \bar{\gamma}} \cdot (1-\gamma) \tag{63}$$

and

$$\gamma \cdot \frac{A_t}{\bar{A}_t} - 1 = \frac{K_t^G + \mu \cdot K_t^U}{K_t^G + K_t^U \cdot \bar{\gamma}} \cdot (\gamma - 1), \tag{64}$$

we can write Equation (61) as:

$$VAR_{TFP,t} = \left(k_t^G + \mu\right) \cdot (1-\mu) \cdot \left[\frac{1-\gamma}{k_t^G + \bar{\gamma}}\right]^2, \tag{65}$$

where $k_t^G \equiv \frac{K_t^G}{K_t^U}$.

The variance of productivity across projects depends only on the ratio of the capital stock employed in $G$-type projects to the capital stock employed in $U$-type projects, $k_t^G$. Formally,

$$\frac{\partial VAR_{TFP,t}}{\partial k_t^G} < 0 \iff k_t^G + \mu > (1-\mu) \cdot \gamma, \tag{66}$$

which is the same as condition (46). Thus, an increase in $K_t^G / K_t^U$ reduces misallocation if and only if the productivity-weighted stock of capital that is employed in $G$-quality projects (i.e., $K_t^G + \mu \cdot K_t^U$) is greater than the productivity-weighted capital stock employed in $B$-quality projects (i.e., $\gamma \cdot (1-\mu) \cdot K_t^U$). In this case, an increase in $K_t^G$ (or, a reduction in $K_t^U$) adds (eliminates) a productivity-weighted unit of capital that is similar to (different from) the average and, in so doing, it reduces dispersion in productivity.

Note that condition (66) does not depend on whether $\gamma$ is greater or smaller than one. Figure 8 illustrates this by depicting the standard deviation of TFP in the modern-sector

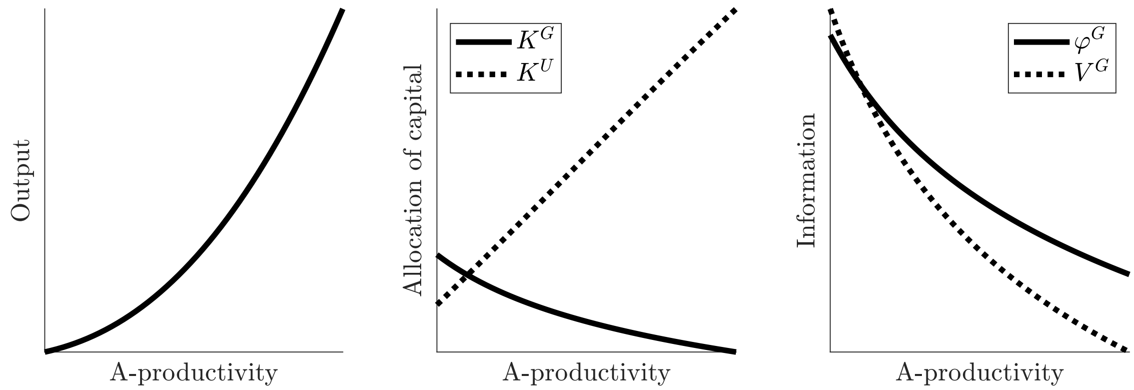


Figure 9: **Effects of productivity when $\rho = 1$ and $q_t = \varepsilon \cdot w_t$.** The figure depicts the output, the allocation of capital in the modern-sector projects, and the stock and price of information as a function of productivity $A$. The variables are expressed in deviation from their counter-factual values in an economy where $q_t$ is exogenous and fixed at its baseline value.

projects when all parameter values are unchanged relative to Figure 7 in the main body of the text, with the exception of $\gamma$ that is assumed to be greater than one. As we can see, nothing changes qualitatively relative to Figure 7.

## A.4 Productivity vs collateral

In this section, we consider a modified version of our model in which collateral is endogenous. In particular, we assume that, instead of trees, each young entrepreneur is endowed with $\varepsilon \in (0, 1)$ units of labor during youth (households are then endowed with the remaining $1 - \varepsilon$ units). In equilibrium, therefore, her labor income is given by $\varepsilon \cdot w_t = \varepsilon \cdot A_t \cdot (1-\alpha) \cdot (\sum_m K_t^m)^\alpha$.

The equilibrium of this modified economy is essentially unchanged, since as before it is characterized by Equations (5), (11), and (21)-(26) with the only exception that $q_t$ in Equation (22) is replaced by $\widetilde{q}_t \equiv \varepsilon \cdot w_t$. We can therefore immediately see the effects of changes in productivity. An increase in realized productivity $A_t$ (holding $E_t A_{t+1}$ fixed) has exactly the same effect as an increase in collateral values in our baseline model: it boosts modern-sector investment but crowds out information production. Instead, as in our baseline model, an increase in expected productivity $E_t A_{t+1}$ (holding $A_t$ fixed) boosts modern-sector investment and information production.

To illustrate that the information depletion effect of collateral is still present in this economy, Figure 9 plots the economy's output, the allocation of capital and the price and stock of information *relative* to our baseline model, as a function of $A$. As we can see, these comparative statics resemble those of our baseline economy depicted in Figure 1. Namely, through its effect on collateral values, a rise in productivity now further boosts output and generates a reallocation of economic activity from screened to unscreened projects, due to information depletion.

## A.5 Privately informed entrepreneurs

We now show our main qualitative results remain robust to the presence of asymmetric information between entrepreneurs and lenders. We modify our baseline setup along two dimensions. First, we assume that before investing entrepreneur knows the quality $\theta$ of each of her projects; thus, entrepreneurs effectively choose what type of project to produce. Second, we assume that $B$-type project allows an entrepreneur to divert a fraction $1-\omega$ of its resources for private consumption; as before $G$-type projects do not permit diversion. Given the above modifications, the following equilibrium properties are straightforward to derive.

Entrepreneurs only produce and screen $G$-quality projects, and there must be zero profits on these units:

$$\psi\left(s_t\right) = \frac{E_t\left\{r_{t+1} - a\right\} \cdot \kappa + (1-\rho) \cdot E_t \psi\left(s_{t+1}\right)}{R}, \tag{67}$$

with

$$\varphi_{t+1}^{G} = s_t + (1-\rho) \cdot \varphi_t^{G}. \tag{68}$$

Comparing with Equations (23)-(24), we note the first difference from our baseline model. Because entrepreneurs know the quality of each project ex-ante, in order to produce a unit of $G$-type project, they only need to screen one unit (rather than $\mu^{-1}$ units). As a result, the price or the production cost of each unit of $G$-type project is now $\psi_t$ (rather than $\frac{\psi_t}{\mu}$).

Entrepreneurs finance unscreened projects with collateral, and lenders will (correctly) infer that all such units are of $B$-quality:

$$K_{t+1}^{U} = \min\left\{\frac{R}{a - \omega \cdot E_t\left\{r_{t+1}\right\}} \cdot q_t,\ \left(\frac{\alpha \cdot E_t A_{t+1}}{a}\right)^{\frac{1}{1-\alpha}} - K_{t+1}^{G}\right\}. \tag{69}$$

Comparing with Equation (22), we note the second difference from our baseline model. Because entrepreneurs know the quality of each unit ex-ante, they will never produce $B$-quality project and screen it. The lenders will (correctly) anticipate that all unscreened units are of $B$-quality; if they thought otherwise, entrepreneurs would have an incentive to produce only $B$-quality projects to increase resource diversion, implying that lenders would make losses. Thus, the lenders fund unscreened units with the anticipation that only a fraction $\omega$ of their revenues can be extracted from the entrepreneur.

Finally, as before, the allocation of capital to $G$-type projects is given by Equation (25) and the marginal product of capital is given by Equation (11). Despite the above differences, it is clear that the qualitative behavior of this model is the same as that of our baseline model.

## A.6 Parameter values used for illustrations

In Table 2, we report the parameter values used to produce all the illustrative figures. The functional form for the cost of screening is as follows: $\psi(s_t) = \psi_0 \cdot s_t^{\psi_1}$.

Table 2: **Parameter values**

| | | |
|---|---|---|
| $\alpha$ | 0.6 | Capital share in the modern sector |
| $\rho$ | 0.25 | Rate of project obsolescence |
| $\mu$ | 0.4 | Probability to draw a good quality project (G) |
| $a$ | 0.7 | TFP in the traditional sector |
| $\kappa$ | 0.8 | Project capacity constraint |
| $\bar{K}$ | 5 | Stock of capital |
| $R$ | 1.02 | International interest rate |
| $\psi_0$ | 0.5 | Parameter of the inverse cdf of screening costs |
| $\psi_1$ | 1.5 | Parameter of the inverse cdf of screening costs |
| $\beta$ | 0.8272 | Growth of collateral/productivity in booms |
| $\lambda_L$ | 0.1 | Probability for a boom to start |
| $\lambda_H$ | 0.1 | Probability for a boom to end |
| **Collateral boom** | | |
| $\overline{q}$ | 0.151 | High collateral state |
| $\underline{q}$ | 0.15 | Low collateral state |
| $A$ | 1 | TFP in the modern sector |
| **Productivity boom** | | |
| $q$ | 0.01 | Value of collateral |
| $\overline{A}$ | 2.01 | High productivity state |
| $\underline{A}$ | 2 | Low productivity state |
| **Static model** | | |
| $\mu$ | 0.5 | Probability to draw a good quality project (G) |
| $a$ | 0.9 | TFP in the traditional sector |
| $\kappa$ | 1 | Project capacity constraint |
| $q$ | 0.06 | Value of collateral when fixed |
| $\gamma$ | $\in \{0.95, 1, 1.05\}$ | Productivity of B-quality projects |
| $\varepsilon$ | 0.3 | Entrepreneurs' share of aggregate labor supply |

# B Appendix: Data, Variables, and Empirical Analysis

## B.1 Data and variable definitions

This section describes the dataset and definitions of the variables used in the empirical analysis in Section 6. The dataset is the same as in Chaney et al. (2012) with two exceptions: we add measures of information and we expand the sample to 2016 in order to cover the post-2007 housing bust. As in Chaney et al. (2012), we start the sample in 1993 because the accumulated depreciation on buildings is not available in COMPUSTAT after 1993. We include firms headquartered in the United States and exclude firms operating in the construction, finance, insurance, real estate, and mining sectors. We keep only firms that appear at least three consecutive years in the sample. This leaves a sample of 3,126 firms and 35,346 firm-year observations for the period 1993 to 2016.

*Information.* We compute the volume-weighted average length of the firm's main bank relationship, expressed in years, at the monthly level using data from LPC Dealscan. Because we need information on the history of loan transactions to construct a measure of lending relationships over our sample period, we use Dealscan data starting in 1985 which is the first year with adequate coverage in the Dealscan dataset. We restrict the sample to US borrowers and syndicated loans issued in US dollars with a defined facility amount and maturity. Following Sufi (2007), we define a lender as lead lender if the variable "Lead Arranger Credit" takes on the value of "Yes," and if the lender is the only bank specified in the loan deal.

As syndicated loan contracts often consist of multiple tranches, each with at least one lead lender, it is common for multiple banks to be registered as lead banks on the same deal. In such cases, we select the "main" lead bank in two steps. First, we filter for the lead banks whose contracts offer the longest loan maturity. Second, we choose among these banks the ones with the largest amount pledged. In those cases where this algorithm leads to multiple 'lead bank-borrower pairs', we treat those as distinct syndicated loans.

As 'lead bank-borrower pairs' interact repeatedly with each other, it is necessary to evaluate information production over the pairs' entire relationship history. We compute the duration of the lending relationship as the difference between the pairs' latest loan contract expiration date and the earliest loan contract signing date, expressed in years. However, when borrowers switch lead banks, we reset this variable to zero for all bank-borrower pairs without active relationships (i.e., no credit outstanding). Moreover, this variable drops to zero whenever the last loan contract in our sample expires and there are no new lending relationships. To smooth this transition, in such cases we set this variable equal to its last positive observation for up to three more years. Our results however are not affected by this adjustment.

To aggregate this relationship variable at the bank-firm level into an information measure at the firm level, the relationship measure is volume-weighted by the respective amount pledged for each 'lead bank-borrower pair' relative to the total loan amount received by each borrower. Loan amounts are expressed in real terms using the US GDP deflator obtained from the US Bureau of Economic Analysis. We follow Chava and Roberts (2008) to merge our relationship measure to COMPUSTAT.

We construct the analyst coverage variable using data on the number of analysts who make annual earnings forecasts for a firm in a given month using data from the I/B/E/S Historical Summary Files. We define the Analyst variable as the maximum number of analysts who make annual earnings forecasts for a given firm in any month during the year.

*Market value of real estate assets.* RE Value is the ratio of the market value of real estate assets normalized by the lagged value of Property, Plant and Equipment (PPE) (COMPUSTAT item No. 8). Real estate assets include buildings, land and improvement, and construction in progress. These assets are valued at historical cost. To impute their market value, we follow the procedure in Chaney et al. (2012), which calculates the average age of these assets and uses historical prices to compute their current market value. The ratio of the accumulated depreciation of buildings (COMPUSTAT item No. 253) to the historic cost of buildings (COMPUSTAT item No. 263) measures the fraction of the initial value of a building that has been depreciated. We impute the average age of real estate assets by assuming that these assets depreciate over 40 years, and we infer the market value of these real estate assets by inflating their historical cost with state-level residential real estate inflation after 1975, and CPI inflation before 1975. We use the headquarter location (COMPUSTAT variables STATE and COUNTY) as a proxy for the location of real estate.

*Real estate prices and land supply.* We use data on residential real estate prices, both at the state and at the MSA level. Residential real estate prices come from the Office of Federal Housing Enterprise Oversight (OFHEO). The OFHEO Home Price Index (HPI) is a broad measure of single-family home prices in the United States. We match the state level HPI to our main dataset using the state identifier from COMPUSTAT. To match the MSA level HPI, we link Federal Information Processing Standards codes from COMPUSTAT to MSA identifiers using a correspondence table obtained from OFHEO.

Following Chaney et al. (2012), we instrument local real estate prices using the interaction of long-term interest rates and local housing supply elasticity. Local housing supply elasticities for a total of 95 MSAs are obtained from Saiz (2010). These elasticities capture the amount of local land that can be developed and are estimated using satellite-generated images of the terrain. We measure long-term interest rates using the 30-year conventional mortgage rate from the Federal Reserve's FRED database.

*Control variables.* We compute cash holdings as the ratio of cash flows (COMPUSTAT item

No. 18 plus item No. 14) to lagged PPE. Market-to-Book ratio is the total market value of equity divided by the book value of assets (COMPUSTAT item No. 6). The market value of equity is calculated by multiplying the number of common stocks (COMPUSTAT item No. 25) by the year-end closing price of common shares (COMPUSTAT item No. 24) plus the book value of debt and quasi equity, computed as book value of assets minus common equity (item No. 60) minus deferred taxes (COMPUSTAT item No. 74). We use the one year lagged value of the market-to-book ratio in the regression. Following Chaney et al. (2012), we include initial firm characteristics to control for potential firm heterogeneity. These controls, measured in 1993, are Return on Assets (operating income before depreciation (COMPUSTAT item No. 13) minus depreciation (COMPUSTAT item No. 14) divided by the book value of assets, Size measured as the natural logarithm of the book value of assets, Age measured as number of years since initial public offering (IPO), two-digit SIC codes and state of headquarters' location. All variables defined in terms of ratios are winsorized at five times the interquartile range from the median.

## B.2 Additional figures and tables for the empirical analysis

Table 3 reports the descriptive statistics, Table 4 reports the first-stage regression results, Table 5 reports additional robustness tests and, finally, Table 6 reports the results with the alternative Analyst measure for information.

Table 3: **Summary statistics**

| | Mean | Median | SD | 25th percentile | 75th percentile | Obs. |
|---|---|---|---|---|---|---|
| Firm-level data | | | | | | |
| Relationship | 3.39 | 1.75 | 4.26 | 0.00 | 5.50 | 26 599 |
| Analysts | 7.93 | 5.00 | 7.46 | 2.00 | 11.00 | 19 921 |
| Cash | 0.04 | 0.26 | 1.78 | -0.09 | 0.63 | 35 204 |
| Market / Book | 2.16 | 1.52 | 1.76 | 1.10 | 2.42 | 32 512 |
| RE Value (State Prices) | 0.89 | 0.26 | 1.44 | 0.00 | 1.14 | 35 430 |
| RE Value (MSA Prices) | 0.88 | 0.26 | 1.42 | 0.00 | 1.13 | 34 892 |
| Regional data | | | | | | |
| State Prices | 0.29 | 0.26 | 0.11 | 0.21 | 0.35 | 1 031 |
| MSA Prices | 0.14 | 0.14 | 0.04 | 0.11 | 0.17 | 3 641 |
| Housing Supply Elasticity | 1.66 | 1.45 | 0.87 | 1.01 | 2.10 | 1 632 |
| Initial firm-level data (1993) | | | | | | |
| Age | 8.09 | 8.00 | 4.66 | 3.00 | 13.00 | 2 855 |
| ROA | -0.01 | 0.07 | 0.25 | -0.04 | 0.12 | 2 844 |
| Log(Asset) | 4.05 | 3.96 | 2.19 | 2.58 | 5.46 | 2 852 |

Notes: Relationship is the volume-weighted average length of the firm's relationship with its main bank, expressed in number of years, computed using data from LPC Dealscan. Analysts is the maximum number of analysts who make annual earnings forecasts in any month over the year, computed following Chang, Dasgupta and Hilary (2006) using data from the I/B/E/S Historical Summary File. Cash is defined as income before extraordinary items + depreciation and amortization (item No. 14 + item No. 18) normalized by lagged PPE (item No. 8). Market / Book is defined as the market value of assets (item No. 6 + (item No. 60 x item No. 24) – item No. 60 – item No. 74) normalized by their book value (item No. 6). RE Value is the ratio of the market value of real estate assets normalized by lagged PPE, computed as in Chaney, Sraer and Thesmar (2012). ROA is defined as operating income before depreciation minus depreciation and amortization normalized by total assets ((item No. 13 – item No. 14) /item No. 6). Age is the number of years since IPO. MSA / State Prices is the level of the MSA / State OFHEO real estate price index, normalized to 1 in 2006. Housing Supply Elasticity comes from Saiz (2010). Sample period is 1993 to 2016.

Table 4: **First-stage regression: the impact of local housing supply elasticity on housing prices**

| VARIABLES | (1)<br>MSA Prices | (2)<br>MSA Prices |
|---|---|---|
| Housing supply elasticity | 0.00990*** | |
| | (0.00274) | |
| First quartile of elasticity | | -0.0225*** |
| | | (0.00682) |
| Second quartile of elasticity | | -0.00548 |
| | | (0.00751) |
| Third quartile of elasticity | | 0.00141 |
| | | (0.00744) |
| Year FE | Yes | Yes |
| MSA FE | Yes | Yes |
| Observations | 2 232 | 2 232 |
| R-squared | 0.892 | 0.893 |

Notes: This table investigates how local housing supply elasticity, as defined by Saiz (2009), affects real estate prices, following Chaney, Sraer and Thesmar (Table 3, 2012). The dependent variable is the residential real estate price index, defined at the MSA level. Column 1 uses the local housing supply elasticity, while column 2 uses quartiles of the elasticity. All regressions control for year as well as MSA fixed effects and cluster observations at the MSA level. T-stats in parentheses. Sample period is 1993 to 2016. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 5: **Information and collateral: Robustness tests**

| VARIABLES | (1) Relationship Unweighted | (2) Relationship No initial years | (3) Relationship Small firms | (4) Relationship No credit rating |
|---|---|---|---|---|
| RE Value (MSA Prices) | -0.0778*** | -0.0633*** | -0.101*** | -0.0998*** |
| | (0.00873) | (0.0101) | (0.0110) | (0.0112) |
| MSA Prices | -3.235*** | -3.545*** | -5.066*** | -4.693*** |
| | (0.963) | (1.220) | (1.252) | (1.307) |
| Cash | 0.00461 | 0.00460 | -0.00251 | 0.000520 |
| | (0.00336) | (0.00390) | (0.00336) | (0.00336) |
| Market/Book | -0.0213*** | -0.0272*** | -0.0184*** | -0.0162*** |
| | (0.00445) | (0.00511) | (0.00482) | (0.00462) |
| Initial Controls x MSA Prices | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes | Yes |
| Observations | 17 632 | 13 877 | 12 821 | 12 760 |
| Adjusted R-squared | 0.640 | 0.678 | 0.585 | 0.592 |

Notes: The table reports robustness checks of the results on the empirical link between the value of real estate assets and information at the firm level presented in Table 1. The dependent variable is ln(1+R), where R is the volume-weighted duration of the firm's main bank relationship in number of years, except in Column 1 where the duration is unweighted. Column 1 excludes the initial years 1993 to 1995. Column 3 restricts the sample to firms with total assets below 1 billion US dollars. Column 4 restricts the sample to firms without a long-term credit rating. RE Value is the ratio of the market value of real estate assets normalized by the lagged value of PPE. MSA Prices are MSA-level residential prices. All regressions control for Cash, previous year Market/Book, and firm-level initial characteristics (five quintiles of age, asset, and ROA, as well as two-digit industry and state of location) interacted with MSA Prices. Results are IV estimates where MSA residential prices are instrumented using the interaction of real mortgage rate interacted with the local elasticity of land supply taken from Saiz (2010) (see column 1 in Table 4 for the first-stage regressions). All specifications use year and firm fixed effects and cluster observations at the MSA-year level. Standard errors are in parentheses. Sample period is 1993 to 2016. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6: **Information and collateral: Alternative measure of information**

| VARIABLES | (1) Analysts OLS | (2) Analysts OLS | (3) Analysts IV |
|---|---|---|---|
| RE Value (State Prices) | -0.136*** | | |
| | (0.00771) | | |
| RE Value (MSA Prices) | | -0.142*** | -0.154*** |
| | | (0.00838) | (0.00919) |
| State Prices | -4.992*** | | |
| | (1.415) | | |
| MSA Prices | | -14.33*** | -1.294 |
| | | (4.792) | (0.865) |
| Cash | 0.0176*** | 0.0198*** | 0.0177*** |
| | (0.00376) | (0.00415) | (0.00434) |
| Market/Book | 0.0646*** | 0.0657*** | 0.0684*** |
| | (0.00375) | (0.00410) | (0.00426) |
| Initial Controls x State Prices | Yes | No | No |
| Initial Controls x MSA Prices | No | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| Firm FE | Yes | Yes | Yes |
| Observations | 17 135 | 14 572 | 12 529 |
| Adjusted R-squared | 0.809 | 0.810 | 0.816 |

Notes: The table reports the empirical link between the value of real estate assets and information at the firm level. The dependent variable is ln(1+A), where A is the maximum number of analysts who make annual earnings forecasts in any month over a 12-month period, computed following Chang et al. (2006) using data from the I/B/E/S Historical Summary File. RE Value is the ratio of the market value of real estate assets normalized by the lagged value of PPE. Column 1 uses state-level residential prices, while Columns 2 and 3 use MSA-level residential prices. All regressions control for Cash, previous year Market/Book, and firm-level initial characteristics (five quintiles of age, asset, and ROA, as well as two-digit industry and state of location) interacted with Real Estate Prices. Column 3 presents IV estimates where MSA residential prices are instrumented using the interaction of real mortgage rate interacted with the local elasticity of land supply taken from Saiz (2010) (see column 1 in Table 4 for the first-stage regressions). All specifications use year and firm fixed effects and cluster observations at the state-year or MSA-year level. Standard errors are in parentheses. Sample period is 1993 to 2016. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.