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Rational overoptimism and limited liability ☆

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Is excessive risk-taking in credit cycles driven by incentives or biased beliefs? I propose a framework suggesting that the two are actually related and, specifically, that procyclical overoptimism can arise rationally from risk-taking incentives. I show that when firms and banks have a limited liability payoff structure, they have lower incentives to pay attention to the aggregate conditions that generate risk. This leads to systematic underestimation of the accumulation of risk during economic booms and overoptimistic beliefs. As a result, agents lend and borrow excessively, further increasing downside risk. Credit cycles driven by this new "uninformed" risk-taking are consistent with existing evidence such as high credit and low-risk premia predicting a higher probability of crises and negative returns for banks. My model suggests that regulating incentives can decrease overoptimistic beliefs and thus mitigate boom-and-bust cycles.

1. Introduction

Recent empirical studies have revived the long-held hypothesis that boom-and-bust credit cycles are driven by overoptimistic beliefs (Minsky, 1977; Kindleberger, 1978). In particular, empirical evidence suggests that high credit growth and low-risk premia are strong predictors of financial crises (Schularick and Taylor, 2012; Jordà et al., 2013; Krishnamurthy and Muir, 2017; Greenwood et al., 2022). Recent literature ascribes this evidence to overoptimistic beliefs, supported by two additional observations. First, credit booms also predict low or even negative excess returns on bank stocks (Baron and Xiong, 2017), and second, forecasts are systematically too optimistic when credit spreads are low (Bordalo et al., 2018; Gulen et al., 2019). Behavioral models of extrapolative beliefs have been particularly successful at explaining this systematic bias in belief formation and excessive risk-taking (Maxted, 2019; Bordalo et al., 2021; Krishnamurthy and Li, 2021). As a result, these models have moved the focus away from the role of risk-taking incentives, which have been previously studied in connection with the excessive risk-taking that contributed to the recent financial crisis (Boyallian and Ruiz-Verdú, 2018; Armstrong et al., 2022). In this paper, I argue that biased beliefs might be the result of risk-taking incentives.

I propose a theory in which overoptimism arises from individuals' rational decision to ignore information about the endogenous buildup of aggregate risk. Additionally, I argue that this lack of attention may be motivated by risk-taking incentives. I present

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these two contributions sequentially. First, I show how the overoptimism driving credit boom and busts stems from inattention to aggregate risk factors. I present a model in which a shock to aggregate productivity leads to an increase in borrowing and production of firms facing the same downward-sloping demand for their combined output. As competitors increase production, each firm will face a lower selling price for their output, i.e. there is strategic substitutability between firms. If firms and banks pay attention to the aggregate economy, they internalize the negative effect on revenue resulting from the increase in competition, and therefore reduce their investment and borrowing, making the economy safer. However, firms and banks that do not pay attention to aggregate investment do not internalize this competition effect and form overly optimistic expectations about their revenues.[1] As a result, these inattentive firms over-borrow and over-invest, creating excess supply in the market and further driving down prices. As firms' revenues fall short of expectations, their default risk increases. My model implies that even rational agents can be systematically optimistic during credit booms (and pessimistic in busts) due to a lack of attention.[2] Furthermore, because inattentive banks underestimate the probability of borrower default, they misprice risk and experience negative excess returns following credit booms, consistent with existing evidence (Schularick and Taylor, 2012; Krishnamurthy and Muir, 2017; Baron and Xiong, 2017).

Second, I demonstrate that inattention to risk factors can be the result of risk-taking incentives in information choice. Because agents form their beliefs rationally, I can use the model to examine the incentives that lead them to either ignore or pay attention to risk factors. I introduce limited liability in their payoffs and allow them to pay a cost access information about aggregate economic conditions.[3] The convex structure of payoffs insures agents from risk, leading to a lower marginal benefit of information and a corresponding decrease in attention to risk. Uninformed firms underestimate the increase in competition and decline in revenue after booms and are overoptimistic about their company's revenue. Importantly, I show that in my model the standard "informed" risk-taking channel produced by only limited liability in full information does not produce the procyclical risk documented in the literature. Instead, the credit boom-and-bust is due to the information channel of risk-taking incentives.

In conclusion, I find that limited liability not only leads to excessive risk-taking for given beliefs but also to neglect of risk and overoptimistic beliefs during periods of economic expansion. This finding helps to bridge the two narratives about excessive risk-taking before the financial crisis of 2008–2009: the initial criticisms of managers' moral hazard incentives (e.g. Blinder 2009) and the more recent behavioral overoptimism theory (e.g., Gennaioli and Shleifer 2018). I show that overoptimism is actually a consequence of risk-taking incentives, and therefore regulating these incentives can reduce biases in belief formation.

Since beliefs depend on incentives, my model suggests that policymakers can reduce overoptimism in credit booms by regulating incentives to collect information. When agents are informed, they reduce borrowing and investment during credit booms, mitigating economic fluctuations. Providing information through public announcement or direct communication could improve risk assessment, but it may still be costly for agents to process this information (Sims, 2003, 2006). Instead, reducing risk-taking incentives by altering payoffs, for example through regulation of managers' compensation, would not only address their "informed" excess risk-taking but also encourage them to pay attention to aggregate risk factors.

Contribution to the literature. This paper contributes to several strands of the literature. First, the theoretical research on financial crises, which can be divided into two categories. The first emphasizes the importance of behavioral bias in belief formation and credit market sentiments (Bordalo et al., 2018; Greenwood et al., 2019; Maxted, 2019; Farhi and Werning, 2020). The most related is (Bordalo et al., 2021), which incorporates extrapolative expectations in a firm dynamic model with lending and default. In their model, beliefs overreact to good news, leading to overoptimism in credit booms. In my model, overoptimism results instead from rational underreaction to bad news. As forecasts exhibit cyclical overoptimism even in a fully rational framework, this setting allows me to study how overoptimism relates to economic incentives.

A second line of research emphasizes the role of financial frictions in intermediation as sources of fragility (Gertler and Kiyotaki, 2010; He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014; He and Krishnamurthy, 2019; Jeanne and Korinek, 2019; Bianchi and Mendoza, 2020). This class of models uses full information and strategic complementarity in leverage choices to rationalize the overaccumulation of debt during booms, as individuals do not internalize the externality effects of their decision on the whole economy. In other words, investors ride the bubble as long as others ride it. Differently from them, my model features strategic substitutability and incomplete information: if investors knew about the increase in aggregate risk, they would reduce leverage and therefore reduce risk. In other words, they would like to exit the bubble before it burst. The lack of information is what leads them to accumulate risk, resulting in *unexpected* boom-and-busts, which is consistent with the existing evidence in asset prices around boom-&-bust episodes.

Finally, my paper relates to the literature on strategic games with incomplete information (Woodford, 2001; Coibion and Gorodnichenko, 2012; Maćkowiak and Wiederholt, 2015; Angeletos and Lian, 2017; Gemmi and Valchev, 2023). Similar to Kohlhas and Walther (2021), the agents in my model pay asymmetric attention to local and aggregate quantities, which gives rise to what is referred to as "extrapolative beliefs", even in a rational framework. Differently from them, the determinant of the attention allocation is not the difference in shock volatility, but risk-taking incentives. Benhima (2019) also provides a model of boom-&-bust, where overoptimistic beliefs are driven by non-fundamental noise shocks. Differently from them, in this paper agents are systematically

[1] This mechanism is consistent with the evidence in Hoberg and Phillips (2010), that market participants in competitive industries do not fully internalize the negative externality of competition on revenues.

[2] I use the term *over*optimism to highlight the fact that this optimism displayed in booms is systematically misplaced, as forecasted revenue is systematically higher than realized one.

[3] While in the model I do not take a stand on the sources of limited liability, it can originate from the convexity of manager compensation, such as option and bonuses versus stock holdings, or the payoffs of shareholders, such as loan guarantees from the government or public bailout policies.

overoptimistic even after fundamental shocks, which generate the predictive power of lower risk premia in forecasting boom-&-busts documented in the existing literature.[4] Finally, Mackowiak and Wiederholt (2012) also studies the impact of limited liability on information choice. However, they consider a simple mean-square error minimization problem, where limited liability affects only the optimal information choice but not the optimal action for a given information. This paper considers instead a macroeconomic model with strategic interactions and endogenous risk, where limited liability also affects agents' risk-taking incentives.

Structure of the paper. The remaining sections of the paper are organized as follows. Section 2 presents a model of credit booms-and-bust with information frictions, Section 3 solves the lending and investment choice problem (second stage), and Section 4 the information choice problem (first stage). Section 5 discusses policy implications and Section 6 concludes.

2. A model of inattentive credit booms

The model presented in this section is motivated by a large set of empirical evidence on information dispersion. First, firms disagree in their expectations about both current and future economic conditions ((Candia et al., 2023) for a review). Second, firms' forecast about aggregates variables depends on local economic condition (Tanaka et al., 2020; Candia et al., 2021; Andrade et al., 2022; Dovern et al., 2023). Third, firm managers' belief updating is consistent with the Bayesian framework, and their attention allocation to aggregates depends on incentives (Coibion et al., 2018). I provide a model of overoptimistic credit boom-&-bust consistent with this set of evidence.[5]

The economy consists of a continuum of islands $j \in [0, 1]$, each of them populated by a firm-bank pair.[6] Banks in each island obtain funds at a risk-free rate from international markets and lend to firms at a premium above the funding rate to cover repayment risk. Firms borrow from banks to finance investment and production of intermediate goods, which they sell to a single aggregate final good producer. If revenues exceed the outstanding debt, the firm repays the bank and keeps the net profit, and otherwise it defaults.

Timeline. The model is divided into three stages. In the first stage, before receiving any information, each bank-firm pair decides whether they want to observe aggregate shocks in the next stage. In the second stage, they observe information and negotiate loans and loan rates. In the final stage, shocks are realized and firms either repay or default. Rather than describing business cycles, the model is intended to depict the phases of a financial bubble, with the second stage representing the building up of the bubble and the third stage its burst.

Final good producer. The economy features a representative final good producer who purchases a bundle of intermediate goods $M = \left[\int^j M_j^{\xi} dj\right]^{\frac{1}{\xi}}$ with elasticity of substitution $\frac{1}{1-\xi}$, to produce final good with production function $Y = M^{\nu}$. Thus, the demand function for intermediate goods M_j in stage 3 is:

$$p_j = \nu M^{\nu-\xi} M_j^{\xi-1} \tag{1}$$

The demand for the intermediate good M_j may increase or decrease with aggregate production M depending on the degree of decreasing return to scale in final good production and the elasticity of substitution between goods. If $\nu < \xi$, there is a negative production externality: an increase in the aggregate supply of intermediates M leads to a decrease in price p_j and therefore lower revenues for intermediate producer j. Conversely, if $\nu > \xi$, the production externality is positive.

Firms. In the second stage, the firm in island j borrows b_j from the bank to purchase capital inputs and cover the capital adjustment cost. For simplicity, I assume firms start with zero net worth and therefore borrowing equal $b_j = k_j + \phi\frac{k_j^2}{2}$. In the third stage, firms combine labor l_j, pre-installed capital k_j and productivity A_j with production function $M_j = A_j^{\zeta} k_j^{\tilde{\alpha}} l_j^{1-\tilde{\alpha}}$, where $\tilde{\alpha} \in (0, 1)$ represents the capital share. Firms hire labor in the third stage after observing the shock realizations and pay workers before repaying their debt to the bank. Define the operating profit of the firm as $\pi_j = p_j M_j - w l_j$. One can maximize labor out of the problem and substitute for the demand function (1) to obtain net operating profit as a function of only capital, technology, and aggregate supply of intermediates $\pi(A_j, k_j, M) = \Lambda(M) A_j k_j^{\alpha}$, where $\alpha = \frac{\tilde{\alpha}\xi}{1-(1-\tilde{\alpha})\xi}$, $\Lambda(M) = \nu^{\frac{1}{1-(1-\alpha)\xi}} M^{\frac{\nu-\xi}{1-(1-\alpha)\xi}}$ with[7]

$$M = \left\{ \left[\frac{w}{(1-\alpha)\xi\nu}\right]^{\frac{(1-\alpha)}{(1-\alpha)\xi-1}} \left[\int^N A_j k_j^{\alpha} dj\right]^{\frac{1}{\xi}} \right\}^{\frac{1-(1-\alpha)\xi}{1-(1-\alpha)\nu}} \tag{2}$$

[4] This paper is also complementary to a growing literature on the link between information generation in the credit market and credit cycles (Martinez-Miera and Repullo, 2017; Gorton and Ordonez, 2020; Asriyan et al., 2022). In these papers, credit booms are associated with lower production of information about borrowers or collateral, leading to lower investment quality and higher financial fragility. Differently from them, I focus on information about aggregate and not idiosyncratic risk factors. As a result, the model presented here produces systematic forecast errors and lenders' negative excess returns after large credit booms.

[5] Online Appendix A provides additional motivational evidence supporting information friction which is consistent with the model presented here.

[6] The island assumption reflects the importance of banking relationships and the cost faced by borrowers in switching lenders (Chodorow-Reich, 2014). I assume that the sorting of lenders and borrowers across islands takes place before markets open and information is observed, at a time when there is no heterogeneity in firms' and banks' characteristics.

[7] Here I have normalized the parameter ζ so that the profit function is linear in technology, and the real wage w so that the constant multiplying $\Lambda(M)$ in the profit function equals 1.

The firm's payoff in stage 3 is as follows. If profits are larger than the outstanding debt $\pi(A_j, k_j, M) \geq (1 + r_j)b_j$, the firm repays the bank and distributes the remaining amount, minus a tax rate, as dividends: $d_{firm,j} = (1 - \tau)[\pi(A_j, k_j, M) - (1 + r_j)b_j]$. Otherwise, the firm pays a default cost proportional to the installed capital, which can be thought of as a liquidation or reorganization cost following the bankruptcy procedure: $d_{firm,j} = -c_d k_j$.[8][9]

Banks. Banks in each island j have deep-pockets and are risk-neutral. In the second stage, they borrow at a risk-free rate r^f from the international market to finance risky loans to firms b_j, at loan rate r_j. They maximize their excess return in the third stage, which equals $d_{bank,j} = [(1 + r_j) - (1 + r^f)]b_j$ if the firm can repay the debt, and otherwise $d_{bank,j} = -(1 + r_j)b_j$, where risk free rate r^f is exogenous. The firm's revenue is lost when the firm defaults, therefore default represents a net loss for the economy.[10]

Exogenous shocks. The logarithm of local technology A_j in each island j is the sum of two independent components: an i.i.d. local island component ϵ_j and an aggregate component θ: $ln(A_j) = \epsilon_j + \theta$. Agents in each island have common prior $\epsilon_j \sim N(0, \sigma^2_\epsilon)$ and $\theta \sim N(0, \sigma^2_\theta)$. The local shock is i.i.d. across islands, so it averages out in the aggregate, $\int^j \epsilon_j dj = 0$. Both shocks are realized in stage 3 and determine aggregate and local production.

2.1. Limited liability

I assume firms and banks' payoff have limited liability, protecting them from downside risk. Specifically, I assume they are insured against a fraction ψ of their losses: higher ψ implies a more convex payoff structure and therefore higher risk-taking incentives. The payoff structures of bank and firm becomes then

$$\begin{aligned} w_{firm,j} &= \begin{cases} (1-\tau)[\pi(A_j,k_j,M) - (1+r_j)b_j] & \text{if } \pi(A_j,k_j,M) \geq (1+r_j)b_j \\ -(1-\psi)c_d k_j, & \text{if } \pi(A_j,k_j,M) < (1+r_j)b_j \end{cases} \\ w_{bank,j} &= \begin{cases} [(1+r_j) - (1+r^f)]b_j & \text{if } \pi(A_j,k_j,M) \geq (1+r_j)b_j \\ -(1-\psi)(1+r_j)b_j & \text{if } \pi(A_j,k_j,M) < (1+r_j)b_j \end{cases} \end{aligned} \tag{3}$$

I consider a general limited liability constraint specification that embeds different real-world cases. First, it can represent the convexity of managerial compensation, e.g., bonuses and option holdings versus shares. In particular, option compensation is one of the most studied sources of moral hazard incentives (Edmans et al., 2017). Moreover, after the 2008–2009 financial crisis, compensation policies were cited as a likely culprit for the excessive risk-taking that led to the crisis (e.g. Bebchuk et al. (2010)).[11] Second, one can interpret the limited liability of the firm as resulting from moral hazard between borrower and lender, such as lower default costs or government bailouts. Third, one can interpret the bank's limited liability as the share of funds coming from insured deposits versus equity (Dell'Ariccia et al., 2014), or the share of loan value covered by government guarantees, an important part of the COVID-19 support packages offered by European governments to firms (OECD, 2020).

2.2. Stage 2: lending and borrowing

I describe the two stages backward, starting with the second stage. Before the shocks are realized and production takes place, banks and firms on each island decide on the quantity of credit b_j and the interest rate r_j based on their expectation about profits in stage 3. The firm submits a take-it-or-leave-it offer to the bank, which, consistent with the literature, implies a zero expected profit condition for the lender (e.g. Strebulaev and Whited (2011)).[12]

Information structure. I assume all information is transmitted during the bargaining process, and therefore shared between the bank and the firm on island j.[13] Before deciding on borrowing and lending, they receive up to two signals. First, they observe a free noisy signal about local productivity:

$$z_j = ln(A_j) + \eta_j \tag{4}$$

[8] I consider here a form of "reorganization" bankruptcy, as in Chapter 11 of the US bankruptcy code, under which the firm is allowed to keep operating after a period of reorganization. These procedures may include reputation costs, asset fire sales, loss of customer or supplier relationships, legal and accounting fees, and management changes, which I assume to depend on the size of the firm (Bris et al., 2006). Notice also that this bankruptcy cost is not necessary for the first set of results derived in Section 3 on the relation between information friction and procyclical overoptimism, but it is necessary for the second set of results in Section 4 on the relation between limited liability and information choice.

[9] Negative dividends can be interpreted as firms raising external finance in the form of equity injections from current shareholders. For a similar interpretation, see Strebulaev and Whited (2011), Sections 3.2 and 3.3.

[10] While I assume a zero recovery rate for simplicity, a positive recovery rate would not change qualitatively the implications of the model. In case of a positive recovery rate $\lambda_r > 0$, the bank payoff in case of borrower's default would be $\lambda_r \pi(A_j, k_j, M) - (1 + r_j)b_j$.

[11] Stock option compensation in US companies has increased considerably during the 1980s, and especially in the 1990s, becoming the largest component of executive pay. Options increased from only 19% of managers' pay in 1992 to 49% by 2000 and started declining from mid-2000 and in 2014 they represent 16% of the pay (Edmans et al., 2017). Online Appendix E reports the case of limited liability originating from managerial compensation incentives.

[12] Alternatively, one can interpret the take-it-or-leave-it offer as the outcome of a Nash bargaining where the firm retains all the bargaining power. In Section 3.3 I study the case where the firm and the bank have the same bargaining power.

[13] Allowing for asymmetric information between the bank and the firm on the same island j would lead strategic considerations in information choice not only *between* islands, as in my baseline model, but also *within* islands. Such considerations are out of the scope of this paper.

with $\eta_j \sim N(0, \sigma_\eta^2)$ and local technology $ln(A_j) = \epsilon_j + \theta$. Second, they may or may not perfectly observe aggregate productivity. Following the Lucas island setting, I assume agents on each island do not freely observe aggregate quantities and prices. However, in stage 1 the bank and the firm in island j can decide whether to pay an information cost to perfectly observe the aggregate shock θ. Let Ω_j be the (common) stage-2 information set of agents in island j: if they pay the cost in stage 1, $\Omega_j = \{z_j, \theta\}$, otherwise $\Omega_j = \{z_j\}$. One can think of this as a cognitive cost of not only collecting but also processing information and computing the optimal individual best response (Sims, 2003, 2006).

Lending and borrowing decision. The zero expected bank's excess implies that the loan rate is proportional to the perceived probability of default, in other words, the risk premium on the loan is proportional only to the perceived risk, with no variation in the price of risk.

$$\frac{1+r_j}{1+r^f} = \frac{(1-\psi)+\psi[1-p(default_j|\Omega_j)]}{[1-p(default_j|\Omega_j)]} \tag{5}$$

The firm internalizes the bank's credit supply $r_j(b_j)$ and chooses the optimal borrowing b_j to maximize the expected payoff

$$\begin{aligned} E[w_{firm,j}|\Omega_j] =&(1-\tau)\int_0^\infty \int_{ln\left(\frac{b_j}{\Lambda(M)k(b_j)^\alpha}\right)}^\infty \Lambda(M)A_j k_j^\alpha f(ln(A_j), M|\Omega_j)dA_j dM \\ &-\left[1-p\left(default_j|\Omega_j\right)\right](1+r_j(b_j))b_j - \left[p\left(default_j|\Omega_j\right)\right](1-\psi)c_d k_j \end{aligned} \tag{6}$$

with the posterior default risk being defined by

$$p(default_j|\Omega_j) = \int_0^\infty \int_{-\infty}^{ln\left(\frac{b_j}{\Lambda(M)k(b_j)^\alpha}\right)} f(ln(A_j), M|\Omega_j)dA_j dM \tag{7}$$

where Ω_j is the information set of island j, $f(ln(A_j), M|\Omega_j)$ is the joint posterior density function of $ln(A_j)$ and M_j, and capital purchased is a monotonic function of borrowing $k(b_j) = \phi^{-1}(\sqrt{1+2b_j\phi} - 1)$.

Definition 1 (*Stage 2 Equilibrium*). Given local shock realization $\{\epsilon, \eta\}_{j\in[0,1]}$, aggregate shock realization $\{\theta\}$ and agents' information set $\Omega_{j\in[0,1]}$, the market equilibrium in stage 2 is defined as a set of local loan prices $r_{j\in[0,1]}$ and local loan quantities $b_{j\in[0,1]}$ such that

- Bank j's expected profits equal zero, i.e. (5) holds.
- Firm j internalizes loan supply function $r_j(b_j)$ and maximizes expected profits (6).

Online Appendix B describes in detail the bargaining process underlying the stage-2 equilibrium.

Strategic motives. The impact of aggregate production of intermediate M on firm j's revenue is described by the term $\Lambda(M) = \nu^{\frac{1}{1-(1-\alpha)\xi}} M^{\frac{\nu-\xi}{1-(1-\alpha)\xi}}$. Depending on the sign of $\nu-\xi$, the model can exhibit strategic substitutability or complementarity between islands in lending and borrowing decisions. First, suppose that $\nu < \xi$: the shifter $\Lambda(M)$ is decreasing in the aggregate intermediate output M and there is *strategic substitutability*. For a given level of local output M_j, a higher aggregate output M implies a lower price p_j and lower revenue for firm j. As a result, the optimal borrowing b_j and loan rate r_j are decreasing in aggregate output M. The opposite happens with $\nu > \xi$: the shifter $\Lambda(M)$ is increasing in the aggregate intermediate output M and there is *strategic complementarity*. I formalize this relation in Section 3.1.

2.3. Stage 1: Information choice

Before observing any signal, each island decides whether to pay the information cost c to perfectly observe aggregate shock θ stage 2, which provides information about the aggregate output M. Similarly to the equilibrium in stage 2, I assume that firms submit a take-it-or-leave-it offer to banks, which again implies a zero expected profit condition for banks. As the firm retains the whole surplus from this bargaining, I also assume the firm pays the entire information cost. As a result, island j's information problem is

$$max_{n_j\in\{0,1\}} \quad E[E[w_{firm,j}(b_j, r_j)|\Omega_j(n_j)] - n_j c] \tag{8}$$

where the binary indicator takes value $n = 1$ if they decide to pay the cost c and $n = 0$ otherwise. The first expectation term is conditional on the information set in stage 1, which consists only of priors, while the second expectation operator is conditioning on stage-2 information set Ω_j. If they pay the cost, they will be able to observe aggregates in the next stage: $\Omega_j(1) = \{z_j, \theta\}$. If they do not pay the cost, they will be not able to observe aggregates: $\Omega_j(0) = \{z_j\}$. In other words, island j decides to pay the attention cost if $E[w^*_{firm,j}(\theta \in \Omega_j, \lambda) - c] \geq E[w^*_{firm,j}(\theta \notin \Omega_j, \lambda)]$, where w^*_{firm} is the firm's payoff given stage-2 equilibrium r_j and b_j, which are function of stage-2 information set Ω_j. As argued in the previous section, optimal local prices and quantities in stage 2 depend on aggregate decisions through the price externality $\Lambda(M)$. Thus, the optimal information choice of island j depends on the share of the other islands that decide to be informed, $\lambda \in [0,1]$, where $\lambda = 1$ if all islands decide to pay the cost to observe aggregate shocks and $\lambda = 0$ if none decides so. In equilibrium, λ^* is such that all islands are indifferent between paying or not paying the cost.[14]

Definition 2 (*Stage 1 Equilibrium*). Given prior beliefs about local shock realization $\{\epsilon, \eta\}_{j\in[0,1]}$ and aggregate shock realization $\{\theta\}$, the market equilibrium in stage 1 is defined by a share $\lambda \in [0,1]$ of islands such that all islands $j \in [0,1]$ are indifferent between paying and not paying the information cost, i.e. Eq. (8) holds with equality $\forall j \in [0,1]$.

3. Credit booms with information frictions

3.1. Analytical results

To illustrate the mechanism of the model, I consider a first-order approximation of the second-stage model around the risky steady state. While an economy near the steady state is not suitable for studying large and rare financial crises like the ones considered in this paper, the basic model's mechanism does not rely on nonlinearities. As a result, the mechanism highlighted in this section applies also in Section 3.2 where I solve the non-linear model numerically.

At the risky steady state, all shocks are zero, $\theta = \epsilon_j = \eta_j = 0$, which implies that all islands observe the same signal $z_j = 0$. However, agents still expect future risk about the local shock ϵ_j, meaning that risk in steady state is not zero.[15] This risk is priced in the steady state spread $r_j > r^f$, meaning there is a positive steady state risk premium. Only in this section, I assume for simplicity no adjustment cost $\phi = 0$, no limited liability $\psi = 0$, and no default cost $c_d = 0$. Because of these assumptions, in equilibrium, the perceived default risk and risk premium are constant (while the actual default risk may not be), but the other qualitative implications of the model are unaffected. I relax all these assumptions in Section 3.2.

Proposition 1 (*Linearized Model*). *Consider a first-order approximation of the second-stage equilibrium assuming $\phi = 0$, $\psi = 0$ and $c_d = 0$. Let $\hat{x}$ indicate the log deviation of any variable x from its steady state value and with $\tilde{x}$ the level deviation from the steady state.*

- *Equilibrium local investment equals*

$$\hat{k}_j = \frac{1}{1-\alpha}(E[lnA_j|\Omega_j] - \gamma E[\hat{M}|\Omega_j]) \tag{9}$$

where $\hat{M} = \mu(\theta + \alpha\hat{K})$, with $\mu > 0$, $\hat{K} = \int^j \hat{k}_j dj$, and $\gamma \equiv \frac{\nu-\xi}{1-(1-\alpha)\xi}$. if $\nu < \xi$ ($\nu > \xi$), then $\gamma < 0$ ($\gamma > 0$) and the economy exhibits strategic substitutability (complementarity) in firms investment decisions.
- *Local loan rate is proportional to perceived default risk, which is constant in equilibrium: $\hat{r}_j \propto -\hat{p}(def_j|\Omega_j) = 0$*
- *Equilibrium aggregate banks' profits in state θ is inversely proportional to the difference between actual and perceived borrower's default risk*

$$E[\tilde{\pi}_{bank}|z_j,\theta] \propto -\int^j [\hat{p}(def_j|z_j,\theta) - E[\hat{p}(def_j|\Omega_j)|\theta]]dj = -\int^j \hat{p}(def_j|z_j,\theta)dj \tag{10}$$

where $\hat{p}(def_j|z_j,\theta)$ is the default risk conditional on signal z_j and aggregate shock θ.

See Online Appendix C for the proof.

Proposition 1 highlights some interesting results. First, the equilibrium loan rate $\hat{r}_j$ is negatively related to the perceived probability of default, as implied by the pricing Eq. (5). Second, perceived default risk is constant in equilibrium (i.e. zero in log deviation from the steady state). This is a knife-edge result, and it depends on the simplifying assumptions introduced in this section, which I relax in the numerical solution. Third, since the loan pricing condition implies no expected profits for the bank, aggregate banks' profits in state θ depend on whether agents perceived risk correctly, i.e. whether the loan is correctly priced conditioning on θ.

PE vs GE. A positive aggregate shock θ has two effects on equilibrium investment: a partial equilibrium effect and a general equilibrium effect.

$$\frac{\partial\hat{k}_j}{\partial\theta} = \frac{1}{1-\alpha}\left(\underbrace{\frac{\partial E[lnA_j|\Omega_j]}{\partial\theta}}_{\text{PE effect}} - \gamma\underbrace{\frac{\partial E[\hat{M}|\Omega_j]}{\partial\theta}}_{\text{GE effect}}\right) \tag{11}$$

First, local productivity A_j in each island increases. Because the firm's fundamental is higher, island j's posterior probability of default decreases, boosting borrowing and investment $\hat{k}_j$. This is the standard channel of productivity shocks examined in the

[14] While I consider the extensive margin of information choice, i.e. observing or not aggregates, the outcome is qualitatively similar to modeling information choice on the intensive margin, i.e. deciding the accuracy of a signal about aggregates as in the rational inattention literature (for a review, Mackowiak et al. (2018)).

[15] The concept of risky steady state, introduced by Coeurdacier et al. (2011), is a tool to depart from the stark assumption of the deterministic steady state while avoiding the difficulty of fully characterizing the stochastic steady state. Formally, given a decision rule $Y_t = g(Y_{t-1}, z_t)$ defining optimal decisions for some states Y_{t-1} and shocks z_t, the risky steady state satisfies $\bar{Y} = g(\bar{Y}, 0)$.

existing literature and it does not depend on the interaction between islands (PE effect). Second, a higher aggregate supply of intermediates can imply a lower or higher demand for the intermediate good j depending on the degree of decreasing return to scale compared to the elasticity of substitution between intermediates (GE effect).

Assumption 1 (*Strategic Substitutability*). Assume that $\nu < \xi$: firms exhibit strategic substitutability in investment decisions.

In Online Appendix F, I show that this assumption holds under fairly mild conditions, such as in the case of similar or higher markup in the intermediate compared to the final good sector, which is supported by existing empirical evidence.

While λ depends endogenously on the stage-1 information choice, I consider here two limit cases to illustrate the mechanism of the model. First, I assume all islands decide to pay attention to aggregates in the first stage ($\lambda = 1$, i.e. full information). Second, I assume no island decides to pay attention to aggregates in the first stage ($\lambda = 0$, i.e. dispersed information).

3.1.1. Full information ($\lambda = 1$)

Consider the full information case, in which all islands decide to observe aggregate shock θ in the first stage in addition to the free signal z_j defined in Eq. (4).

Proposition 2 (*Full Information*). *If $\Omega_j = \{z_j, \theta\}$, the solution to the linear game of proposition 1 is*

$$\hat{K}^{fi} = \frac{1-\gamma\mu}{1-\alpha+\gamma\mu\alpha}\theta \tag{12}$$

See Online Appendix C for the proof.

After an aggregate shock, the increase in local technology leads to higher aggregate debt and investment, but its effect is dampened by the endogenous decline in intermediate goods prices (increasing in $0 < \gamma < 1$), which lowers firms' optimal investment.

Corollary 1 (*Actual Default Rate In FI*). *If $\Omega_j = \{z_j, \theta\}$, actual default risk coincides with perceived default risk, which is constant by Proposition 1: $\hat{p}(def_j | z_j, \theta) = \hat{p}(def_j | \Omega_j) = 0$.*

Notice that the negative endogenous GE effect on the firm's expected revenue cannot be larger than the positive PE effect in full information, which means that the actual default risk cannot be larger either. If this were the case, then the lower expected revenues would cause firms to reduce their debt and investment (Proposition 1), resulting in lower aggregate supply, a higher price, and a positive endogenous GE effect. In other words: If default risk were higher, the agents would optimally reduce investment and risk. This is a consequence of the strategic substitutability between firms. As a result, the full information economy is not riskier during credit booms, which is inconsistent with the existing empirical evidence (Schularick and Taylor, 2012; Krishnamurthy and Muir, 2017).

Corollary 2 (*Bank's Profit In FI*). *If $\Omega_j = \{z_j, \theta\}$, bank's profit are zero conditioning on z_j and θ: $E[\tilde{\pi}_{bank} | z_j, \theta] = 0$.*

Since perceived risk is equal to actual risk, default risk is correctly priced given the aggregate economic conditions. In other words: since banks observe θ, they do not make systematic errors conditioning on it. The zero expected profit condition implies that, on average, banks make zero excess return in each aggregate state θ. More generally, fully informed banks would not accept predictable losses, which is at odds with the evidence of systematic negative excess returns on bank stocks after large credit booms (Baron and Xiong, 2017).

3.1.2. Dispersed information ($\lambda = 0$)

Consider the dispersed information case, in which no island decides to pay the cost to observe aggregate shock θ in the first stage, so they only observe the free signal z_j defined by Eq. (4).

Proposition 3 (*Dispersed Information*). *If $\Omega_j = \{z_j\}$, the solution to the linear game of Proposition 1 is*

$$K^{di} = \frac{(m-\gamma\mu\delta)}{1-\alpha+\gamma\mu\alpha\delta}\theta \tag{13}$$

where $m = \frac{\sigma_e^2+\sigma_\theta^2}{\sigma_e^2+\sigma_\theta^2+\sigma_\eta^2}$ and $\delta = \frac{\sigma_e^2}{\sigma_e^2+\sigma_\theta^2+\sigma_\eta^2}$ are the Bayesian weights on signal z_j in the posterior means of $ln(A_j)$ and θ respectively, with $0 < \delta < m < 1$.

See Online Appendix C for the proof.

Agents do not observe aggregates, but only the local signal, which provides information about the local technology. Since the local technology is the sum of local and aggregate shocks, they cannot distinguish between the two without additional information. Agents are rational and form Bayesian posterior beliefs that assign a positive probability to both shocks. This is consistent with the empirical evidence that firms' expectations about macroeconomic conditions are sensitive to industry-specific shocks, even though these shocks do not have aggregate effects (Andrade et al., 2022).

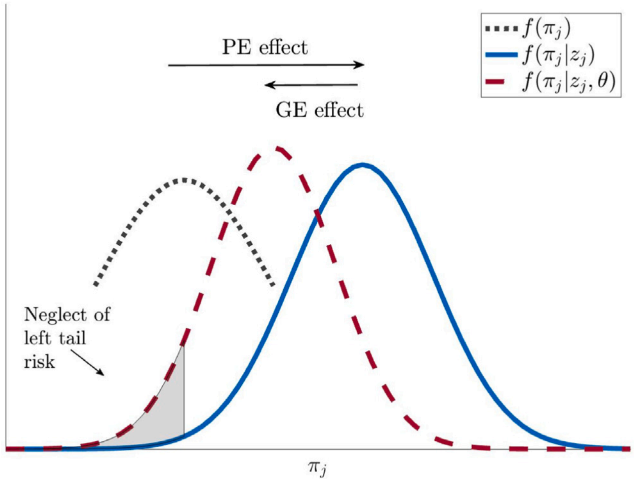

Fig. 1. Rationally extrapolative beliefs in booms.
Notes: The figure illustrates the posterior belief on firm's operating profits after a positive aggregate shock under three different information sets. The black dotted line represents the posterior of an agent not observing any new information. The blue solid line represents the posterior of an agent observing only local signal z_j. The red dashed line represents the posterior of an agent observing both local signal z_j and aggregate shock θ. Not observing aggregate shock θ leads to overestimating equilibrium price p_j and therefore individual revenues π_j. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Corollary 3 (*Boom Amplification*). *The difference in aggregate investment in dispersed information* (13) *and full information* (12) *depends positively on θ, and therefore the information friction leads to an amplification of credit booms if*

$$\Upsilon \equiv (m - \gamma\mu\delta)(1 - \alpha + \gamma\mu\alpha) - (1 - \gamma\mu)(1 - \alpha + \gamma\mu\alpha\delta) > 0 \tag{14}$$

Assume that the condition (14) is satisfied. Then, after a positive aggregate shock, agents observe a signal about higher local technology and partially mistake it for a local shock. As a result, they underestimate the endogenous increase in aggregate output and the associated decrease in selling price. Incomplete information therefore dampens the negative general equilibrium effect on investment and leads to an amplification of individual borrowing and investment.[16] However, this is true only if condition (14) is satisfied: in general, aggregate shock θ affects revenues positively by increasing local technology (PE effect) and negatively by endogenously increasing competition (GE effect). Whether not observing aggregates amplify or dampen booms depends on the informativeness of θ about each of these effects. Online Appendix D provides a more detailed discussion of this topic.

Now consider the case of an individual island, consisting of both a bank and a firm, forming expectations on the local firm's operating profit. Define the forecast errors as the difference between realized and expected revenue, $fe \equiv \hat{\pi}(A_j, k_j, M) - E[\hat{\pi}(A_j, k_j, M)|\Omega_j]$.

Corollary 4 (*Rationally Extrapolative Beliefs And Underreaction*). *If $\Omega_j = \{z_j\}$, the average forecast errors of firm j's on own revenue in aggregate state θ is*

$$E[\hat{\pi}_j|z_j,\theta] - E[E[\hat{\pi}_j|z_j]|\theta] \propto -\Upsilon\theta \tag{15}$$

while the average forecast error on aggregate output is

$$E[\hat{Y}|z_j,\theta] - E[E[\hat{Y}|z_j]|\theta] = (1-\gamma\mu)\left(\frac{1-\alpha+\alpha m}{1-\alpha+\gamma\mu\alpha\delta}\right)\theta \tag{16}$$

If condition (14) *holds, then if $\theta > 0$ agents underestimate aggregate output and overestimate individual revenues, meaning they are overoptimistic in booms. Conversely, if $\theta > 0$ they are overpessimistic in busts.*

The firm's revenue depends positively on the PE effect and negatively on the GE effect. Since agents do not observe aggregates, they rationally confuse an aggregate shock with a local shock and underestimate the negative GE effect. The lack of information leads to extrapolative-like beliefs, as agents are systematically overoptimistic after positive aggregate shocks and overpessimistic after negative shocks. Differently from behavioral models, where extrapolation results from overreaction to positive news (Bordalo et al., 2018, 2019), here it is due to rational underreaction to the endogenous negative general equilibrium effect. As a result, booms are associated with both overoptimism about local revenues and underestimation of aggregate quantities, consistent with

[16] The amplifying effect of dispersed information in the presence of strategic substitutability between agents is explored also in Angeletos and Lian (2017), Benhima (2019) and Kohlhas and Walther (2021).

Table 1
Calibration.

Parameter	Interpretation	Value
α	Return to scale intermediate good sector	0.624
ν	Return to scale final good sector	0.5
r^f	Risk-free rate	0.1
ϕ	Investment adj cost coefficient	1
σ_θ	Volatility aggregate shock	0.2
σ_e	Volatility local shock	0.6
σ_η	Volatility signal noise	0.64
ψ	Limited liability	0
c_d	Default cost	0.5
τ	Corporate tax	0.20
c	Information cost	0.0017

the existing evidence on information frictions (see Online Appendix A). Importantly, even if agents are rational and correct on average conditioning on their information set, they are consistently mistaken conditioning on unobserved aggregate states.

Fig. 1 illustrates this mechanism. The dotted line represents the prior belief about the firm's revenue before receiving any information. A positive aggregate technology shock increases the firm's fundamentals and implies on average a good signal z_j that shifts the posterior beliefs on revenue to the blue solid line (positive PE effect). However, because of the endogenous increase in the supply of intermediate goods, the price of good j will be lower and the actual posterior revenue of an informed agent will shift back to the red dashed line (negative GE effect). However, if agents do not observe aggregates, they underestimate this last shift and consequently, the left tail risk, shown in the figure as the shaded area between their posterior and the actual posterior distribution of revenues.[17]

Corollary 5 (*Actual Default Rate In DI*). *If $\Omega_j = \{z_j\}$, the equilibrium default rate is proportional to $\hat{p}(def|\theta) \propto Y\theta$, where $\hat{p}(def|\theta) = \int^j \hat{p}(def_j|z_j,\theta)dj$. If condition (14) holds, default rate increases in aggregate shock θ*

See Online Appendix C for the proof.

As dispersed information amplifies booms, the higher supply of intermediate goods further lowers prices and firms' revenues. Market participants confuse aggregate shocks with local shocks and increase debt too much relative to their future revenues, leading to a higher default rate. As a result, credit booms are times when default risk is greater. This is consistent with the existing evidence that low-risk premia and high credit growth predict higher financial fragility (Krishnamurthy and Muir, 2017).

Corollary 6 (*Bank's Profit In DI*). *If $\Omega_j = \{z_j\}$, the equilibrium average bank profits are proportional $E[\tilde{\pi}_{bank}|z_j,\theta] \propto Y\theta$. If condition (14) holds, average bank profits are negative after a credit boom.*

Since the risk premium in equilibrium is such that, on average, banks earn a zero expected profit, when banks underestimate default risk they misprice loans and earn negative profits. This result is consistent with the evidence that credit booms generate negative returns for bank stocks documented by Baron and Xiong (2017).

Information choice. In the first stage, firms and banks on each island decide whether to observe aggregates based on their expected profits in the final stage. In general, a share $\lambda \in [0,1]$ of the islands chooses to acquire the information. While Fig. 1 illustrates individual beliefs for a given aggregate output M, this quantity is endogenous to the aggregate amount of information in the economy. If all agents in each island are informed, $\lambda = 1$, Corollary 3 states that the increase in aggregate supply during the boom is smaller, and therefore the price decrease is smaller as well. In Fig. 1, this would be a shorter distance between informed and uninformed posteriors since the neglected GE effect would be smaller. On the other hand, if agents on each island are uninformed, $\lambda = 0$, the credit boom is amplified, and the price decline is larger. In Fig. 1, this would imply a larger gap between informed and uninformed posteriors, as the neglected GE effect would be higher. Therefore, the benefit of information for the individual island depends negatively on the average level of information in the economy, meaning there is strategic substitutability in information choice.

3.2. Numerical illustrations

I provide a numerical illustration of the nonlinear model. The contribution of examining numerical solutions of the model is twofold. First, I relax some parametric assumptions that are necessary to keep the analytical model tractable. Second, nonlinear global solutions are better suited than approximations around the steady state to examine the nature of large and rare credit booms such as those considered in this paper. In this section, I abstract from limited liability and set $\psi = 0$, while I perform comparative statics with it in the next section. Table 1 reports the rest of the model's calibration, which is discussed in Online Appendix F.

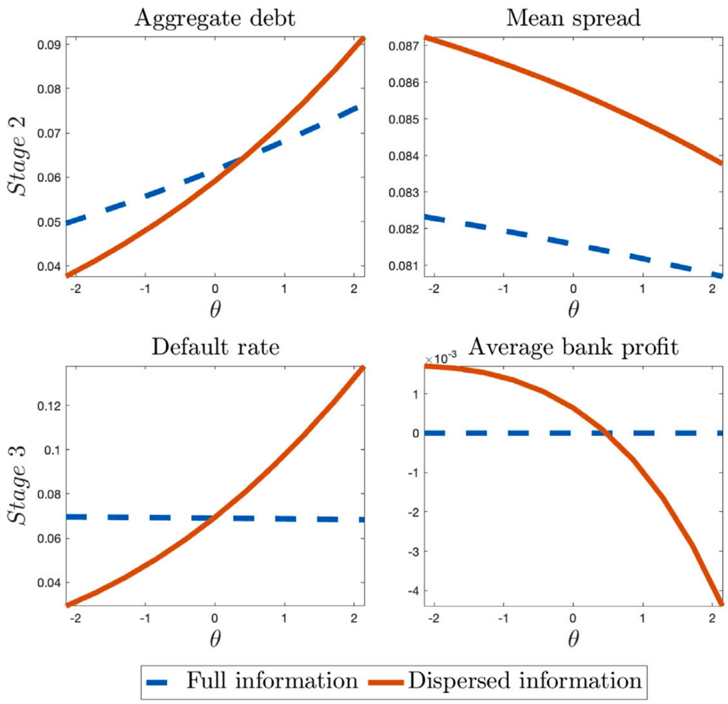

Fig. 2. Comparison of economies with full information and dispersed information.
Notes: The figure illustrates the equilibrium stage-2 borrowing choice and stage-3 default and profit realizations in the full information ($\theta \in \Omega_j$, in blue) and dispersed information economy ($\theta \notin \Omega_j$, in red). The aggregate shock θ in the x-axis is expressed in standard deviations.

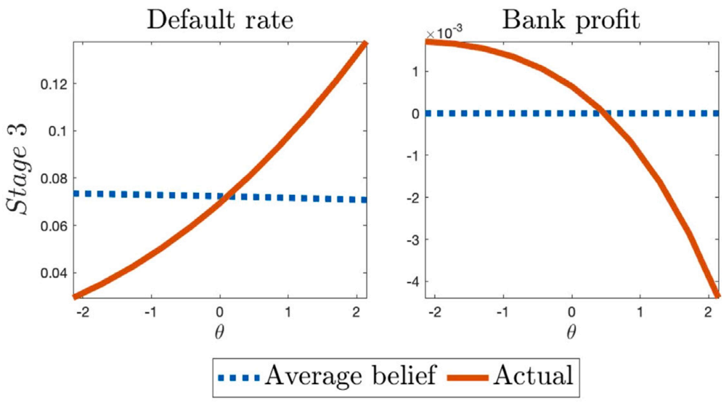

Fig. 3. Average beliefs and actual realizations in the economy with dispersed information.
Notes: The figure illustrates the average actual realization (in red) and expectation (in blue) of bank excess return and default rate in the dispersed information economy ($\theta \notin \Omega_j$). The aggregate shock θ in the x-axis is expressed in standard deviations.

Full information ($\lambda = 1$). Consider the full information, in which all islands decide to observe the aggregate shock θ in the first stage. The blue dashed lines in Fig. 2 show the response of aggregate credit, average risk premium, default rate, and average bank profits in this economy as functions of the standard deviations of aggregate shock θ. Differently from the linear model in Section 3.1, I allow for nonzero investment adjustment costs. As a result, the probability of default is not constant but falls after the boom, and since banks know that the risk of default is lower, the risk premium also falls. But as risk is priced correctly, banks still make zero average profits conditional on the aggregate state. The nonlinear model confirms the analytical results, as the full information economy is

[17] Notice that more information also means lower posterior uncertainty. Thus, the difference between informed and non-informed posteriors is not only a lower posterior mean but also a lower posterior variance.

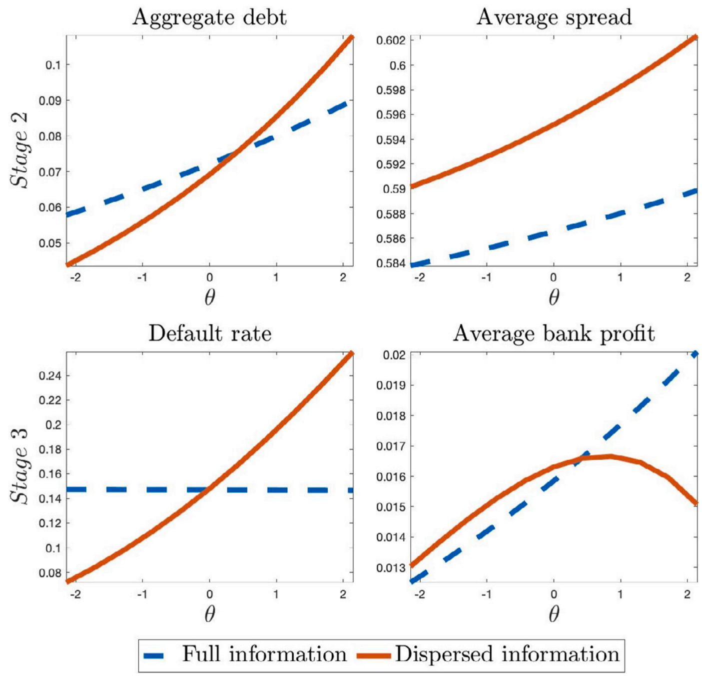

Fig. 4. Full information and dispersed information economies: bank and firm with equal bargaining power.
Notes: The figure illustrates the equilibrium stage-2 borrowing choice and stage-3 default and profit realizations in the full information ($\theta \in \Omega_j$, in blue) and dispersed information economy ($\theta \notin \Omega_j$, in red) with bargaining power $\beta = 0.5$. The aggregate shock θ in the x-axis is expressed in standard deviations.

not consistent with the existing evidence.[18] The only difference with a benchmark model abstracting from strategic considerations is that the negative externality dampens the boom.

Dispersed information ($\lambda = 0$). Consider the dispersed information case, where no island decides to observe the aggregate shock θ in the first stage. The red solid lines in Fig. 2 show the response of aggregate credit, average risk premium, default rate, and average bank profits in this economy as functions of the standard deviations of aggregate shock θ. The figure confirms the analytical results from Section 3.1. As agents underestimate the magnitude of the negative GE effect, the credit boom is amplified, as shown by the solid red line in the upper left panel. The excess supply of intermediate goods lowers intermediate goods prices and revenues, but firms do not observe aggregates and take on too much debt. Default risk peaks after a credit boom, consistent with the evidence on credit boom-and-busts (Schularick and Taylor, 2012). Banks are also inattentive to aggregates and confuse the aggregate shock with a local shock. As a result, the risk premium on loans is lower in credit booms when default risk is larger, consistent with the predictive power of lower risk premia for financial downturns (Krishnamurthy and Muir, 2017).

The decline in risk premia is not due to a change in risk tolerance but to an underestimation of the endogenous increase in default risk. Fig. 3 illustrates this point by plotting the actual and average expected bank profit in the left panel, and the actual and average expected default rate in the right panel. Banks do not internalize the increase in default risk and expect a zero average excess return. However, because of the increase in default risk, excess returns are negative on average after a credit boom. Assuming that the bank stock price is correlated with its operating profit, the results are consistent with the evidence of average negative returns on bank stocks during booms in Baron and Xiong (2017).

3.3. Different bargaining power

In the baseline model, I assume that firms present a take-it-or-leave-it offer to the bank, implying that firms retain all bargaining power. This results in the standard implication that the loan price reflects only the quantity of risk, with no alteration in the price of risk. Now consider the case where the firm and bank on island j determine lending and investment through Nash bargaining, characterized by respective bargaining powers β and $1-\beta$:

$$max_{q_j,b_j}\ (E[w_{firm}|\Omega_j])^{\beta}(E[w_{bank}|\Omega_j])^{1-\beta} \tag{17}$$

[18] While it would be possible to set up a model in which firms had higher risk tolerance and were willing to take on more risk during credit booms, the pricing Eq. (5) implies that the risk premium would rise as a result, which is inconsistent with the evidence in Krishnamurthy and Muir (2017). If banks had higher risk tolerance in booms as well, risk premia could be lower in times of high risk (e.g. Krishnamurthy and Li 2021), but it would still not be possible for rational bankers to accept negative excess returns on average, as documented in Baron and Xiong (2017).

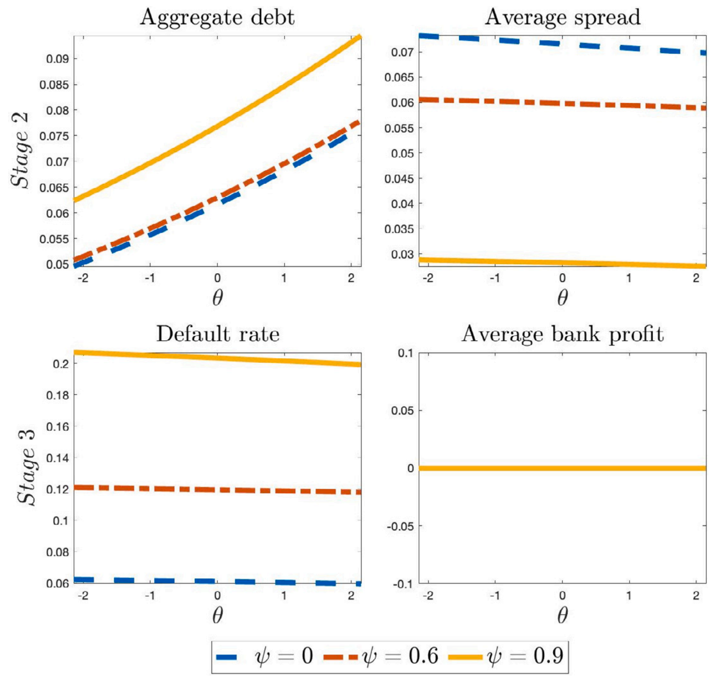

Fig. 5. Full information economy with different levels of limited liability.
Notes: The figure illustrates the equilibrium stage-2 borrowing choice and stage-3 default and profit realizations in the full information economy ($\theta \in \Omega_j$) for different values of payoff convexity ψ. The aggregate shock θ in the x-axis is expressed in standard deviations.

Online Appendix B provides a detailed description of this bargaining stage. Fig. 4 illustrates the equilibrium where $\beta = 0.5$. Unlike in the baseline model, the average spread increases during booms even if risk decreases, as both the bank and firm agree to share the additional surplus created.[19] However, while the bank's profit increases during moderate booms, it declines during very large booms, as the losses from risk mispricing outweigh the increase in rent extraction from the firm

4. Information choice with limited liability

The previous section demonstrates how overoptimism during credit booms can be caused by information frictions. In this section, I explore the determinants of these information frictions. Specifically, I show that limited liability leads agents to pay less attention to aggregate risk factors, even for a low information cost. As a result, they become overoptimistic in booms and overpessimistic in busts. To do that, I allow for limited liability in payoffs $\psi > 0$ and study its implications on stage 2 and stage 1 equilibrium allocations. I calibrate the cost of information c such that with no limited liability it is optimal for all islands to collect information ($\lambda = 1$).[20]

Stage 2: Risk-taking in lending. An increase in limited liability has a standard risk-taking effect on stage-2 borrowing and lending decisions. First, consider the firms' decision. As described in Eq. (6), there is a trade-off between the expected profits in the absence of default and the probability of default when determining the amount of debt to issue b_j. Higher payoff convexity ψ lowers firms' losses in case of default, encouraging them to take on more risk. Second, consider the banks' decision. As described in Eq. (5), a higher payoff convexity ψ implies lower losses in the event of default, and therefore lower elasticity of credit spread with respect to default risk. This is the typical effect of risk-taking incentives for a given information structure, i.e. "informed" risk-taking.

To isolate the effect of limited liability on borrowing decisions, I first shut down the information choice in stage 1. Fig. 5 shows the equilibrium debt, average spread, default rate, and bank's profits in the full information economy for different levels of limited liability ψ. A higher payoff convexity leads to more risk-taking and a lower price of risk, resulting in a higher unconditional default rate. However, similar to the full information model in the previous section, in the baseline calibration, credit booms are periods where the economy is safer and the default rate decreases, which does not align with empirical evidence (Schularick and Taylor, 2012; Krishnamurthy and Muir, 2017). Therefore, the full information model with only moral hazard incentives in stage-2 borrowing decisions is not able to reproduce the qualitative patterns of credit cycles seen in the data.

19 In this case the spread between risk-free rate and loan rate does not only reflect the amount of risk and the price of risk, but also some rent extraction from the firm.

20 The information cost corresponds to around 3% of the firm's dividends in the full information economy.

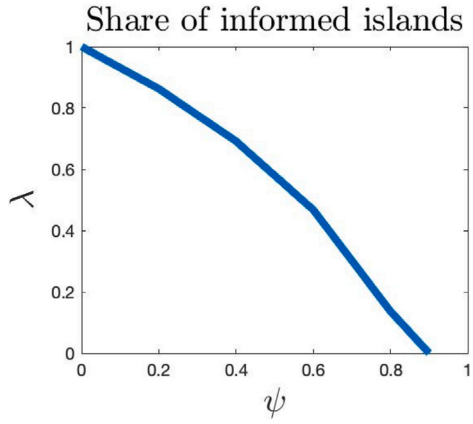

Fig. 6. Information Choice and limited liability.
Notes: The figure illustrates the result of stage-1 information choice under different calibration of payoff convexity ψ. It shows that higher payoff convexity is associated with lower information choice.

Stage 1: Risk-taking in information. In the first stage, banks and firms on each island decide whether to pay the cost of observing aggregate shocks in the second stage. Both agents benefit from information, as not observing aggregate shocks leads to higher default risk and losses. I set the attention cost such that, with no limited liability $\psi = 0$, it is optimal for all islands to pay the cost and be fully informed in the next stage, $\lambda = 1$. Fig. 6 shows that the equilibrium share of informed island λ decreases in limited liability ψ. Intuitively, the higher is payoff convexity, the lower is exposure to losses and therefore the lower is marginal benefit of information.

Fig. 7 shows the equilibrium debt, average spread, default rate, and bank profit for different values of limited liability ψ, which in turn lead to different levels of attention λ. As limited liability increases, optimal attention choice decreases, resulting in a higher default rate and lower bank profit during booms, as discussed in the previous section. As a result, credit booms are periods of higher default risk but lower risk premia, which is consistent with the empirical evidence on credit cycles. Comparing Fig. 5 with Fig. 7 we can see that risk-taking in information choice can explain the patterns of credit cycles observed in the data, while "informed" risk-taking in investment decisions alone cannot.

Online Appendix G extends the model to an infinite-period setting to compare its predictions to the existing evidence on credit cycles. While a full quantitative estimation of the model is beyond the scope of this paper, I demonstrate that the model with a standard calibration can generate realistic boom-and-bust dynamics.

4.1. Extensive and intensive margins of information choice

This model considers the extensive margin of information acquisition, i.e. heterogeneous binary choices of observing aggregates. However, the negative effect of limited liability on the benefit of information is a more general result that applies to models of information acquisition on the intensive margin as well, i.e. homogeneous agents' choices of signal accuracy. While (Mackowiak and Wiederholt, 2012) follows the latter strategy to study information choice and limited liability in a stylized setting, this paper introduces a more sophisticated model with strategic interactions and endogenous risk. In this setting, modeling the extensive margin of information choice facilitates the numerical solution of the nonlinear model.

4.2. Asymmetry in limited liability

While the previous section explores the impact of a change in the island's overall limited liability on its choice of information acquisition, this section investigates the distinct consequences arising from changes in the limited liability of banks and firms separately. Fig. 8 reveals that an increase in the convexity of the bank's payoff has the most significant influence on the island's choice of information. Intuitively, as banks are less affected by downside risk, they have diminished incentives to collect information. Conversely, an increase in the firm's payoff convexity has a more subdued impact. Firms with greater payoff convexity undertake more risk and collect less information for a given credit spread. However, this information is shared with banks, and higher uncertainty results in higher average spreads charged by banks, thereby rendering risk-taking more expensive for firms. This effect dampens the initial negative impact of limited firm liability on information acquisition. However, if the convexity of banks' payoffs also increases, the loan price becomes less elastic with respect to firms' risk-taking behavior, obviating this dampening effect. As a result, the contemporaneous decline in limited bank and firm liability has an amplified effect on the island's information choice.

5. Discussion

My model suggests that inattentive agents over-accumulate debt and investment during booms, which increases default risk and economic fragility. Contrary to the existing body of research on boom-and-bust driven by financial frictions, information here plays a central role and points towards novel macro-prudential policy implications.

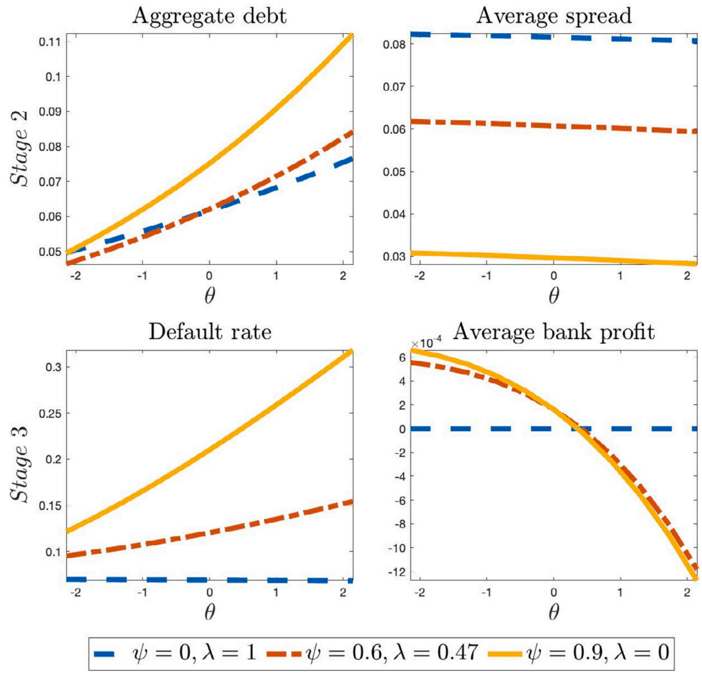

Fig. 7. Economy with endogenous information.
Notes: The figure illustrates the equilibrium stage-2 borrowing choice and stage-3 default and profit realizations with different values of payoff convexity ψ, which endogenously determine different values of share of informed islands λ. The aggregate shock θ in the x-axis is expressed in standard deviations.

Unexpected boom-and-bust. A large class of models in the macro-financial literature ascribes the over-accumulation of debt during booms to strategic complementarity in leverage choices with full information. In these models, it is individually optimal to increase leverage when other agents do it, as individuals do not internalize the impact of their decision on the aggregate economy. However, it is socially suboptimal, as it leads to high levels of leverage and financial fragility (Gertler and Kiyotaki, 2010; He and Krishnamurthy, 2013; Brunnermeier and Sannikov, 2014; He and Krishnamurthy, 2019; Bianchi and Mendoza, 2020). In this framework, a Pigouvian tax on investment corrects this externality by mitigating the increase in leverage (Jeanne and Korinek, 2019).

In my model, the socially suboptimal high borrowing and investment during booms results instead from the combination of strategic substitutability and imperfect information. If firms and banks were fully informed about the increase in aggregate investment, they would decrease their lending and investment, making the economy safer. However, because they are not informed, they contribute to aggregate financial fragility by increasing their lending and investment. Providing information would then mitigate the overoptimism and therefore the boom-and-busts cycles. The model suggests two alternative policies to mitigate the credit boom-and-bust. First, an increase in public information about the accumulation of risk. Second, a change in individual incentives to privately collect information.

Public communication. The procyclical fragility of the economy in this model arises from a lack of coordination caused by dispersed information. To address this issue, policymakers can provide information regarding the build-up of risk. A growing body of literature has examined the role of central banks in communicating financial stability and its impact (Born et al., 2014; Harris et al., 2019; Londono et al., 2021).[21] However, even if the central bank can provide such information for free, agents may still incur cognitive costs in processing this information, as suggested by the rational inattention literature (Sims, 2003; Mackowiak et al., 2018). Alternatively, policymakers can incentivize agents to pay attention to macroeconomic risk by modifying their incentives.

Risk-taking incentives. My model demonstrates how risk-taking incentives discourage agents from accurately assessing risks, resulting in procyclical overoptimistic beliefs.[22] To promote information collection, policymakers can modify agents' incentives, particularly by reducing risk-taking incentives. One policy example that achieves this is the regulation of managers' compensation structures, such as stock options. For instance, the Tax Cuts and Jobs Act (TCJA) implemented in 2017 reduced the tax deductibility of performance-based compensation in the form of stock options (Durrant et al., 2020). However, it is important to note that reducing stock option

[21] While research on financial stability communication is still evolving, this study emphasizes the potential of providing information about the overall economic fragility to mitigate credit booms and busts.

[22] Experimental evidence provided by Cole et al. (2014) illustrates the impact of compensation incentives, including limited liability, on loan officers' efforts to assess the risk of borrowers in a commercial bank.

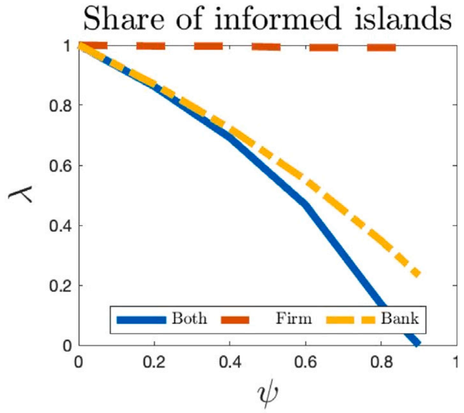

Fig. 8. Information choice and limited liability: asymmetric convexity.
Notes: The figure illustrates the result of stage-1 information choice for different values of payoff convexity ψ of firm (red), bank (yellow) and both at the same time (blue).

compensation may also have unintended consequences, such as discouraging innovation and investment in risky projects as a whole. In a broader sense, stock options can serve as a crucial tool for shareholders to incentivize risk-taking among risk-averse managers.[23]

6. Conclusions

I present a theoretical framework in which overoptimism during credit booms originates from risk-taking incentives in information choice. While existing models attribute overoptimism to behavioral extrapolation of good news, I propose a rational framework in which overoptimism results from inattention to negative news. Periods of low-risk premia predict higher default rates and systematic bank losses, consistent with empirical evidence. Additionally, I show that such information frictions can result from limited liability in payoffs, as convex payoff structures discourage managers from collecting information. Because beliefs depend on incentives, my model suggests that compensation regulation has an important role in terms of macro-prudential policy.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jmoneco.2023.11.002.

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[23] While this paper uncovers some unintended consequences of convex compensation structures, specifically the diminished incentives to accurately assess macroeconomic risk, a comprehensive understanding of the optimal contract between shareholders and managers would necessitate a detailed examination of the trade-offs involved in compensation settings. Thus, this study does not delve into a full characterization of such an optimal contract, which falls outside the scope of this paper (see Lindbeck and Weibull (2017) for more details).

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