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A BEHAVIORAL MODEL OF THE CREDIT BOOM

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A behavioral model of the credit boom*

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ABSTRACT

We offer a simple model of herding and limits of arbitrage in retail credit markets that follows the behavioral approach of Shleifer (2000). We show why solely behavioral biases by participants in the industry could explain how a credit bubble might be fed by the banking sector. According to our model, optimistic banks would lead the industry while it would be rational for unbiased banks to herd under conditions we derive. An important finding is the role of limits of arbitrage in the industry: there would be no incentives for rational banks to correct the misallocations of their biased competitors.

Keywords: Credit bubbles, EMH, information economics, banking efficiency, behavioral finance, limits of arbitrage

JEL Classification: D03, E32, G21

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1. INTRODUCTION

Behavioral economics has identified a wide range of anomalies that challenge standard theories, from consumption to finance, from crime to voting, from charitable giving to labor supply (DellaVigna, 2009). We suggest an additional area where it might be helpful: explaining how credit booms are fueled by the banking sector. Academics have analyzed, among others, the role that incentives (Fahlenbrach and Stulz, 2011), securitization (Keys et al., 2010) or risk-taking moral hazard by banks (Acharya and Naqvi, 2012) could have played in the current crisis. Behavioral finance could offer a simpler but complementary interpretation. As Borio and Shim (2007) note, unsustainable credit and asset price booms are likely to occur in stable macroeconomic conditions. Excessive optimism might had led economic agents to believe good times would last forever, but it also revealed a financial sector unable to make a proper evaluation of demand for credit and the risks involved.

Some antecedents to our model are Lewis (2010) and Leiser et al. (2010), who trace some effects of social psychology on financial cycles, Niu (2010), who present evidence that banks managed by overconfident CEOs take more risk, and Rötheli (2012a,b), who proposes a model of oligopolistic bank competition where just a minority of boundedly rational banks are enough to aggravate the credit cycle. Our main contribution is to introduce a behavioral approach that helps to analyze whether and when behavioral biases by participants in the banking industry might explain credit cycles.

Our approach in this paper is summarized as follows. We focus on retail credit markets, that is, transactions between retail banks and their customers (personal loans, mortgages, etc.) which are broadly funded with deposits from other customers. Informational efficiency at a macro level may be analyzed using a three-step behavioral approach by Shleifer (2000), which would split in determining: (i) whether behavioral biases influence CEOs and employees in that industry, conforming a market sentiment, (ii) whether market sentiment could exhibit trends or predictable patterns, and (iii) whether there are limits of arbitrage in retail credit markets.

Then, we offer a simple model that follows the three-step approach above, which shows why solely behavioral biases by participants in the industry could explain how a credit bubble might be fed. According to it, biased banks would lead the industry while it would be rational for unbiased banks to herd (a result similar to Rötheli, 2012a). We derive the conditions under which rational banks would follow the biased ones, and show a credit boom of loans of low quality is generated. This is welfare improving for low-quality borrowers. A strong result is the role limits of arbitrage would play in the industry: there would be no incentives for rational banks to correct the misallocations of their biased competitors. The proof of the main results is relegated to an Appendix.

2. The model

We follow a behavioral approach (Shleifer, 2000) to test informational efficiency at a macro level in retail credit markets. Following Shleifer, EMH rests on three arguments that rely on progressively weaker assumptions: first, investors are rational, so they value securities rationally; second, to the extent that some investors are not rational, their trades are random, cancelling each other out without affecting prices; and third, to the extent that noise traders are irrational in similar ways, they are met at the market by rational arbitrageurs who eliminate their influence on prices.

Hence, a three-step process could be used to determine whether efficiency holds in a market or not. Applied to retail credit markets, this approach requires first to determine whether CEOs and employees in the industry exhibit beliefs that, based on heuristics rather than Bayesian rationality, could conform a market sentiment. Second, it requires analyzing whether market sentiment could exhibit trends or predictable patterns. Several causes have been proposed to explain this correlated behavior. Finally, we must identify limits of arbitrage in retail credit markets.[1] This stepwise procedure provides a framework to test informational efficiency in bank-based systems, considering the two elements that could challenge it: market sentiment and limited arbitrage.

Assume the economy consists of the banking sector, savers and potential borrowers. Banks may be of two types, type A and type B, the first being an unbiased bank and the second a biased bank.[2] In particular, a bank of type B is boundedly rational in terms of excessive optimism (perhaps fostered by overconfidence too), so we often

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[1] For instance, in the scope of market-based systems, behaviorists suggest arbitrage would be risky and limited for several reasons, including the absence of close substitutes, risk arbitrage and performance based arbitrage. See Shleifer and Vishny (1997) for a detailed analysis.

[2] Obviously, this is a simplification of language: banks are neither biased nor unbiased; who may be biased are executives, employees, and procedures for decision-making inside those banks.

refer to it as an optimistic or overconfident bank. There are no agency problems between shareholders and managers, and no information asymmetries.[3]

The only business banks run are taking deposits and granting loans. For tractability, assume deposits can only be invested in loans (i.e., there is no interbank market or rates are zero there), the Central Bank requires no reserves, deposits are hold until maturity (banks face no liquidity restrictions, so no fraction of the deposits are hold as liquid reserves, R=0), and we do not consider bankruptcy effects. Banks receive deposits from savers, who have other investment alternatives that pay a competitive rate of return, r, $r \geq 0$. There is an unlimited source of deposits available, hence we assume banks take rate r as given and set a volume of deposits D^i, $i=A,B$ equal to the volume of loans they grant, as to finance them.[4] Banks are risk-neutral and compete *à la Cournot* by setting loan volumes as the decision variables. Banks have a linear cost function C(D, L), but since they set a volume of deposits equal to the volume of loans we may simplify it to $C(L) = c \cdot L$, $c>0$.

There are two types of borrowers, high-quality and low-quality. We denote the former by subscript *h* and the later by subscript *l*. Banks are confronted with two linear downward sloping demand functions for loans, one for each type of borrower: $L(r_h) = \alpha - \beta r_h$ and $L(r_l) = \alpha - \beta r_l$, $\alpha>0$, $\beta>0$. The (gross) rate of return on loans is r_h and r_l , respectively, r_l , $r_h > r$. Both banks are able, after a screening process, to correctly assign any new potential borrower to the type she belongs to. Each type of borrower is associated to a probability of success, θ_h and θ_l , $0 < \theta_l < \theta_h < 1$ (meaning the probabilities that a loan of each type is fully repaid), while whenever the borrower defaults the bank gets zero. Key to our model is the definition of rational and overly optimistic banks in terms of these probabilities.

[3] We want to determine the conditions under which solely behavioral biases could foster a credit boom. We suggest banks, under some circumstances (availability of collateral, securitization) might have behaved as if information asymmetries did not exist or were easy to overcome (see power theories of credit). Hence, though potential borrowers may be of different quality, we assume there are no adverse selection problems. Intermediation would be justified by economies of scale (Benston and Smith, 1976).

[4] When there are no liquidity restrictions and banks are not competing for deposits (given they are paying a competitive rate r and there is an unlimited amount of deposits available), there is no reason to accumulate (and pay interests for) a volume of deposits higher than necessary.

Assumption 1. $\theta_h^B = \theta_h^A$, $\theta_l^B > \theta_l^A$.

That is, if a bank is of type A, it observes the true probabilities of success given information available[5] of both types of borrowers; conversely, a bank of type B estimates an unbiased probability for high-quality borrowers, but a lower probability of default by low-quality borrowers than banks of type A. Assumption 1 sets overestimation of probabilities of success by low-quality borrowers as the main driver of the model. From now on denote $\theta_l^A \equiv \theta_l$ and $\theta_l^B \equiv \theta_l^O$ (superscript ^{O} denoting 'overconfident') such that $0 < \theta_l < \theta_l^O < \theta_h < 1$.

Assumption 2. $\alpha > \beta \cdot \dfrac{1 + r + c - \theta_l^O}{\theta_l^O}$.

Assumption 2 imposes a restriction on the demand size for loans. It states that the size of the market needs to be sufficiently large to guarantee that interest rates are well defined (meaning they are neither negative nor they exceed the maximum possible value α/β in the possible equilibria of the model).

Under this setup we analyze informational efficiency following the behavioral approach above described: do banks behave rationally when granting credit to the economy? (Section 2.1); may biased strategies be correlated across the industry? (Section 2.2); are there limits of arbitrage in the banking industry? (Section 2.3). Note that the results of our model only depend on whether banks are rational or biased: no information asymmetries, agency problems or liquidity restrictions have been assumed.

2.1 Analysis of rationality

The purpose of this section is to determine how to identify whether banks behave rational or biased and what would be the effects over the credit aggregates. Consider the case of two banks competing in this economy. How would this duopoly be characterized if both banks are unbiased? And what if one of them, or both, are

[5] That is, banks correctly infer whether a borrower is of a good or a bad quality. However, either good or bad clients could default if the economic environment becomes too negative, where of course chances of default are higher for bad borrowers. We consider that, given information available, rational banks are able to correctly calibrate the probabilities of success of both good and bad borrowers; optimistic banks, instead, believe bad-borrowers' chance of success is higher than they should have rationally presumed.

excessively optimistic? We model this market following the Monti-Klein model of an oligopoly (see Freixas and Rochet, 1998 for a description) where the banks' decision variables are volumes L_h and L_l of loans. Banks analyze borrowers' quality and decide how much credit they grant.

Having two banks in this industry, we may face three different situations: (i) both banks are unbiased; (ii) one bank is boundedly rational; (iii) both banks are biased. First, if both banks are of type A (we denote this a 'rational duopoly'), we have symmetric Cournot competitors solving a similar optimization program:

$$\begin{aligned}&\max E\left[\Pi^i\left(L_h^i, L_l^i\right)\right] = \theta_h \cdot r_h\left(L_h^i + L_h^{j*}\right)\cdot L_h^i - \left(1-\theta_h\right)\cdot L_h^i + \theta_l \cdot r_l\left(L_l^i + L_l^{j*}\right)\cdot L_l^i - \left(1-\theta_l\right)\cdot L_l^i - r\cdot D^i - C(D, L)\\ &s.t.: L_h^i + L_l^i = D^i\end{aligned} \tag{1}$$

The solution is given by

$$L_h^{A*} = L_h^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta\cdot\left(1+r+c\right)}{3}\cdot\frac{1}{\theta_h} \tag{2}$$

$$L_{l,rD}^{A*} = L_{l,rD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta\cdot\left(1+r+c\right)}{3}\cdot\frac{1}{\theta_l} \tag{3}$$

where $L_{l,rD}^{i*}$ denotes the volume granted by bank *i*, *i=A,B* to low-quality borrowers in a rational duopoly (denoted by subscript $_{rD}$), with rates

$$r_h^* = \frac{\alpha}{3\beta} + \frac{2\cdot\left[1+r+c-\theta_h\right]}{3\theta_h} \tag{4}$$

$$r_{l,rD}^* = \frac{\alpha}{3\beta} + \frac{2\cdot\left[1+r+c-\theta_l\right]}{3\theta_l} \tag{5}$$

where $r_{l,rD}^*$ denotes the interest rate for low-quality borrowers in a rational duopoly.

We may see the decision problem between high- and low-quality markets is separable; i.e., L_h^* and L_l^* are independent. This makes that all along this version of the model the only relevant results will be found in market niches where at least one bank is biased. However, it can be proved that assuming banks have convex cost functions L_h^* and L_l^*

are intertwined,[6] such that behavioral biases could feed externalities even in niches where all participants are behaving rational (see Peón and Antelo, 2013).

Second, what would happen if we have an asymmetric duopoly where one bank is unbiased in both markets (type A) and the other is biased when analyzing the probability of success of low-quality borrowers (type B)? Since markets are separable, volumes and interest rates in the high-quality market are identical to the results above (equations 2 and 4). On the contrary, in the low-quality market we get

$$L_{l,aD}^{A*} = \frac{\alpha+\beta}{3} - \frac{\beta\cdot(1+r+c)}{3}\cdot\left(\frac{2}{\theta_l} - \frac{1}{\theta_l^O}\right) \tag{6}$$

$$L_{l,aD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta\cdot(1+r+c)}{3}\cdot\left(\frac{2}{\theta_l^O} - \frac{1}{\theta_l}\right) \tag{7}$$

where $L_{l,aD}^{i*}$ denotes the equilibrium volume provided by bank *i* to low-quality borrowers in an asymmetric duopoly (denoted by subscript $_{\mathrm{aD}}$), with the interest rate being

$$r_{l,aD}^{*} = \frac{\alpha-2\beta}{3\beta} + \frac{1+r+c}{3}\cdot\left[\frac{1}{\theta_l} + \frac{1}{\theta_l^O}\right] \tag{8}$$

where $r_{l,aD}^{*}$ denotes the interest rate for low-quality borrowers in an asymmetric duopoly.

The consequence of having a biased bank in the industry is that a rational bank would reduce the amount of credit granted to low-quality borrowers –it is easy to see credit volume in equation (3) is larger than in equation (6)- while the boundedly rational bank sets a larger volume. In fact, it may happen that a bank of type A would end up driven out of the market of low-quality borrowers. Setting $L_{l,aD}^{A*} = 0$ in equation (6) and solving for θ_l we define the cut-off value θ_l^{M}

$$\theta_l^{\mathrm{M}} = \frac{2\beta\cdot(1+r+c)\cdot\theta_l^O}{(\alpha+\beta)\cdot\theta_l^O + \beta\cdot(1+r+c)} \tag{9}$$

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[6] This happens because both interest rates would be dependent on the first derivative of the cost function with respect to loans, C_L', which for a convex function would be a function of L.

being $0 < \theta_l^{\mathrm{M}} < 1$, such that a no-monopoly condition $\theta_l > \theta_l^{\mathrm{M}}$ is defined. When $\theta_l > \theta_l^{\mathrm{M}}$, the volume of credit granted to low-quality borrowers by a bank of type A is strictly non-negative, hence this market is an asymmetric duopoly. Alternatively, when $\theta_l \le \theta_l^{\mathrm{M}}$ there would be a monopoly by bank B. In such case the boundedly rational bank would solve

$$\begin{aligned} &\max E\left[\Pi^B(L_h^B, L_l^B)\right] = \theta_h \cdot r_h\left(L_h^B + L_h^{A*}\right) \cdot L_h^B - (1-\theta_h) \cdot L_h^B + \theta_l^O \cdot r_l(L_l^B) \cdot L_l^B - (1-\theta_l^O) \cdot L_l^B - r \cdot D^B - C(D,L) \\ &\text{s.t} : L_h^B + L_l^B = D^B \end{aligned} \quad (10)$$

setting a volume of loans granted to low-quality borrowers and subsequent interest rate

$$L_{l,M}^* = \frac{\alpha+\beta}{2} - \frac{\beta \cdot (1+r+c)}{2} \cdot \frac{1}{\theta_l^O} \quad (11)$$

$$r_{l,M}^* = \frac{\alpha}{2\beta} + \frac{1+r+c-\theta_l^O}{2\theta_l^O} \quad (12)$$

where $L_{l,M}^*$ denotes the volume of loans granted and $r_{l,M}^*$ the interest rate to low-quality borrowers when we have a monopoly (denoted by subscript $_{\mathrm{M}}$) by bank B in that niche.

Finally, we may have a market where both banks are of type B (denoted 'biased duopoly'). They would be symmetric Cournot competitors solving a similar problem as in equation (1), but where the probability of success of low-quality borrowers is replaced by θ_l^O. Banks set (2) and (4) at the high-quality market, while for low-quality borrowers we have

$$L_{l,bD}^{A*} = L_{l,bD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \frac{1}{\theta_l^O} \quad (13)$$

$$r_{l,bD}^* = \frac{\alpha}{3\beta} + \frac{2 \cdot \left[1+r+c-\theta_l^O\right]}{3\theta_l^O} \quad (15)$$

where $L_{l,bD}^{i*}$ denotes the volume granted by bank *i* to low-quality borrowers at a rate $r_{l,bD}^*$ in a biased duopoly (denoted by subscript $_{\mathrm{bD}}$).

Lemma 1. If $\theta_l > \theta_l^{\mathrm{M}}$, $L^*_{l,bD} > L^*_{l,aD} > L^*_{l,rD}$. *Alternatively, if* $\theta_l \leq \theta_l^{\mathrm{M}}$, $L^*_{l,bD} > L^*_{l,M} > L^*_{l,rD}$.

Proof. See Appendix.

Lemma 1 shows both the biased and the asymmetric duopolies (or the monopoly when the no-monopoly condition does not hold) generate a credit boom in the low-quality market above what it would be informationally efficient, with the largest credit boom coming in a duopoly market where both banks follow the biased strategy.

2.2 Herd behavior

The purpose of this section is to determine whether biased strategies could be correlated across the industry, even making unbiased participants following their biased competitors. Consider now a banking sector formed by two banks, A (unbiased) and B (biased). Assume for now the no-monopoly condition $\theta_l > \theta_l^{\mathrm{M}}$ does hold. We would expect this market to be described by equations (2), (6) and (7), with correspondent interest rates in equations (4) and (8), as we saw in Section 2.1.

Consider now banks are able to observe their competitor's estimated probabilities. Though each bank considers its own estimations as –by definition- unbiased, a key feature of the model is that, when banks of a different nature compete, they consider an *ex-ante* analysis of strategies to determine whether it is more profitable to them playing rational or biased (regardless of their true nature), given the possible alternatives the opposite bank may follow, and assuming both banks move simultaneously. This may be summarized as the game below.

		BANK B plays	
		UNBIASED	**BIASED**
BANK A plays	**UNBIASED**	RATIONAL DUOPOLY (at the low-quality market)	ASYMMETRIC DUOPOLY (at the low-quality market)
	BIASED	INVERTED ASYM. DUOP (at the low-quality market)	BIASED DUOPOLY (at the low-quality market)

Figure 1 Possible market configurations of the low-quality market

For instance, if bank A considers bank B will follow its own priors (playing biased or optimistic), bank A compares whether it is better to determine how much credit to grant using its own probabilities (playing unbiased or rational, hence we have an asymmetric duopoly) or imitating the optimistic bank to share one half of the market in a biased duopoly. Considering all the alternatives, the possible market configurations are a rational duopoly when both banks play unbiased (regardless of their true nature), a biased duopoly when both play biased, an asymmetric duopoly when they follow their own convictions, or an inverted asymmetric duopoly where bank B plays unbiased and bank A plays biased, both playing against their own true nature.[7]

The equilibrium volumes and interest rates of each possible market configuration would be those analyzed in Section 2.1. Nonetheless, in order to determine the possible Nash equilibria we must estimate the expected profits banks have in each possible scenarios, but using their own priors θ_l (bank A) and θ_l^O (bank B), since those are the probabilities they truly observe, to compute the expected profits. The following results are obtained.

Lemma 2. *Playing biased is a dominant strategy for bank B.*

Proof. See Appendix.

Lemma 2 leads to the following proposition.

Lemma 3. *Bank A herds whenever* $\theta_l > \theta_l^{\mathrm{T}}$, *where* $\theta_l^T = \dfrac{6\beta \cdot (1+r+c) \cdot \theta_l\, \theta_l^O}{(\alpha+\beta) \cdot \theta_l\, \theta_l^O + \beta \cdot (1+r+c) \cdot (3\theta_l + 2\theta_l^O)}$.

Proof. See Appendix.

Lemma 3 shows there may be market conditions where even unbiased participants would follow their biased competitors. In particular, there is a threshold bias $\theta_l^O - \theta_l^{\mathrm{T}}$ such that when bank B is not too biased, bank A herds to grant credit as if it had biased

[7] Similar volumes and market rates apply when we have an inverted asymmetric duopoly, but with equation (6) applying to bank B (which now would play rational) and equation (7) applying to bank A (which now would play biased). Were this market a monopoly (i.e., when the no-monopoly condition is not satisfied) bank A would be the monopolist instead of bank B.

expectations. When the no-monopoly condition does not hold (i.e., when $\theta_l \leq \theta_l^{\mathrm{M}}$) the cut-off value becomes $\theta_l^{\mathrm{T}} = \frac{3\beta \cdot (1+r+c) \cdot \theta_l^O}{(\alpha+\beta) \cdot \theta_l^O + 2\beta \cdot (1+r+c)}$. It can be shown (see Appendix) in this situation $\theta_l^T > \theta_l^{\mathrm{M}}$ so, when the asymmetric market of low-quality borrowers is a monopoly by bank B, it always becomes the equilibrium (since bank A chooses to play rational).

Proposition 1. *When a rational and a biased bank compete there may be three possible equilibria in the market of low-quality borrowers:*

- *When* $\theta_l^{\mathrm{M}} < \theta_l^T < \theta_l$ *the equilibrium is a biased duopoly where bank A herds;*
- *When* $\theta_l^{\mathrm{M}} < \theta_l \leq \theta_l^T$ *the equilibrium becomes an asymmetric duopoly where both banks use their own priors;*
- *When* $\theta_l \leq \theta_l^{\mathrm{M}}$ *the equilibrium becomes a monopoly by the biased bank B.*

Proof. See Appendix.

Figure 2 below provides a visual interpretation of Proposition 1, where θ_l^O has been set to be $\theta_l^O = 0.9$ and θ_l varies all along the dotted line.[8]

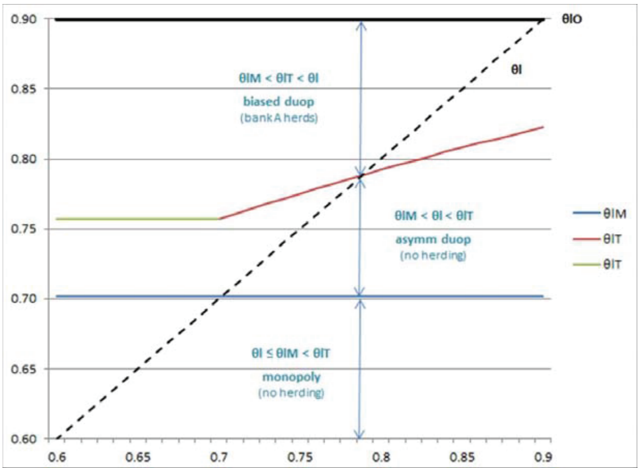

Figure 2 Possible equilibria in the market of low-quality borrowers

[8] We have also considered r=0.1, c=0.05, and α=β=1 in this example.

We may note the kinked feature of θ_l^T (when $\theta_l \leq \theta_l^{\mathrm{M}}$ the expression for θ_l^T in Lemma 3 simplifies to $\theta_l^{\mathrm{T}} = \frac{3\beta \cdot (1+r+c) \cdot \theta_l^O}{(\alpha+\beta) \cdot \theta_l^O + 2\beta \cdot (1+r+c)}$, which is insensitive of θ_l , hence horizontal). Since $\theta_l^T > \theta_l^{\mathrm{M}}$ is always satisfied, as the bias $\theta_l^O - \theta_l$ increases (i.e., as we move all the way down the dotted line) we may have the three different possible equilibria. Namely, in this example, a biased duopoly for $0.789 < \theta_l < 0.9$, an asymmetric duopoly for $0.702 < \theta_l \leq 0.789$ and a monopoly whenever $\theta_l \leq 0.702$.

Remark 1. *In all the three possible equilibria a credit boom of loans of low quality at a lower-than-rational rate is generated, being welfare increasing for low-quality borrowers. The largest credit boom follows when the unbiased bank herds.*

Proof. See Appendix.

2.3 Limits of arbitrage

The purpose of this third and final step is to determine whether there are limits of arbitrage in the banking industry. In credit markets, arbitrage between close substitutes makes no sense from a micro perspective: since there are no securities, a bank observing other bank granting a loan that underestimates the creditor's risk would only be able to make profit out of arbitrage if it were possible to grant a new loan to other customer and short-sell the former somehow. Besides, the risk assumed in each credit operation cannot be offset with the reduction of credit granted to any other agent in the market. Therefore, hedging should be considered in retail credit markets only at a macro level: are there market participants able to rectify the excess credit provided by the banking system during credit bubbles –the opposite with credit rationing- for their own profit?
However, the main drawback for arbitrage for the aggregate market to be performed by private agents refers to the impossibility for this strategy to be profitable. During credit booms, when optimistic banks are making money by giving credit to anyone who demands it, an arbitrageur should be willing not to win that *easy money* and lose market share. Rather than that, we have seen that whenever $\theta_l > \theta_l^{\mathrm{T}}$ an unbiased bank will be willing to fuel the credit boom to low-quality borrowers, hence not pricing loans to low-quality borrowers at their fundamental value given information available. Besides, we

should neither expect rational banks reduce the loans they grant to high quality borrowers (in order to compensate in aggregate terms for the higher volume of credit granted to low quality borrowers) because that would make them lose money, too.

On the other hand, banks could also use deposits for arbitrage purposes, but only with similar results: during credit bubbles, arbitrageurs (commercial banks) might raise the interest rate paid on deposits to a higher rate $r+\delta$, forcing competitors to do the same. This way, the cost of funding rises and banks would impose more stringent conditions on credit: they would be willing to reduce deposits (hence loans) to optimize their expected profits. However this strategy is neither profitable for bank A, since it could only be done by paying more on its existing deposits –hence reducing its expected profits.

Proposition 2. *In retail credit markets there would be no rationale for private banks to correct mispricing.*

The ultimate set of arguments for efficient financial markets is that, as long as there are a sufficient number of rational arbitrageurs making profit out of the mispricing (Fama, 1970) efficiency would be guaranteed. Rather than that, our model suggests that in retail credit markets the only presence of a biased bank may be a sufficient condition for a bubble to be generated. Arbitrage must be profitable at no risk or it does not work, but private banks will not have an economic motivation to hedge credit markets given the assumptions in our model. Ensuring informational efficiency, therefore, would rely only on authorities. Furthermore, banks themselves could, rather than hedge the market, play a speculative role: the classic moral hazard problem that has been suggested to have been a key factor in the recent crisis, specially by too-big-to-fail entities (Bernanke, 2010). Therefore, a key conclusion would be that limits of arbitrage might suggest bank-based systems are less likely to be informationally efficient than market-based ones,[9] even when informational asymmetries don't exist or are easy to overcome.

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[9] Shleifer (2000) suggests something similar about Central Banks in the context of fire sales and limits of arbitrage: *[I]t is easy to see how [fire sales] lead to chains of liquidations, and to financial distress of many market participants. When these market participants are financial intermediaries, they may curtail their lending to firms, thereby engendering a recession. (...) Financial panics can thus have severe real consequences. This model [Shleifer and Vishny, 1997] provides a potential justification for the Central Bank or another institution becoming the lender of last resort that can step in at the time of crisis and stop the chain of liquidations* (Bagehot 1872, Kindleberger 1978). *In this model, such intervention would improve the efficiency of financial markets. In a more general model, it can perhaps preserve the integrity of the financial system as well, and even prevent an economic rather than just a financial meltdown* (p. 107).

3. CONCLUDING REMARKS

We have introduced a behavioral approach to analyze and empirically test whether behavioral biases by participants in the banking industry might explain credit cycles. It complements literature on credit bubbles by suggesting that moral hazard, incentives, etc. could have been even more pervasive due to psychological biases, and the necessity for an enhanced macroprudential regulation due to limits of arbitrage in the banking sector.

A behavioral analysis of credit bubbles in retail credit markets could be achieved by extending the informational efficiency of the classical EMH approach to bank-based systems. Even in a world with no information asymmetries –or where banks are able to solve them- behavioral biases could still challenge market efficiency. Informational efficiency in bank-based systems may be analyzed at a macro level and using a three-step behavioral approach (Shleifer, 2000), which would split in determining: (i) whether behavioral biases influence CEOs and employees in that industry, conforming a market sentiment, (ii) whether market sentiment could exhibit predictable trends, and (iii) whether there are limits of arbitrage in retail credit markets.

We offer a model that follows the approach above, which shows why solely behavioral biases by participants in the industry could explain how a credit bubble might be fed by the banking sector. According to this model, biased banks would lead the industry while it may be rational for unbiased banks to herd. We derive the conditions for unbiased banks to herd, and show a credit boom of loans of low quality at a lower-than-rational rate is generated in all possible equilibria, which are welfare increasing for low-quality borrowers. For high-quality borrowers there are no welfare effects. A stronger result is the role of limits of arbitrage in the industry: there would be no incentives for rational banks to correct the misallocations of their biased competitors. A key conclusion is that limits of arbitrage might suggest bank-based systems are less likely to be informationally efficient than market based ones. Informational efficiency, therefore, would rely solely on authorities.

We are aware of the limitations of this approach. There are no financial systems that are solely bank-based or market-based, we would need a holistic view of the financial system and its links to macroeconomy (Borio and Shim, 2007), considering the effects of informational asymmetries and adverse selection, etc. However, our work may be a valid contribution in two aspects. First, we introduce an alternative approach to analyze informational efficiency in the banking industry that, to the best of our knowledge, had not been raised so far. Second, our model shows how behavioral biases might guide retail credit markets and why limits of arbitrage would be more pervasive in bank-based financial systems than in market-based ones. This could be a valid contribution to the current debate on macroprudential regulation.

Would tests of rationality and correlated behavior provide evidence on the pervasiveness of behavioral biases in the banking industry, then banking regulation should account for it. Some biases might be corrected through internal debiasing procedures (incentives, career opportunities, firewalls, etc.); others, however (e.g., herding) would require authorities to intervene. Examples are allowing authorities to monitor bank's scorings to statistically ensure banks are not incurring in excessive risk-taking or predatory lending,[10] or other alternatives authorities may use to arbitrate credit markets (through enhanced regulation, central banking, public banking, or other forms of market intervention).

APPENDIX

Proof of Lemma 1. We first calculate volumes and rates in the possible market configurations.

I.- Rational duopoly. When both banks have an unbiased probability θ_l they simultaneously solve the same optimization program

$$\begin{aligned} &\max E\left[\Pi^i\left(L_h^i, L_l^i\right)\right] = \theta_h \cdot r_h\left(L_h^i + L_h^{j*}\right) \cdot L_h^i - \left(1-\theta_h\right) \cdot L_h^i + \theta_l \cdot r_l\left(L_l^i + L_l^{j*}\right) \cdot L_l^i - \left(1-\theta_l\right) \cdot L_l^i - r \cdot D^i - C(D, L) \\ &s.t.: L_l^i + L_l^i = D^i \end{aligned} \tag{A1}$$

We introduce the restriction –since it is an equality- to have

$$\max E\left[\Pi^i\left(L_h^i, L_l^i\right)\right] = \left[\theta_h \cdot r_h\left(L_h^i + L_h^{j*}\right) - \left(1-\theta_h\right) - r\right] \cdot L_h^i + \left[\theta_l \cdot r_l\left(L_l^i + L_l^{j*}\right) - \left(1-\theta_l\right) - r\right] \cdot L_l^i - c \cdot \left(L_h^i + L_l^i\right)$$

[10] This is actually a suggestion by Professor Stiglitz, following our conversation in a private meeting in November 2011, available at http://www.dpeon.com/index.php/english/8-prof-stiglitz-in-a-coruna.html

The solutions are

$$L_h^{A*} = L_h^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \frac{1}{\theta_h} \tag{A2}$$

$$L_{l,rD}^{A*} = L_{l,rD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \frac{1}{3\theta_l} \tag{A3}$$

where $L_{l,rD}^{i*}$ denotes the equilibrium volume provided by bank i to low-quality borrowers in a rational duopoly, and the subsequent interest rates

$$r_h^* = \frac{\alpha}{3\beta} + \frac{2 \cdot [1+r+c-\theta_h]}{3\theta_h} \tag{A4}$$

$$r_{l,rD}^* = \frac{\alpha}{3\beta} + \frac{2 \cdot [1+r+c-\theta_l]}{3\theta_l} \tag{A5}$$

where $r_{l,rD}^*$ denotes the equilibrium interest rate for low-quality borrowers in a rational duopoly.

II.- Asymmetric market. When we have a rational and a boundedly rational bank in the industry, banks optimize

$$\max E\left[\Pi^A\left(L_h^A, L_l^A\right)\right] = \left[\theta_h \cdot r_h\left(L_h^A + L_h^{B*}\right) - (1-\theta_h) - r\right] \cdot L_h^A + \left[\theta_l \cdot r_l\left(L_l^A + L_l^{B*}\right) - (1-\theta_l) - r\right] \cdot L_l^A - c \cdot \left(L_h^A + L_l^A\right)$$

and

$$\max E\left[\Pi^B\left(L_h^B, L_l^B\right)\right] = \left[\theta_h \cdot r_h\left(L_h^{A*} + L_h^B\right) - (1-\theta_h) - r\right] \cdot L_h^B + \left[\theta_l^O \cdot r_l\left(L_l^{A*} + L_l^B\right) - (1-\theta_l^O) - r\right] \cdot L_l^B - c \cdot \left(L_h^B + L_l^B\right)$$

The assumption of linear costs guarantees markets are separable, so volumes and interest rates in the high-quality market are identical to results in the rational and biased duopolies (equations A2 and A4). In the low-quality market, on the contrary, we have

$$L_{l,aD}^{A*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \left(\frac{2}{\theta_l} - \frac{1}{\theta_l^O}\right) \tag{A6}$$

$$L_{l,aD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \left(\frac{2}{\theta_l^O} - \frac{1}{\theta_l}\right) \tag{A7}$$

where $L_{l,aD}^{i*}$ denotes the volume provided by bank i to low-quality borrowers in an asymmetric duopoly, with the interest rate at equilibrium being

$$r_{l,aD}^{*} = \frac{\alpha - 2\beta}{3\beta} + \beta \cdot (1 + r + c) \cdot \left[\frac{1}{\theta_l} + \frac{1}{\theta_l^O} \right] \tag{A8}$$

where $r_{l,aD}^{*}$ denotes the interest rate for low-quality borrowers in an asymmetric duopoly. Whenever the no-monopoly condition –see equation (11) in the text- does not hold, the volume granted by bank A according to equation (A6) would be $L_{l,aD}^{A*} \leq 0$. In such case, the market for low-quality borrowers would become a monopoly by bank B, such that (since high- and low-quality markets are separable) it would alternatively solve

$$\max E\left[\Pi^B (L_h^B, L_l^B)\right] = \left[\theta_h \cdot r_h (L_h^B + L_h^{A*}) - (1 - \theta_h) - r\right] \cdot L_h^B + \left[\theta_l^O \cdot r_l (L_l^B) - (1 - \theta_l^O) - r\right] \cdot L_l^B - c \cdot (L_h^B + L_l^B) \tag{A9}$$

It affords the following loan volumes at equilibrium:

$$L_{l,M}^{*} = \frac{\alpha + \beta}{2} - \frac{\beta \cdot (1 + r + c)}{2} \cdot \frac{1}{\theta_l^O} \tag{A10}$$

where $L_{l,M}^{*}$ denotes the volume granted to low-quality borrowers in a monopoly by bank B, and consequent price

$$r_{l,M}^{*} = \frac{\alpha}{2\beta} + \frac{1 + r + c - \theta_l^O}{2\theta_l^O} \tag{A11}$$

where $r_{l,M}^{*}$ denotes the interest rate for low-quality borrowers in a monopoly.

III.- <u>Biased duopoly</u>. Finally, if both banks in the industry are biased in the low-quality market, they solve a similar optimization problem as in equation (A1), but where the probability of success of low-quality borrowers is replaced by θ_l^O. Consequently, we get the same strategy for high-quality borrowers (A2 and A4) and for low-quality borrowers we have

$$L_{l,bD}^{A*} = L_{l,bD}^{B*} = \frac{\alpha+\beta}{3} - \frac{\beta \cdot (1+r+c)}{3} \cdot \frac{1}{\theta_l^O} \tag{A12}$$

where $L_{l,bD}^{i*}$ denotes the volume provided by bank *i* to low-quality borrowers in a biased duopoly, with the subsequent interest rate

$$r_{l,bD}^{*} = \frac{\alpha}{3\beta} + \frac{2 \cdot \left[1+r+c-\theta_l^O\right]}{3\theta_l^O} \tag{A13}$$

where $r_{l,bD}^{*}$ denotes the equilibrium interest rate for low-quality borrowers in a biased duopoly.

Lemma 1 follows from equations (A3), (A6), (A7), (A10) and (A12). First, using equations (A3) and (A12) it is clear $L_{l,bD}^{*} > L_{l,rD}^{*}$ since $\theta_l^O > \theta_l$. Next, to see what happens in an asymmetric market where one bank is rational and the other biased, consider now the situation where the no-monopoly condition $\theta_l > \theta_l^{\mathrm{M}}$ holds (i.e., we have an asymmetric duopoly). Using (A12) and rearranging we get the volume of loans $L_{l,bD}^{*} = L_{l,bD}^{A*} + L_{l,bD}^{B*} = \frac{2\alpha+2\beta}{3} - \beta \cdot (1+r+c) \cdot \frac{2}{3\theta_l^O}$ in a biased duopoly, while in an asymmetric duopoly the total volume granted would be given by $L_{l,aD}^{*} = L_{l,aD}^{A*} + L_{l,aD}^{B*} = \frac{2\alpha+2\beta}{3} - \beta \cdot (1+r+c) \cdot \left[\frac{1}{3\theta_l} + \frac{1}{3\theta_l^O}\right]$ (using equations A6 and A7). It is clear now $L_{l,bD}^{*} > L_{l,aD}^{*}$ since $\frac{2}{3\theta_l^O} < \frac{1}{3\theta_l} + \frac{1}{3\theta_l^O}$. Besides, using (A3) we get the volume in a rational duopoly $L_{l,rD}^{*} = L_{l,rD}^{A*} + L_{l,rD}^{B*} = \frac{2\alpha+2\beta}{3} - \beta \cdot (1+r+c) \cdot \frac{2}{3\theta_l}$, which makes $L_{l,aD}^{*} > L_{l,rD}^{*}$ since $\frac{2}{3\theta_l} < \frac{1}{3\theta_l} + \frac{1}{3\theta_l^O}$.

Finally, when the no-monopoly condition does not hold ($\theta_l \le \theta_l^{\mathrm{M}}$, $\theta_l^{\mathrm{M}} = \frac{2\beta \cdot (1+r+c) \cdot \theta_l^O}{(\alpha+\beta) \cdot \theta_l^O + \beta \cdot (1+r+c)}$) we have to compare the volume granted to low-quality borrowers in the monopoly market $-L_{l,M}^{*}$, given by equation (A10)- with $L_{l,rD}^{*}$ and $L_{l,bD}^{*}$. First, substituting the monopoly condition in $L_{l,rD}^{*} = \frac{2\alpha+2\beta}{3} - \beta \cdot (1+r+c) \cdot \frac{2}{3\theta_l}$ we get $L_{l,rD}^{*} = \frac{\alpha+\beta}{6} - \frac{\beta \cdot (1+r+c)}{6} \cdot \frac{1}{\theta_l^O}$, which is clearly lower than $L_{l,M}^{*}$ in equation (A10). Last,

$L^*_{l,bD} = \frac{2}{3}\left[\frac{\alpha+\beta}{3} - \beta \cdot (1+r+c) \cdot \frac{1}{\theta_l^O}\right]$ is obviously larger than $L^*_{l,M} = \frac{1}{2}\left[\frac{\alpha+\beta}{3} - \beta \cdot (1+r+c) \cdot \frac{1}{\theta_l^O}\right]$ in any case. ■

Proof of Lemma 2. Lemma 2 and Lemma 3 require to compare the expected profits banks A and B would obtain in different market configurations. Consequently, we must be aware that the rational bank A would estimate

$$E\left[\Pi_x^A\right] = \left[\theta_h \cdot \left(1+r_h^*\right) - (1+r+c)\right] \cdot L_h^{A*} + \left[\theta_l \cdot \left(1+r_{l,x}^*\right) - (1+r+c)\right] \cdot L_{l,x}^{A*} \tag{A14a}$$

where $r_{l,x}^*$ and $L_{l,x}^{A*}$ are, respectively, the interest rate and the loan volumes granted by bank A in the market configuration *x* we are considering, whereas bank B would instead use

$$E\left[\Pi_x^B\right] = \left[\theta_h \cdot \left(1+r_h^*\right) - (1+r+c)\right] \cdot L_h^{B*} + \left[\theta_l^O \cdot \left(1+r_{l,x}^*\right) - (1+r+c)\right] \cdot L_{l,x}^{B*} \tag{A14b}$$

where θ_l^O replaces θ_l.

For playing biased to be a dominant strategy for bank B we have to prove: (i) its expected profit in the asymmetric duopoly, $E\left[\Pi_{aD}^B\right]$ (alternatively, in the monopoly $E\left[\Pi_M^B\right]$ when the no-monopoly condition does not hold) is higher than in the rational duopoly, $E\left[\Pi_{rD}^B\right]$, and (ii) its expected profit in the biased duopoly, $E\left[\Pi_{bD}^B\right]$ is higher than in the inverted duopoly, $E\left[\Pi_{iD}^B\right]$ (alternatively, in the inverted monopoly $E\left[\Pi_{iM}^B\right]$) –where in both inverted scenarios banks' strategies go against their own priors, such that equation (A6) applies to bank B and equations (A7) and (A10) to bank A.

Consider first the no-monopoly condition holds.

(i) If we compare $E\left[\Pi_{aD}^B\right] = \left[\theta_h \cdot \left(1+r_h^*\right) - (1+r+c)\right] \cdot L_h^{B*} + \left[\theta_l^O \cdot \left(1+r_{l,aD}^*\right) - (1+r+c)\right] \cdot L_{l,aD}^{B*}$ and $E\left[\Pi_{rD}^B\right] = \left[\theta_h \cdot \left(1+r_h^*\right) - (1+r+c)\right] \cdot L_h^{B*} + \left[\theta_l^O \cdot \left(1+r_{l,rD}^*\right) - (1+r+c)\right] \cdot L_{l,rD}^{B*}$, since markets are separable we have to prove $\left[\theta_l^O \cdot \left(1+r_{l,aD}^*\right) - (1+r+c)\right] \cdot L_{l,aD}^{B*} > \left[\theta_l^O \cdot \left(1+r_{l,rD}^*\right) - (1+r+c)\right] \cdot L_{l,rD}^{B*}$. Substituting equations (A7), (A8), (A3) and (A5) we get bank B plays biased if

$$\frac{\beta \cdot (1+r+c)^2 \cdot \left[3\left(\theta_l^O\right)^2 - 7\theta_l^O\theta_l + 4\theta_l^2\right] + (\alpha+\beta) \cdot (1+r+c) \cdot \left[\theta_l\left(\theta_l^O\right)^2 - \theta_l^2\theta_l^O\right]}{9\theta_l^2\theta_l^O} > 0 \tag{A15}$$

This is satisfied for $\alpha > 4\beta \cdot \frac{1+r+c}{\theta_l^O} - 3\beta \cdot \frac{1+r+c}{\theta_l} - \beta$, which is true under Assumption 2.[11]

(ii) If we compare $E[\Pi_{bD}^B] = [\theta_h \cdot (1+r_h^*) - (1+r+c)] \cdot L_h^{B*} + [\theta_l^O \cdot (1+r_{l,bD}^*) - (1+r+c)] \cdot L_{l,bD}^{B*}$ and $E[\Pi_{iD}^B] = [\theta_h \cdot (1+r_h^*) - (1+r+c)] \cdot L_h^{B*} + [\theta_l^O \cdot (1+r_{l,iD}^*) - (1+r+c)] \cdot L_{l,iD}^{B*}$, since markets are separable we have to prove $[\theta_l^O \cdot (1+r_{l,bD}^*) - (1+r+c)] \cdot L_{l,bD}^{B*} > [\theta_l^O \cdot (1+r_{l,iD}^*) - (1+r+c)] \cdot L_{l,iD}^{B*}$. Substituting equations (A12), (A13), (A6) –note we pick (A6) since $L_{l,iD}^{B*} = L_{l,aD}^{A*}$- and (A8) we get bank B plays biased if

$$\frac{\beta \cdot (1+r+c)^2 \cdot \left[2(\theta_l^O)^2 - 5\theta_l^O\theta_l + 3\theta_l^2\right] + (\alpha+\beta) \cdot (1+r+c) \cdot \left[\theta_l (\theta_l^O)^2 - \theta_l^2 \theta_l^O\right]}{9\theta_l^2 \theta_l^O} > 0 \qquad \text{(A16)}$$

This is satisfied for $\alpha > 3\beta \cdot \frac{1+r+c}{\theta_l^O} - 2\beta \cdot \frac{1+r+c}{\theta_l} - \beta$, which is true under Assumption 2.[12]

Consider now the no-monopoly condition does not hold.

(i) Following the same logic as above, $E[\Pi_M^B] > E[\Pi_{rD}^B]$ requires, given markets are separable, that $[\theta_l^O \cdot (1+r_{l,M}^*) - (1+r+c)] \cdot L_{l,M}^{B*} > [\theta_l^O \cdot (1+r_{l,rD}^*) - (1+r+c)] \cdot L_{l,rD}^{B*}$. Substituting equations (A7), (A8), (A3) and (A5) we get bank B plays biased if

$$\frac{\begin{array}{l}\left[8\beta^2 \cdot (1+r+c)^2 - 4\beta \cdot (\alpha+\beta) \cdot (1+r+c) \cdot \theta_l + 5 \cdot (\alpha+\beta)^2 \cdot \theta_l^2\right] \cdot (\theta_l^O)^2 \\ - \left[12\beta^2 \cdot (1+r+c)^2 \cdot \theta_l + 6\beta \cdot (\alpha+\beta) \cdot (1+r+c) \cdot \theta_l^2\right] \cdot \theta_l^O + 9\beta^2 \cdot (1+r+c)^2 \cdot \theta_l^2\end{array}}{36\beta\theta_l^2\theta_l^O} > 0 \qquad \text{(A17)}$$

We need to prove this is positive only for $\theta_l \leq \theta_l^M$, so we proceed as follows. First we may show equation (A17) is positive at $\theta_l = \theta_l^M$.[13] A sufficient condition for

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[11] Using wxMaxima we get $\alpha = 4\beta \cdot \frac{1+r+c}{\theta_l^O} - 3\beta \cdot \frac{1+r+c}{\theta_l} - \beta$ makes equation (A15) equal to zero. Besides, the first derivative of equation (A15) with respect to α is equal to $\frac{1+r+c}{9} \cdot \left(\frac{\theta_l^O}{\theta_l} - 1\right)$, which is always positive. Hence, the difference in profits is always positive for any alpha above that threshold. Finally, it is easy to check $\alpha > \beta \cdot \frac{1+r+c}{\theta_l^O} - \beta$ imposed by Assumption 2 is higher than $4\beta \cdot \frac{1+r+c}{\theta_l^O} - 3\beta \cdot \frac{1+r+c}{\theta_l} - \beta$ since $\theta_l^O > \theta_l$. Calculations are available upon request to the authors.

[12] This holds for identical reason as in footnote 30. The derivative of equation (A16) with respect to α is the same as in the previous footnote, hence positive, while it is again easy to check the minimum alpha imposed by Assumption 2 is larger than $3\beta \cdot \frac{1+r+c}{\theta_l^O} - 2\beta \cdot \frac{1+r+c}{\theta_l} - \beta$.

profits to be positive below θ_l^{M} would be that the first derivative of equation (A17) with respect to θ_l is negative for all $\theta_l \leq \theta_l^{\mathrm{M}}$. The first derivative is $\frac{\beta\cdot(1+r+c)^2\cdot(3\theta_l - 4\theta_l^O)+(\alpha+\beta)\cdot(1+r+c)\cdot\theta_l\,\theta_l^O}{9\theta_l^3}$, equal to zero at $\theta_l^{1st} = \frac{4\beta\cdot(1+r+c)\cdot\theta_l^O}{(\alpha+\beta)\cdot\theta_l^O+3\beta\cdot(1+r+c)}$ and negative below that point, since we may rearrange $\frac{\beta\cdot(1+r+c)^2\cdot(3\theta_l - 4\theta_l^O)+(\alpha+\beta)\cdot(1+r+c)\cdot\theta_l\,\theta_l^O}{9\theta_l^3}<0$ to see the denominator is positive and the numerator satisfies $\theta_l < \theta_l^{1st} = \frac{4\beta\cdot(1+r+c)\cdot\theta_l^O}{(\alpha+\beta)\cdot\theta_l^O+3\beta\cdot(1+r+c)}$. It is easy to prove $\theta_l^{\mathrm{M}} = \frac{2\beta\cdot(1+r+c)\cdot\theta_l^O}{(\alpha+\beta)\cdot\theta_l^O+\beta\cdot(1+r+c)}$ satisfies $\theta_l^{\mathrm{M}} < \theta_l^{1st}$ whenever $\alpha > \beta\cdot\frac{1+r+c-\theta_l^O}{\theta_l^O}$ (i.e., under Assumption 2). Consequently, the first derivative is negative below θ_l^{1st} and hence profits in equation (A17) are positive below θ_l^{M}.[14]

(ii) Finally, $E[\Pi_{bD}^B] > E[\Pi_{iM}^B]$ requires $[\theta_l^O\cdot(1+r_{l,bD}^*)-(1+r+c)]\cdot L_{l,bD}^{B*}>0$. Substituting (A12) and (A13) we get bank B plays biased if

$$\frac{[(\alpha+\beta)\cdot\theta_l^O-\beta\cdot(1+r+c)]^2}{9\beta\theta_l^O}>0 \tag{A18}$$

which is positive in all cases except at $\alpha = \beta\cdot\frac{1+r+c-\theta_l^O}{\theta_l^O}$ which is zero, but Assumption 2 imposes $\alpha > \beta\cdot\frac{1+r+c-\theta_l^O}{\theta_l^O}$. ■

Proof of Lemma 3. Given playing biased is a dominant strategy for bank B, in order to determine the conditions for bank A to herd we have to compare its expected profits if bank A plays biased (the biased duopoly) versus the expected profits if it plays rational (the asymmetric duopoly, or the monopoly by bank B if the no-monopoly condition does not hold).

[13] If we substitute θ_l^{M} in equation (A17) we get $\frac{5\cdot[(\alpha+\beta)\cdot\theta_l^O-\beta\cdot(1+r+c)]^2}{36\beta\theta_l^O}$ which is positive for all values except at $\alpha = \beta\cdot\frac{1+r+c-\theta_l^O}{\theta_l^O}$ which is zero, but Assumption 2 imposes $\alpha > \beta\cdot\frac{1+r+c-\theta_l^O}{\theta_l^O}$

[14] Detailed calculations of this demonstration are available upon request to the authors.

Consider first the no-monopoly condition holds. Bank A herds if the expected profit in the biased duopoly is higher than in the asymmetric duopoly, $E[\Pi_{bD}^{A}] > E[\Pi_{aD}^{A}]$. That requires, given markets are separable, that $[\theta_l \cdot (1 + r_{l,bD}^{*}) - (1 + r + c)] \cdot L_{l,bD}^{A*} > [\theta_l \cdot (1 + r_{l,aD}^{*}) - (1 + r + c)] \cdot L_{l,aD}^{A*}$, which rearranging it makes $\theta_l > \dfrac{(1 + r + c) \cdot (L_{l,bD}^{A*} - L_{l,aD}^{A*})}{[(1 + r_{l,bD}^{*}) \cdot L_{l,bD}^{A*}] - [(1 + r_{l,aD}^{*}) \cdot L_{l,aD}^{A*}]}$ provided $[(1 + r_{l,bD}^{*}) \cdot L_{l,bD}^{A*}] - [(1 + r_{l,aD}^{*}) \cdot L_{l,aD}^{A*}]$ is positive.[15] We may expand that expression substituting equations (A6), (A8), (A12) and (A13) for volumes and interest rates to get $\theta_l > \dfrac{6\beta \cdot (1 + r + c) \cdot \theta_l \, \theta_l^{O}}{(\alpha + \beta) \cdot \theta_l \, \theta_l^{O} + \beta \cdot (1 + r + c) \cdot (3\theta_l + 2\theta_l^{O})}$.

Consider now the no-monopoly condition does not hold. Bank A would herd if the expected profit in the biased duopoly is higher than in the monopoly for bank B, $E[\Pi_{bD}^{A}] > E[\Pi_{M}^{A}]$ which, given markets are separable, would imply $[\theta_l \cdot (1 + r_{l,bD}^{*}) - (1 + r + c)] \cdot L_{l,bD}^{A*} > 0$. Rearranging we get $\theta_l > \dfrac{1 + r + c}{1 + r_{l,bD}^{*}}$. This threshold level may be extended –substituting equation (A13)- to $\theta_l^{\mathrm{T}} = \dfrac{3\beta \cdot (1 + r + c) \cdot \theta_l^{O}}{(\alpha + \beta) \cdot \theta_l^{O} + 2\beta \cdot (1 + r + c)}$. Compared to the no-monopoly condition $\theta_l^{\mathrm{M}} = \dfrac{2\beta \cdot (1 + r + c) \cdot \theta_l^{O}}{(\alpha + \beta) \cdot \theta_l^{O} + \beta \cdot (1 + r + c)}$ it is easy to prove $\theta_l^{\mathrm{T}} > \theta_l^{\mathrm{M}}$ provided $\alpha > \beta \cdot \dfrac{1 + r + c - \theta_l^{O}}{\theta_l^{O}}$ (i.e., given Assumption 2 is satisfied). Consequently, the herding condition $\theta_l > \theta_l^{\mathrm{T}}$ is not satisfied when the no-monopoly condition does not hold. Hence, when the asymmetric market is a monopoly it will always be the equilibrium (bank A does not herd). ■

Proof of Proposition 1. It follows from Lemmas 2 and 3. ■

Proof of Remark 1. It follows from Proposition 1 and Lemma 1. ■

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[15] We may check it using (A6), (A8), (A12) and (A13) to expand $[(1 + r_{l,bD}^{*}) \cdot L_{l,bD}^{A*}] - [(1 + r_{l,aD}^{*}) \cdot L_{l,aD}^{A*}]$ to get $\dfrac{\beta \cdot (1+r+c)^2 \cdot [2 \cdot (\theta_l^{O})^2 + \theta_l^{O}\theta_l - 3\theta_l^2] + (\alpha+\beta) \cdot (1+r+c) \cdot (\theta_l^{O}\theta_l) \cdot (\theta_l^{O} - \theta_l)}{9\theta_l^2 \cdot (\theta_l^{O})^2}$, which is positive given $\theta_l < \theta_l^{O} < 1$.

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