Topic 4
Topic 2
Topic 3
Topic 1
Topic 5

Topic3
p6, p29

BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers

No 488

Bank Competition and Credit Booms

by Phurichai Rungcharoenkitkul

Monetary and Economic Department

February 2015

JEL classification: G21, D82, D86, E51, E52

Keywords: Bank competition, credit booms, asymmetric information, optimal contract, coordination failure, finance-neutral rate of interest, monetary policy

BIS Working Papers are written by members of the Monetary and Economic Department of the Bank for International Settlements, and from time to time by other economists, and are published by the Bank. The papers are on subjects of topical interest and are technical in character. The views expressed in them are those of their authors and not necessarily the views of the BIS.

This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

Bank Competition and Credit Booms*

Phurichai Rungcharoenkitkul
Bank for International Settlements

February 3, 2015

Abstract

A model of imperfectly competitive banks is examined under asymmetric information about borrower quality. Greater bank competition and a lower risk-free rate raise the screening costs of lending, which can result in pooling Nash equilibria with credit booms. Such equilibria are characterised by sharp increases in credit supply and deteriorations in average loan quality, which are inefficient for banks. In the model, banks' incentives to make risky loans can vary despite unchanged capital structure, thus highlighting the role of a risk-taking mechanism. This approach helps explain the existing mixed empirical results on the relationship between bank competition and financial stability. The model can be used to define a neutral interest rate in the context of financial cycles, namely a finance-neutral interest rate, which is estimated in the case of the United States.

JEL Classification: G21, D82, D86, E51, E52
Keywords: Bank competition, credit booms, asymmetric information, optimal contract, coordination failure, finance-neutral rate of interest, monetary policy
Author's E-mail: phurichai.rungcharoenkitkul@bis.org

*I thank the discussants Pongsak Luangaram and Wirawat Panthawangkun, as well as Claudio Borio, Piti Disyatat, Andrew Filardo, Leonardo Gambarcota, Hyun Song Shin and other seminar participants at the Bank of Thailand and the Bank for International Settlements for their helpful comments. This paper grew out of a previous project with Nakarin Amarase, who I thank for numerous discussions. Any errors are my own.

1 Introduction

The nexus between economic performance, financial access, and financial stability has been explored in a broad range of research fields. Modern macro theory suggests that an easing of financial constraints of otherwise productive firms has a positive effect on economic activity, through a short-term financial accelerator mechanism. Over longer horizons, increasing financial access can unlock the economy's productive potential, improve risk-sharing, facilitate the allocation of information and capital, and thereby raise economic growth (Levine (2005)).

On the other hand, there is a growing recognition that the relationship between finance and growth may be unstable in practice. Past financial crises serve as painful reminders that increasing financial access by too much too fast is subject to diminishing returns at best, and can even lead to severe output losses when the financial sector is in disarray. Despite ample evidence for this perverse nonlinearity, there is less understanding about the exact mechanism by which excessive finance that is harmful for stability can arise as an equilibrium phenomenon. Similarly, the role of policy in navigating the trade-off between growth and financial stability, unlike that between growth and inflation, remains a relatively uncharted territory.

This paper proposes a simple model of bank lending decision, where 'credit boom' could emerge as an equilibrium phenomenon. Two key forces interact to determine the equilibrium. First, banks have an incentive to screen out bad clients by restricting the amount of lending per contract, as riskier firms are known to seek larger loans despite a lower chance of success. Such screening entails costs to both banks and good firms, given that credits are being rationed to meet incentive compatibility conditions. This feature is essentially the classic credit rationing result in Stiglitz and Weiss (1981).

The second force comes into play when banks enjoy some monopolistic power over their loan market, but can attempt to poach clients from another bank by offering cheaper loan contracts. Lowering prices of loans raises the screening costs, because it necessitates even greater credit rationing if banks were to screen out risky firms. When the degree of bank competition for borrowers is sufficiently intense, it becomes optimal for banks to stop screening and rush to dominate the market by offering contracts with larger loans to all firms. This new pooling equilibrium is characterised by a low lending interest rate (relative to the average productivity of underlying projects), a larger loan size, and a higher probability of loan defaults.

The results shed light on the interactions between financial stability, lending competition, and monetary policy. The risk-free interest rate is exogenously set by the central bank, which interacts with the degree of lending competition in determining the outcome. A lower risk-free rate increases the banks' incentives to lend by lowering the opportunity cost of funds. But how the credit market equilibrium responds to changes in the risk-free rate also depends on the market structure in which banks operate. In particular, when a bank can gain more market share for a given cut in lending rate, the degree of competiton tends to be higher in equilibrium for any level of risk-free rate. Credit booms are therefore more likely to occur when banks compete more aggressively and/or the risk-free rate is low. In this context, the notion of 'financial stability neutral' monetary policy can be given an explicit definition, namely that which will prevent a pooling equilibrium from occuring. At the same time, the presence of intense bank competition can limit the effectiveness of monetary policy in containing a credit boom and achieving the financial stability objective.

1.1 Literature

Empirical work in recent years has investigated the role of excessive credit growth in creating financial fragilities. Reinhart and Rogoff (2009) provide a sweeping assessment, highlighting the role of debt accumulation (both private and public) in fueling financial bubbles, increasing systemic risks, and ultimately leading to financial/sovereign default crises. Their analysis over a long time span across countries reaffirms the notion that excessive credit growth plays an important role in the run-up to financial crises. In an early warning exercise, Borio and Drehmann (2009) find the credit-to-GDP gap to be a good predictive indicator of crises in advanced economies when used in conjunction with asset prices. In Schularick and Taylor (2012), credit booms historically have been a predictor of financial crises. They show further that despite being more aggressive in combating the fallout of financial crises after 1945, monetary policy did not reduce the output costs of financial crises. These studies point to the importance of understanding the emergence of financial fragilities and what role, if any, policy has in mitigating them.

To address issues raised by this empirical evidence, this paper constructs a theoretical model of imperfectly competitive financial intermediaries under asymmetric information. There is a vast literature that takes an industrial organisation approach to the study of banking (for a comprehensive review, see Freixas and Rochet (2008)). Of particular relevance is the strand that studies competition's effects on banks' risk-taking and financial stability (see Allen and

Gale (2004) for a survey). Keeley (1990), in a seminal work, shows that competition increases banks' risk-taking due to agency and risk-shifting problems. With limited liability, banks stand to gain from upside shocks to profit, while depositors (as debt holders) lose out on the downside. Competition forces down the charter value of banks, worsens risk-shifting and thereby increases banks' incentives to take more risks. These agency costs are exacerbated when depositors cannot monitor banks' risk-taking or there is deposit insurance.

The trade-off between bank competition and financial stability is not always straightforward, however, in the models with risk-shifting problems. For example, in Boyd and De Nicolo (2005), firms are the ones that choose the level of risk to take when investing. Firms take more risks when their profit (analogous to charter value) is lower. In this instance, greater bank competition raises firms' profits and lowers the degree of risk-taking by firms, fostering financial stability. De Nicolo and Lucchetta (2011) extend the model to the general equilibrium case where both banks and firms jointly set the level of risk-taking and show that perfect competition is optimal and encourages financial stability, in the case of increasing returns to scale technology.

The point of departure in this paper is that the source of financial instability does not stem from the relationship between risk-shifting problems and banks' charter value. Banks here are financed in their entirety by their own capital. The lending decisions by banks are based purely on their assessment of risks and the degree of competition. In this sense, this paper derives a stronger result: there can still be excessive risk-taking as a result of bank competition even if the entire assets are exactly equal to banks' charter value (thus leaving no room for risk-shifting).[1]

The paper contributes to the expanding literature that highlights the role of strategic interactions among banks as a driver of the credit cycle. Gorton and He (2008) consider a repeated game, in which banks compete by adjusting private lending standards. Normal periods where banks collude on little screening (and thus avoid worsening each other's pool quality) are punctuated by punishment periods where banks raise lending standards, resulting in a credit crunch. This paper, on the other hand, focuses on the boom phase, namely the build-up of excessive lending that leaves the banks inefficiently exposed to low-quality borrowers. While a credit crunch is not explicitly modelled, the multiplicity of possible outcomes in the stage game

[1] Abstracting away deposit market confers another advantage, in that the model could have broader applications than banking. For example, the mechanism can also be helpful for understanding higher risk-taking by real money investors in debt instruments such as pension funds.

provides a representation of how the equilibrium could be subject to endogenous volatility and swings.

In Dell'Ariccia and Marquez (2006), credit booms occur when banks trade off borrower quality for greater market share by pooling new borrowers of unknown worthiness. As aggregate information about the borrowers declines (namely when the pool of new borrowers grows relative to those that have been rejected by some banks), banks have greater incentives to lend more by lowering screening efforts. In this paper, banks do not have private information, and thus there is no informational gain from experimenting with new borrowers. There is a fixed pool of borrowers and the proportion of borrower types are common knowledge. Credit booms can arise despite no change in the belief about the average quality of the pool. It is the cost of screening, which rises with competition, that can offset incentives to compete only for good borrowers.

Aikman et al. (2014) propose yet another mechanism, relying on bank managers' incentives to signal their superior ability to choose investment projects to shareholders (even if falsely) by keeping short-term earnings high. There are strategic complementarities, owing to the incentive of others to do the same. In the present paper, there is also a coordination failure problem, which causes a credit boom to be inefficient from the banks' points of view (and for the social planner who cares about financial stability). However, the motive for risk-taking does not rely on banks' short-termism, as banks maximise their expected returns in a conventional way in an essentially static setup. The frictions stem purely from the coordination failure problem.

1.2 Model Sketch and the Outline

The main theoretical argument can be sketched as follows. Borrower types are not observable by outsiders. It is common knowledge, however, that riskier borrowers are more inclined to request larger loans despite a lower probability of project success. Banks have incentives to screen out these riskier firms by limiting loans and ration credit by keeping prices high. But such agency costs rise as lending competition exerts downward pressure on loan prices. A bank can instead forgo the asymmetric information constraint, and aim to capture a higher market share by offering a cheaper and larger-amount contract. Intensifying bank competition can then trigger an equilibrium switch, from a separating one with credit rationing to a pooling type, a caricature of credit boom.

In the model, a single bank is assumed to always prefer a contract that successfully separates out the high-risk firms (a separating contract) to a pooling contract. Section 3 derives the optimal lending contract under this case, and shows that this assumption puts restrictions on the range of risk-free interest rate. Section 4 examines the setting of two banks, where the loan market is imperfectly competitive because different firms have varied access costs to each bank. Optimal contracts are derived, corresponding to the 2×2 combinations of the two banks' strategies (separating versus pooling). When the firms' cost of switching banks is sufficiently low, it is shown that a joint pooling contract may be the only Nash equilibrium. Such an outcome is obtained for the same set of parameters that guarantees an optimal separating contract under a single bank. Multiple equilibria could also exist, serving as a representation of credit market outcome that adjusts nonlinearly in response to shocks.

Section 5 parameterises the model, derives explicit solutions, and discusses the implications. The likelihood of a credit boom equilibrium is shown to be inversely related to the risk-free interest rate, and positively to how easy it is to poach new clients. The notion of a 'finance-neutral' rate of interest can be given an explicit definition, a useful metric for describing the challenge of preventing or reversing a credit boom.

Section 6 turns to two empirical issues raised by the model. It first discusses the existing mixed empirical evidence on the links between bank competition and financial stability. The theory supports the competition-fragility view in the context of banks competing to lend to a fixed set of borrowers. Past failures to detect a robust negative relationship between bank competition and financial stability may arise partly from not controlling this factor sufficiently. More recent empirical exercises with richer controls yield results that are congruent with the model's predictions. Secondly, an empirical procedure is proposed for estimating the finance-neutral rate of interest and is applied to the US data. The results illustrate the extent of trade-offs between the macroeconomic and financial stability objectives in the recent US history. At the same time, the estimate also quantifies how the delayed monetary policy normalisation may have contributed to the subsequent financial crisis.

Section 7 concludes.

2 The Model

A continuum of firms borrows capital from the bank to finance their projects. Firms come in good and bad varieties, the sizes of which are commonly known to be 1 and γ respectively. Only the firm itself can observe its own type. The good firms can convert k units of capital into $F(k)$

units of output with probability p, and zero output otherwise. The bad firms can produce $G(k)$, but with a lower success probability $q < p$. In addition to being riskier, the bad technology requires greater start-up capital to get the project going, but potentially yields a higher return as long as the capital input is sufficiently large. Specifically, it is assumed that $F(1) = G(1)$, with $F(k) > G(k)$ for all $0 < k < 1$, and $F(k) < G(k)$ for all $k > 1$.[2] Figure 1 depicts a pair of technologies obeying this 'single-crossing' condition, which will enable the bank to sort between the two types of firms by offering appropriate contracts.

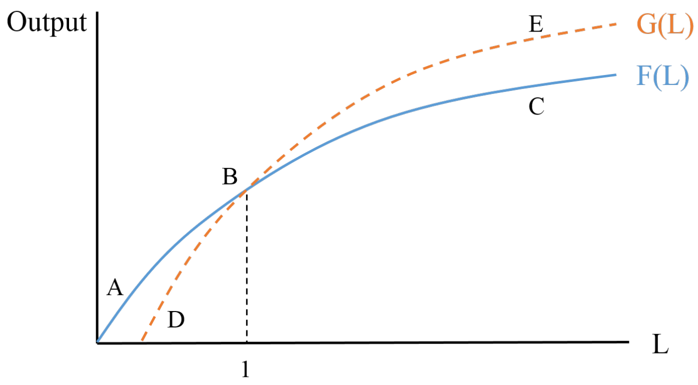


Figure 1: Single-crossing technologies

There are two periods. In the first period, the bank offers a take-it-or-leave-it loan contract to the firms, specifying the lending amount L and the gross interest rate R. Because firm types are not observable to the bank, only one contract can be offered to firms. Once a loan contract is agreed, production is carried out subject to the capital raised, and output is realised in the second period. Loans are then repaid and residual output consumed by the firms. Perfect monitoring is assumed, so that loans and interests are always repaid in full provided the output is sufficient to cover the repayments. Firms are protected by limited liability, and can default if the production fails. Being risk-neutral, firms will only accept a loan contract if the expected payoff is greater than zero:

$$U_{Good} = p(F(L) - RL) + (1 - p)0 \geq 0 \tag{2.1}$$

$$U_{Bad} = q(G(L) - RL) + (1 - q)0 \geq 0 \tag{2.2}$$

[2]The two technologies are not rankable in the stochastic dominance sense. However, under certain restrictions of the parameters, a monopoly bank would always prefer lending to the firms with technology F than the ones with G, thus providing the definition for 'good' and 'bad' firms. These parametric assumptions will be spelled out below.

Thus, good and bad firms accept the contract $\{L, R\}$ if it gives them non-negative surpluses, that is if, respectively,

$$F(L) \geq RL \tag{2.3}$$

$$G(L) \geq RL \tag{2.4}$$

The bank is risk-neutral and can either lend to the firms or invest in a risk-free technology with gross interest rate R_f. The bank is funded entirely by own capital C, assumed to be large enough so that the bank is never constrained to lend. The marginal cost of lending is therefore always R_f.[3]

In the basic model, the bank exercises absolute monopoly power on its client base. An important case will also be considered, where two banks, A and B, compete in a monopolistic environment. In this case, a Hotelling-like spatial structure is assumed, where all firms are equally distributed over the interval $[0, 2]$, with Bank A located at point 0, and Bank B's position at point 2. A firm living on point $\theta \in [0, 2]$ must pay a linear transaction (or distance) cost of $d\theta/2$ if it chooses to get a loan from Bank A, or $d(1 - \theta)/2$ if it were to get a loan from Bank B, where $d > 0$. A firm can only borrow from one bank, and chooses the one with the highest expected surplus net of the transaction costs.

3 Optimal Contract under a Single Bank

With only one bank to borrow from, firms have no choice but to accept any contract offering non-negative surplus. It is thus optimal for the bank to give no more than zero surplus to the firms it wishes to attract. Complications arise because the bank may want to have only good firms on its portfolio, but cannot identify them a priori. The contract design must perform dual functions of extracting surplus as well as sorting firm types. In particular, if the bank were to lend any more than 1, it cannot offer a contract acceptable to the good type without also attracting the bad type. Such a pooling contract lies on the arc BC in Figure 1, which would give good firms zero surplus and bad firms positive surplus $G(L) - F(L)$. The offered contract

[3]This simplifying assumption obviates the need to model deposit supply and interest rate, but is not critical for the analysis.

$\{L, R\} = \{L, F(L)/L\}$ gives the bank an expected profit of

$$\pi_p(L) = R_f(C - (1+\gamma)L) + (p + \gamma q)F(L) \tag{3.1}$$

for $L > 1$. The first term on the right-hand side is the return from a safe asset investment, given that a pooling contract will attract both types of borrowers, and hence the aggregate lending is $(1+\gamma)L$. The second term is the return from lending, given that the good firms can repay the debt of $RL = F(L)$ with probability p, while a mass γ of bad firms can repay the same amount with probability q.

Maximising equation 3.1 gives the optimal lending amount under a pooling contract L_p, which solves

$$F'(L_p) = \frac{(1+\gamma)R_f}{p + \gamma q} \tag{3.2}$$

The existence of an interior solution $L_p > 1$ to equation 3.2 is necessary (but not sufficient) for the pooling equilibrium to be supported. Unless it is satisfied, the bank will always offer a separating contract on the segment AB in Figure 1 as a unique optimal contract. The necessary condition $L_p > 1$ can be equivalently stated as $F'(1) > \frac{(1+\gamma)R_f}{p+\gamma q}$, and is satisfied as long as

$$R_f < \overline{R} \equiv \frac{(p + \gamma q)F'(1)}{1 + \gamma} \tag{3.3}$$

Intuitively, the bank is interested in lending a larger amount, which is a characteristic of a pooling contract, only if the competing risk-free return is not too high. To allow for the possibility of a pooling equilibrium (which represents a credit boom), this condition is assumed to hold.

If the bank instead wishes to screen out the bad firms, it must limit its lending and offer a contract along the arc AB in Figure 1. This will give the bank an expected profit of

$$\pi_s(L) = R_f(C - L) + pF(L) \tag{3.4}$$

valid for $L \leq 1$. The optimal loan size L_s does not obey the first-order condition $F'(L_s) = \frac{R_f}{p}$, but instead is a corner solution

$$L_s = 1 \tag{3.5}$$

since condition 3.3 implies that $F'(1) > \frac{(1+\gamma)R_f}{p+\gamma q} > \frac{R_f}{p}$.

Assumption 1. *A separating equilibrium prevails under one bank. Namely, despite condition 3.3 being met, the bank prefers to screen out bad firms*

$$\pi_s(1) > \pi_p(L_p) \tag{3.6}$$

Condition 3.3 and Assumption 1 jointly imply

$$\underline{R} < R_f < \overline{R} \tag{3.7}$$

where $\underline{R}$ is the level of R_f that solves

$$R_f = \frac{(p+\gamma q)F(L_p) - pF(1)}{(1+\gamma)L_p - 1} \tag{3.8}$$

In general, the right-hand term need not be monotonic in R_f. But for large enough R_f, it is decreasing in R_f. A solution $\underline{R}$ therefore exists. When more than one solution exists, the smaller one applies. Namely, $\underline{R}$ is the lowest possible rate that makes the bank indifferent between separating and pooling. Assumption 1 requires $\underline{R}$ to be less than $\overline{R}$.

The intuition for the inequalities 3.7 is as follows. For a moderate range of the risk-free interest rate, the bank prefers a contract with limited lending to select only good firms over a large-lending pooling alternative. Too high an interest rate would constrain the optimal lending amount to below 1, rendering the asymmetric information constraint non-binding. Too low an interest rate would incentivise the bank to increase its risky investment, which is possible only by extending loans to both types of firms in the pooling equilibrium.

Finally, the bad firms are now given a tighter definition, in order to rule out the uninteresting case where a separating contract is offered to attract only the bad type. It is assumed that

Assumption 2.

$$qG'(1) < \underline{R} \tag{3.9}$$

This condition says that the default probability is sufficiently high and/or marginal product G' is sufficiently low, such that for all R_f of interest, the interior optimal lending to bad firms is less than one. But a contract with $L < 1$ is not a feasible separating one, as it will attract the good type. Suppose that there exists such a separating contract with $L \geq 1$. This second best contract satisfying incentive compatibility is $\{L, R\} = \{1, G(1)\}$, the same as the optimal contract that selects only the good type. Thus, it is essentially a pooling contract, which is necessarily inferior to the optimal pooling contract satisfying equation 3.2: a contradiction. Under Assumption 2, one can thus ignore the possibility of any separating equilibrium involving only bad firms.

The separating equilibrium has the standard feature of credit rationing along the line of Stiglitz and Weiss (1981). The bank would want to lend more than $L = 1$ to good firms but is constrained by the adverse selection problem which threatens to dilute the quality of asset pool. The good firms are in turn denied more financing even though they have a productive means to employ the resources, and despite their willingness to pay a higher interest rate.

4 Bank Competition

Consider the case of two banks, A and B, competing in a monopolistic environment. Heterogeneous costs of accessing banks are now assumed, which give each bank some market power on its natural client base. For any pair of contracts offered by banks, there exists a cutoff firm $\hat{\theta} \in [0, 2]$, where all firms $\theta < \hat{\theta}$ choose to be with Bank A and all $\theta > \hat{\theta}$ choose to be with Bank B, because of the increasing transaction cost $d\theta/2$, where $d > 0$. When deciding which bank to borrow from, each firm compares the surpluses under the two contracts, against the transaction costs. Let S_A and S_B denote the surpluses that firms enjoy under Bank A's and Bank B's contracts respectively; then $\hat{\theta}$ represents the indifferent firm:

$$S_A - S_B = \frac{d\hat{\theta}}{2} - \frac{d(2 - \hat{\theta})}{2} = d(\hat{\theta} - 1) \tag{4.1}$$

thus

$$\hat{\theta} = 1 + \frac{1}{d}(S_A - S_B) \tag{4.2}$$

The market share for Bank A, $\hat{\theta}$, is thus an increasing function of $S_A - S_B$, and is more sensitive to contract surplus if the cost function is relatively flat. In the extreme case of homogeneous costs where $d \to 0$, the competition becomes that of Bertrand.

Bank competition introduces two levels of strategic calculations. Each bank must decide what *type* of contracts to offer (separating or pooling), taking into account the rival bank's offer type. Conditional on the resulting combination of contract types, each bank then determines the optimal contract specification $\{L, R\}$, again taking into account its rival's actions. Nash equilibrium concepts can be used in both stages of interactions.

In determining the optimal contract specifications, there exist four main cases corresponding to the 2×2 combination of contract types offered by two banks. The two cases where both banks offer the same type of contracts are potential candidates for a symmetric Nash equilibrium of the overall game. The Nash equilibria with joint pooling and joint separating contracts represent the 'credit boom' and 'credit rationing' equilibria, respectively. Under a credit rationing equilibrium, both banks find it optimal to lend only to good firms. With a credit boom equilibrium, both banks choose not to screen out risky borrowers, and maximise total profits unconstrained by the asymmetric information problem. A credit boom in the model is therefore characterised by higher total credit (both per firm, and the number of firms getting credits) and higher proportion of defaults.

To verify the strategic stability of each potential Nash equilibrium, two deviation scenarios are analyzed—'rushing to dominate' and 'skimming the cream'—where a bank attempting to break a symmetric equilibrium offers a contract of a different type. When such profit-maximising deviation delivers a higher payoff, the original contract configuration cannot be a Nash equilibrium.

Strategic considerations matter for the design of optimal lending contract specifications through both market share competition and informational frictions. The interest rate set determines the split between a bank's profit and firms' surpluses, which in turn affects market share. With banks competing to offer more attractive, cheaper contracts, firms would benefit by getting positive surpluses in equilibrium. The optimal loan amount, on the other hand, may be affected by worsened adverse selection problems, as competition intensifies.

4.1 Credit Boom Equilibrium

Consider first the case where Bank A is offering a pooling contract, assuming that its competitor is also doing the same. Bank A has a choice of giving some surplus S_A to the firms, which could boost its client base to $\hat{\theta} > 1$ if $S_A > S_B$. If both banks offer pooling contracts, the composition of the firm types is the same to both banks regardless of the surpluses offered, as long as they are positive for the good type (namely without violating the participation constraint). The ratio of bad to good types therefore remains γ. Bank A's expected profit is given by

$$\pi_{pp}(L) = R_f(C - \hat{\theta}(1+\gamma)L) + \hat{\theta}(p+q\gamma)(F(L) - S_A) \tag{4.3}$$

The optimal contract design consists of two steps. First, Bank A maximises profit over L, taking as given the surplus $S_A > 0$ that it plans to give to good firms (as well as S_B set by the opponent), and thus the resulting market share $\hat{\theta}$. The first-order condition with respect to L in equation 4.3 gives the same optimal lending amount as equation 3.2 in the single bank case. Competition therefore does not matter for the amount of lending in the joint pooling equilibrium, and the optimal contract continues to entail L_p.

In the second step, Bank A optimises over S_A (taking S_B as fixed) by changing the gross interest rate charged. The first-order condition is

$$\hat{\theta}(p+q\gamma) = \frac{\partial \hat{\theta}}{\partial S_A}\left[(p+q\gamma)\left(F(L_p) - S_A\right) - R_f(1+\gamma)L_p\right] \tag{4.4}$$

In the symmetric Nash equilibrium where $\hat{\theta} = 1$, either the optimal surplus is the interior non-negative solution to equation 4.4, or the participation constraint is binding and $S_A = 0$. Thus

$$S_A = \max\left\{0, F(L_p) - d - \frac{R_f(1+\gamma)}{p+q\gamma}L_p\right\} \tag{4.5}$$

The profit accrued to Bank A in a joint pooling equilibrium is then reduced to

$$\pi^*_{pp} = \begin{cases} R_f C + d(p+q\gamma) & \text{if } S_A > 0 \\ R_f C + (p+q\gamma)F(L_p) - (1+\gamma)L_p & \text{otherwise} \end{cases} \tag{4.6}$$

Each bank's profit in equilibrium is less than the monopoly counterpart $\pi_p(L_p)$ as long as a positive surplus is offered to firms. However each bank retains some supernormal profit above the risk-free return on its capital, given its market power captured by the term $d(p+q\gamma)$. As market power weakens (and d decreases), this supernormal profit declines.

4.2 Credit Rationing Equilibrium

When both banks offer separating contracts, the lending amount and the surplus given to firms cannot be decided independently from each other. Recall that the single-bank separating contract on point B in Figure 1 is just out of reach for the bad firms. If a bank were to offer a positive surplus to good firms while keeping bad firms out, it has no choice but to curtail its lending amount below 1. At the same time, banks have no interest in cutting back the lending amount any more than required by the adverse selection constraint, since they were already lending less than if they were unconstrained (recall that $F'(1) > \frac{R_f}{p}$).

The optimal separating contract with bank competition therefore always lies on the schedule G (or rather just above it), namely the segment DB in Figure 1. By choosing to lend L along this curve, a bank is automatically choosing to give good firms a surplus of $F(L) - G(L)$. The surplus and lending choices are effectively interdependent, as the binding adverse selection constraint removes one degree of freedom. The profit function of Bank A under joint separating contracts is therefore

$$\pi_{ss}(L) = R_f(C - \hat{\theta}(L)L) + p\hat{\theta}(L)G(L) \tag{4.7}$$

where $\hat{\theta}(L)$ is the market share implied by the decision to lend L, and is the solution to

$$S_A - S_B = F(L) - G(L) - S_B = d(\hat{\theta}(L) - 1) \tag{4.8}$$

Curtailing lending boosts a bank's market share by

$$-\frac{\partial\hat{\theta}}{\partial L} = \frac{G'(L) - F'(L)}{d} \tag{4.9}$$

guaranteed to be positive around the neighbourhood of $L = 1$ due to the single-crossing property.

Offering a surplus to firms is doubly costly for banks because, in addition to being a direct transfer from banks to firms, it requires further deviation from the unconstrained optimal lending. Lower per-contract loans must therefore raise market share sufficiently so that they increase total loans. Deviating from the zero-surplus contract of $\{L, R\} = \{1, F(1)\}$ gives a bank positive profit if the derivative of equation 4.7 is negative, namely

$$p(\hat{\theta}G' + G\hat{\theta}')|_{L=1} < R_f(\hat{\theta} + \hat{\theta}')|_{L=1} \tag{4.10}$$

In such case, the bank has the incentive to continue lowering the per-contract loan to expand its market share until the marginal benefit of doing so is equal to the marginal cost of risk-free investment:

$$p(\hat{\theta}G' + G\hat{\theta}')|_{L=L_{ss}} = R_f(\hat{\theta} + L\hat{\theta}')|_{L=L_{ss}} \tag{4.11}$$

In a symmetric Nash equilibrium, banks end up splitting the market share equally. If condition 4.10 is satisfied, then the equilibrium contract is $\{L_{ss}, G(L_{ss})/L_{ss}\}$ where $L_{ss} < 1$ solves

$$p(G' + G\hat{\theta}')|_{L=L_{ss}} = R_f(1 + L\hat{\theta}')|_{L=L_{ss}} \tag{4.12}$$

Otherwise, the optimal contract in equilibrium is simply $\{1, F(1)\}$, the same as in the single-bank separating case.

The bank's profit in equilibrium is

$$\pi^*_{ss} = R_f(C - L_{ss}) + pG(L_{ss}) \tag{4.13}$$

which is less than π_s because of lower investment in loans at a lower return.

4.3 Rushing to Dominate

So far, the focus has been on the optimal contract specifications when the competing bank is assumed to offer the same type of contract. A bank may, however, offer a different type of contract from its competitor's. When such unilateral deviation is profitable, there cannot exist a Nash equilibrium with the same contract type.

Consider first the case where Bank A attempts to break away from a joint separating contract equilibrium by offering a pooling-type contract. Bank A's motivations come from the fact that it can freely offer surplus to firms without being constrained by the adverse selection. It may therefore 'rush to dominate' the loan market by offering cheaper contracts to all firm types. Such a unilateral strategy would subject Bank A to more severe adverse selection, as it would attract bad firms more than proportionately since Bank B is not competing in that sector.

Let $\hat{\theta}_g$ and $\hat{\theta}_b$ denote Bank A's market shares of good and bad firms respectively, which satisfy

$$S_A = d(\hat{\theta}_b - 1) \tag{4.14}$$

$$S_A - S_B = d(\hat{\theta}_g - 1) \tag{4.15}$$

where $S_B = F(L_{ss}) - G(L_{ss})$ is the surplus offered by Bank B to good firms under the joint separating equilibrium. Bank B is not offering any surplus to the bad types as its contract is separating. Equations 4.14 and 4.15 suggest that $\hat{\theta}_b > \hat{\theta}_g$, as Bank A attracts more bad firms than good ones by deviating from the joint separating equilibrium.

Profit function for Bank A is given by

$$\pi_{ps}(L) = R_f(C - (\hat{\theta}_g + \hat{\theta}_b\gamma)L) + (\hat{\theta}_g p + \hat{\theta}_b q\gamma)(F(L) - S_A) \tag{4.16}$$

whose first-order condition pertaining the lending amount is

$$F'(L_{ps}) = \frac{(\hat{\theta}_g + \hat{\theta}_b\gamma)R_f}{\hat{\theta}_g p + \hat{\theta}_b q\gamma} > \frac{(1+\gamma)R_f}{p + q\gamma} = F'(L_p) \tag{4.17}$$

Thus, $L_{ps} < L_p$ as Bank A takes into account the deterioration of average loan quality. It is also clearly the case that $L_{ss} \leq 1 < L_{ps}$.

The first-order condition for the optimal surplus is given by

$$(F(L_{ps}) - S_A)(p + q\gamma) = d(\hat{\theta}_g p + \hat{\theta}_b q\gamma) + R_f L_{ps}(1+\gamma) \tag{4.18}$$

Equations 4.17 and 4.18 together determine the optimal contract features should Bank A choose to deviate from a credit rationing equilibrium.

4.4 Skimming the Cream

Bank A may instead opt to deviate from a joint pooling contract equilibrium and offer a contract of the separating type. By 'skimming only the cream', Bank A's profit function is identical to that of equation 4.7, since the contract will entice only good firms. The market share is given by equation 4.8, where the surplus offered by the competing bank, S_B, is that under the joint pooling contract equilibrium in equation 4.5.

Combining these relationships with the first-order condition results in the following joint conditions

$$p(\hat{\theta}G' + G\hat{\theta}')|_{L=L_{sp}} = R_f(\hat{\theta} + L\hat{\theta}')|_{L=L_{sp}} \tag{4.19}$$

$$F(L_{sp}) - G(L_{sp}) - F(L_p) + \frac{R_f(1+\gamma)}{p+q\gamma}L_p = d(\hat{\theta}(L_{sp}) - 1) - d \tag{4.20}$$

which together determine the optimal L_{sp} and S_A. A bank has an incentive to deviate from the equilibrium when the market share forgone is more than made up by the improvement in credit quality.

4.5 The Intuition

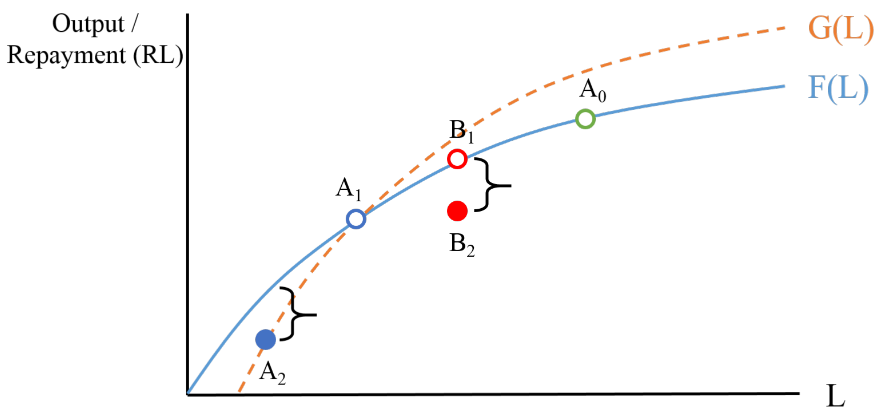


Figure 2: How bank competition fosters credit booms

Figure 2 outlines the basic mechanism of how bank competition may foster a credit boom. If there was only one bank which could identify firm types and thus lend an unrestricted amount only to the good firms, it would equate the risk-adjusted marginal product of capital to the risk-free return. Being a monopoly, it would also leave the good firms with only zero profits. Let this first-best optimal contract be represented by contract A_0 in Figure 2.

Constrained by asymmetric information, the monopoly bank can either offer an optimal separating contract A_1, or an optimal pooling contract B_1. By Assumption 1, contract A_1 is preferred to B_1, although both are inferior to the first-best outcome where contract A_0 is accepted by only the good firms.

With banks competing, more surplus needs to be given to firms in equilibrium. For pooling contracts, banks can lower the interest rate and offer a contract such as B_2 (as established in Section 4.1, the optimal lending amount remains unchanged from the single bank case). For separating contracts, however, banks cannot lower the interest rate without attracting the bad firms. To satisfy the screening constraint, banks must exercise further credit rationing as they compete to offer more surplus to good firms. Such competition to screen for good firms is doubly costly for banks, as not only do they need to forgo more surplus, but they need to curtail lending further away from the already second-best amount. Although contract A_2 offers the same surplus to good firms as contract B_2, the former entails greater cost for banks. As competition intensifies, banks could prefer B_2 to A_2, even if initially they prefer A_1 to B_1. A credit boom could then arise as a Nash equilibrium.

5 Equilibrium and Implications

5.1 Baseline Solution

The model's solution will now be derived under explicit functional form and parameterisation, chosen to illustrate a variety of possible outcomes. Let the production functions take the power form, $F(L) = b_1 L^{a_1}$ and $G(L) = b_2 L^{a_2}$. Consider the parameterisation in Table 1 (under which all optimal contract features satisfy interior solutions described in the previous section). As depicted in Figure 3, the single-crossing condition is satisfied under this pair of technologies.

Table 1: Parameterisation 1

a_1	b_1	a_2	b_2	p	q	γ	C	d
0.4	4	0.7	4	0.9	0.1	0.2	10	2

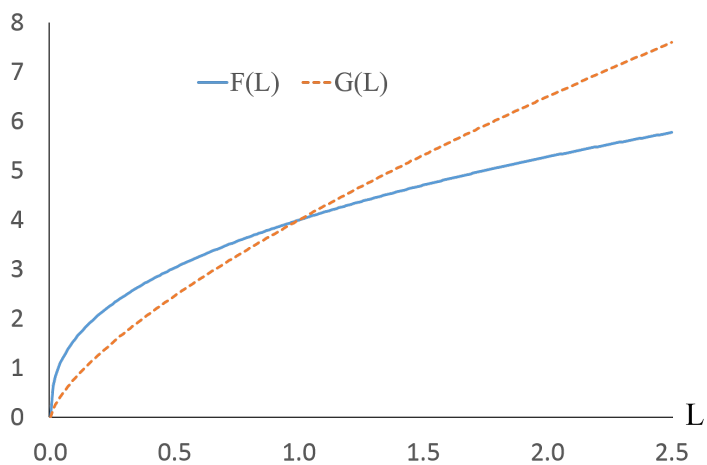


Figure 3: Technologies under parameterisation 1

Under this parameterisation, $\underline{R} = 0.915$ and $\overline{R} = 1.227$. For R_f within this interval, Assumption 1 is satisfied, and a single bank always wants to offer a separating contract $\{L, R\} = \{1, 4\}$. It can be readily checked that Assumption 2 is also satisfied in this case. With competition, banks must compare profits under optimal contracts for four cases, namely 'credit rationing', 'credit boom', 'rushing to dominate' and 'skimming the cream'. Figure 4 plots these profits as a function of $R_f \in [0.915, 1.227]$.

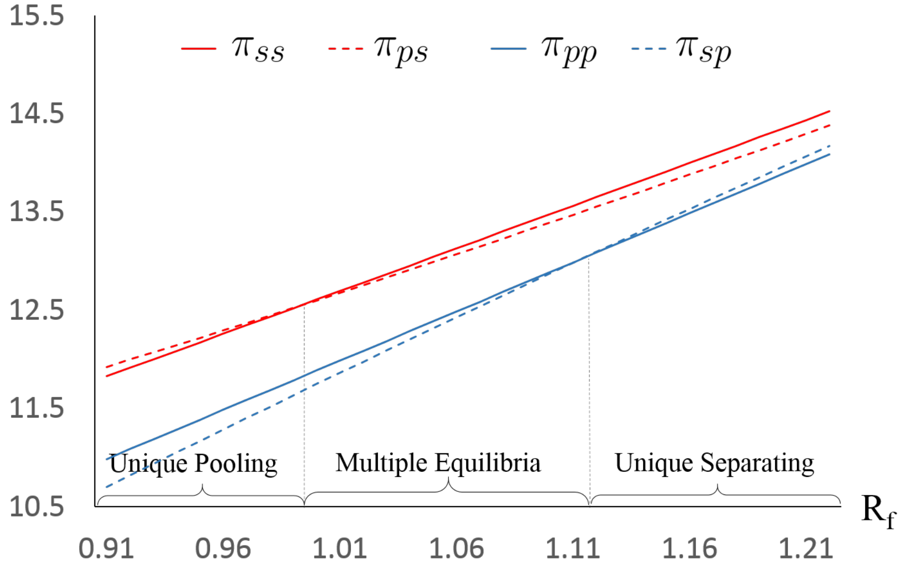
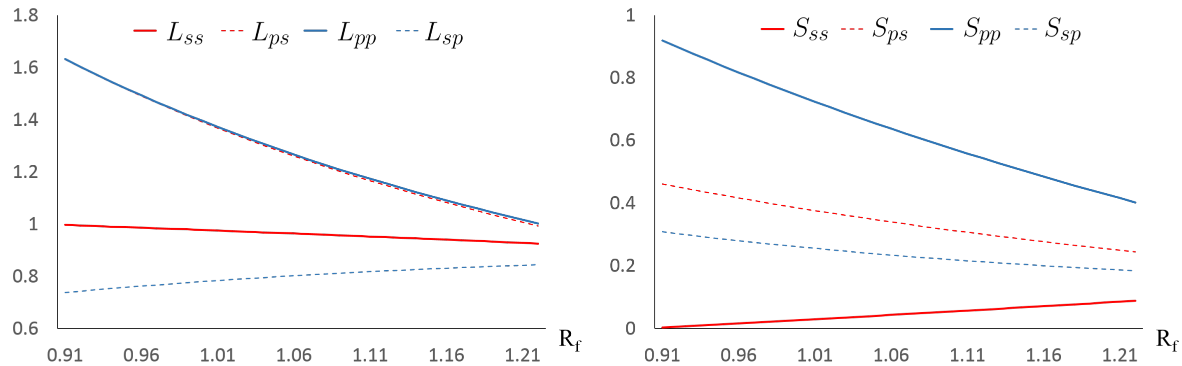


Figure 4: Banks' equilibrium profits under parameterisation 1

Three possibilities can emerge with bank competition, even if the risk-free rate still falls in the range $[0.915, 1.227]$. For sufficiently low R_f (below 1.00), the joint-pooling equilibrium of a credit boom is a unique Nash equilibrium. Over this interval, the joint-separating outcome of credit rationing cannot be supported as a Nash equilibrium, as a bank can increase its profit by rushing to dominate. On the other hand, for sufficiently high R_f (above 1.12), the joint-pooling equilibrium of a credit boom is dominated by skimming-the-cream strategy, so that credit rationing is the unique Nash equilibrium. When R_f falls within the interval $[1.00, 1.12]$, both credit rationing and a credit boom are symmetric Nash equilibria, and it is indeterminate which outcome will be obtained without a further equilibrium refinement criterion.

Optimal loan amounts and surpluses as a function of R_f are depicted in Figure 5. In both symmetric equilibria, loan size decreases with the interest rate R_f, as incentives to take risks decline. The sensitivity of the optimal loan size to changes in R_f is lower under the credit-rationing equilibrium, because cutting back loans in this case entails giving a higher surplus to good firms, an expensive strategy that is made necessary by the adverse selection constraint.[4]

[4] A binding adverse selection constraint also implies that skimming the cream must offer a higher loan size as



(a) Loan size

(b) Surpluses

Figure 5: Optimal contracts under parameterisation 1

This is shown in the right panel of Figure 5, where the optimal surplus rises with R_f in the separating equilibrium. In the pooling case, the surplus shrinks with R_f as banks curtail loan supply.

5.2 'We're Still Dancing'

The existence of multiple equilibria highlights the potential instability of credit market equilibrium, and opens up the possibility of endogenous credit booms. For example, under parameterisation 1 and for $R_f \in [1.00, 1.12]$, lending decision depends on the outcome of a coordination game, which can vary with synchronised shifts in banks' expectations. An equilibrium switch involves a jump in total lending as well as the average quality of banks' assets, with repercussions on total production and its volatility. The quantitative implications of such a switch are significant and realistic under this choice of parameterisation, as Table 2 shows.

Table 2: Multiple Equilibria Comparison

	Total lending		Expected output		Output variance	
R_f	ss	pp	ss	pp	ss	pp
1.005	0.977	1.674	3.567	4.214	1.414	1.971
1.025	0.973	1.620	3.561	4.158	1.409	1.918
1.045	0.968	1.569	3.554	4.104	1.403	1.868
1.065	0.964	1.520	3.547	4.051	1.398	1.820
1.085	0.959	1.473	3.540	4.000	1.393	1.774
1.105	0.954	1.429	3.534	3.951	1.387	1.730

For example, when $R_f = 1.065$, there exist two equilibria with $L_{ss} = 0.964$ and $L_{pp} = 1.267$. Suppose the two banks somehow successfully coordinate their expectation shifts from a

R_f increases. With the surplus in a credit boom declining with R_f, a deviating bank can counter-offer with a separating contract involving a lower surplus and a higher loan amount.

joint separating equilibrium to a joint pooling one. The resulting growth in total lending per bank is $(1+\gamma)L_{pp}/L_{ss} = 1.520/0.964$, a 58 percent increase. The average default probability more than doubles from $1-p = 10$ percent under credit rationing equilibrium to $((1-p)+\gamma(1-q))/(1+\gamma) = 23$ percent in a credit boom. The expected output produced by firms in the pooling equilibrium is 4.05, a 14 percent increase from the credit rationing benchmark, but there is also a marked increase in average output volatility. Rapid credit acceleration accompanied by deterioration of asset quality and higher output volatility is a pattern consistent with actual credit boom phenomena.

It is clear from Figure 4 that both banks would prefer a credit rationing equilibrium over a credit boom equilibrium for any interest rate. But if the other bank is expected to offer a pooling contract, a bank's optimal response is to comply and contend with a larger loan size and higher default probability, for fear of losing market share. The underlying coordination failure problem captures an essential aspect of the now famous quote:

> *"When the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you've got to get up and dance. We're still dancing."*
>
> Charles Prince
>
> Former Citigroup CEO, interview with the Financial Times, July 2007

In the model, both banks would prefer a quiet sit-down to dancing. But neither is willing to be the first to stop.

Even when the system starts off in a credit rationing state, it takes only one bank's temporary deviation to alter the equilibrium. For example, when one bank commits to offering a pooling contract, the competing bank's optimal response is to follow suit. Once a credit boom is triggered, the coordination problem means that there is no automatic correction mechanism to return the system to the initial credit rationing equilibrium. Thus, one bank's suboptimal deviation or error is sufficient to cause long-lasting and far-reaching implications for the credit market.[5] In this sense, a bank may be regarded as systemically important even in the absence of direct financial linkages with other financial institutions. The externalities exist because banks' strategic considerations are interdependent.

[5] Consider the role of state-owned financial institutions in emerging market economies. They often compete in the same market segment as private banks, sometimes in pursuit of non-profit mandate that necessitates a rapid expansion of lending (for example to promote financial access by households). Such action can induce responses by the private commercial banks, leading to lending competition that accentuates the credit cycle. See World Bank (2013) for a recent review of the role of state finance after the crisis.

A credit boom in this model causes a social welfare loss by making banks more fragile (and thus worse off). This 'financial stability' cost is important to the extent that stable banks are needed to intermediate funds and make production at all possible. Appendix A discusses how such considerations can be introduced in the current static setup. It provides a social-welfare case for intervening to steer the economy clear of a credit boom, and help banks resolve their coordination failure problem. One possible policy instrument is monetary policy, which is now discussed.

5.3 Finance-neutral Rates of Interest

Suppose that R_f is set by a central bank, who has the autonomy to set monetary policy. In a general equilibrium model, it would be the government that pays R_f on its short-term debt, financed through tax revenue. The risk-free technology, in the long run, would therefore be pinned down by the taxable national income. In this paper, it is assumed that the central bank can set R_f autonomously without worrying about fiscal budget constraints.

Through setting R_f, the central bank may attempt to affect the credit market equilibrium by influencing banks' incentives to make risky loans. The effect is an example of the risk-taking channel of monetary policy discussed in Borio and Zhu (2012), as a lower interest rate boosts the present value of returns to investment. The objective of the central bank is to safeguard financial stability and minimise the likelihood of a credit boom. The 'finance-neutral rates of interest' are defined to be the levels of R_f consistent with such objective, namely the interest rates such that the credit rationing equilibrium is obtained rather than the credit boom.

Consider again the model's baseline solution under parameterisation 1 in Table 1. To guard against financial instability in this instance, R_f must be higher than 1.00 to rule out the case of a unique credit boom equilibrium. But this may not be sufficient if the two banks choose to coordinate on the pooling equilibrium, which remains a possibility as long as $R_f \in [1.00, 1.12]$. To secure financial stability for certain, R_f needs to be above 1.12 to enforce a unique credit rationing equilibrium.

The indeterminacy of the finance-neutral rate of interest suggests that there may be practical limits to using conventional monetary policy as the only policy instrument to target financial stability. The rate of interest should certainly not be as low as to result in a unique credit boom equilibrium. But setting R_f high enough to guarantee a unique credit rationing equilibrium could potentially cause a material conflict with the broader macroeconomic considerations in practice.[6]

An additional macroprudential policy tool can be useful here to the extent that it provides a more effective means to strengthen banks' belief in the credit rationing equilibrium, and thereby facilitate a coordination on it. For example, suppose that the central bank can enforce an upper bound L^h on each bank's lending. Setting $L^h = 1$ would be sufficient to rule out the possibility of a credit boom, resulting in a unique credit rationing equilibrium with $L_{ss} < L^h$ (so that the macroprudential policy, in fact, appears not to be binding). The role of such a credit limit is therefore not to curb credit per se, but to solve the underlying coordination failure problem.[7]

The range of finance-neutral R_f varies with the structural factors determining bank competition. Financial innovation, for instance, could lower firms' financial access costs d, thus intensifying competition among banks. Changes in d could also serve as a rough proxy for the exogenous shifts in banks' preferences for size, or their degree of risk appetite (although banks are risk-neutral in this model, a lower d indirectly decreases the cost of taking on additional risky loans). Rajan (2005) suggests that the two may even interact, as financial innovation may contribute to a surge in the degree of risk-taking. By taking these developments into account, it is argued, monetary policy could play a greater role in securing financial stability. Figure 6 sheds light on how monetary policy is related to financial stability outcomes, by showing the range of R_f corresponding to each type of equilibrium, as a function of d.

A credit rationing equilibrium is guaranteed for R_f in the region above the upper line. When R_f falls between the two lines, there is indeterminacy as both a credit boom and credit rationing are Nash equilibria. When R_f is below the lower line, a unique credit boom equilibrium emerges. As d declines as a result of either financial innovation or higher bank risk appetite, the range of interest rates that can guarantee financial stability narrows, and eventually vanishes. This effectively places a limit on how much the risk-free rate can do to prevent financial instability.[8] The range of interest rates over which there is multiplicity also expands as d declines. Thus, the range of finance-neutral interest rates is not fixed, but is inversely re-

[6]Yellen (2014): "But such risk-taking can go too far, thereby contributing to fragility in the financial system. This possibility does not obviate the need for monetary policy to focus primarily on price stability and full employment–the costs to society in terms of deviations from price stability and full employment that would arise would likely be significant."

[7] In fact, it is easy to see that there exists $L^H \in (1, L_{pp})$ such that any $L^h \in (L_{ss}, L^H)$ would deliver the same credit rationing outcome. The macroprudential stance just needs to be sufficiently tight to make a constrained pooling equilibrium inferior to a separating one.

[8]While there is no strict upper bound on interest rates, recall the assumption that $R_f < \overline{R_f}$, which is needed for the pooling contract to be nondegenerate.

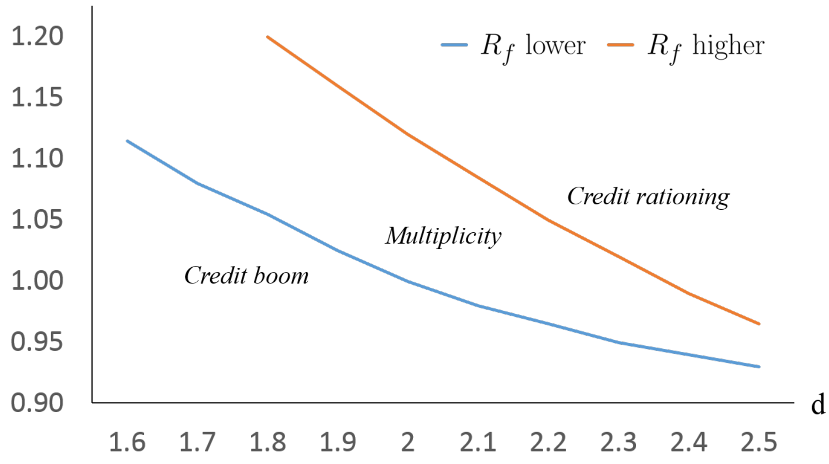


Figure 6: Finance-neutral rates as a function of d

lated to d. As financial innovation deepens or risk appetite intensifies, the level of the risk-free rate required to maintain financial stability must grow, and could worsen the macro-financial stability trade-offs facing the policymaker.

After the global financial crisis, there is much debate about the extent to which monetary policy should play a more active role in safeguarding financial stability (for a recent debate, see Yellen (2014) and Bank for International Settlements (2014)). However, the linkage between monetary policy and financial stability remains less well understood when compared to macroeconomic stability, which can be summarised succinctly in terms of output and inflation gaps. There have been recent attempts to introduce analogous 'financial gaps', based for example on a deviation of credit-to-GDP ratio from its trend. While useful, such a reduced-form approach lacks an explicit theoretical underpinning, especially regarding the role of monetary policy. The model proposed here is one attempt to fill this theoretical gap, and articulate the scope as well as the limits to using monetary policy to secure financial stability. In particular, the notion of a 'finance-neutral' rate of interest as defined here is a useful metric in analysing financial stability implications of monetary policy.

The concept proposed here is related to, but distinct from the definition of sustainable output in Borio et al. (2014), which is generalised to incorporate financial information. There, a sustainable level of output is modelled as being consistent with both stable inflation and an acyclical financial cycle. Implications for monetary policy could then be inferred from the estimated generalised output gap. In this paper, the finance-neutral rate of interest is defined purely in relation to the financial stability objective, namely to prevent a credit boom. The neutral rate of interest from macroeconomic stability viewpoint is a separate and independent concept, and in general the two neutral rates need not coincide. When the two rates diverge, the monetary policy trade-offs deteriorate. Section 6.2 introduces an empirical procedure for estimating the finance-neutral rate in the case of the United States, and discusses the extent of policy trade-offs in recent years.

6 Empirical Applications

The theoretical implications motivate at least two important empirical questions. First, how does the model help interpret the existing evidence on bank competition and financial stability, and explain the seemingly conflicting results? Second, how may the finance-neutral rate of interest as defined by the model be estimated, and how has it evolved in the recent past? This section tackles each of these issues in turn.

6.1 Perspectives on the Competition and Stability Evidence

A large body of literature has empirically examined the relationship between bank competition and financial stability, an issue that has become even more pertinent after the global financial crisis.[9] The overall results are mixed, and discussion about whether greater bank competition poses higher risks to financial stability remains largely inconclusive. Given the lack of a robust *unconditional* relationship, more recent works have tried to identify the relevant context, in order to reconcile the 'competition-fragility' and 'competition-stability' views. For example, Beck et al. (2013) permit heterogeneity across countries, and examine more closely the conditions under which higher competition may lead to fragility. They find that the 'competition-fragility' view tends to hold in countries with more restrictive regulations, and a more effective sharing of credit information between banks (among other factors). Focusing on evidence in Asia, Fu et al. (2014) distinguish two measures of competition, namely pricing power and market concentration. They find that greater competition in the sense of lower pricing power increases the degree of bank fragility, but that higher bank concentration is stability-negative. In other words, both views of the debate can be correct, depending on the aspect of competition being examined.

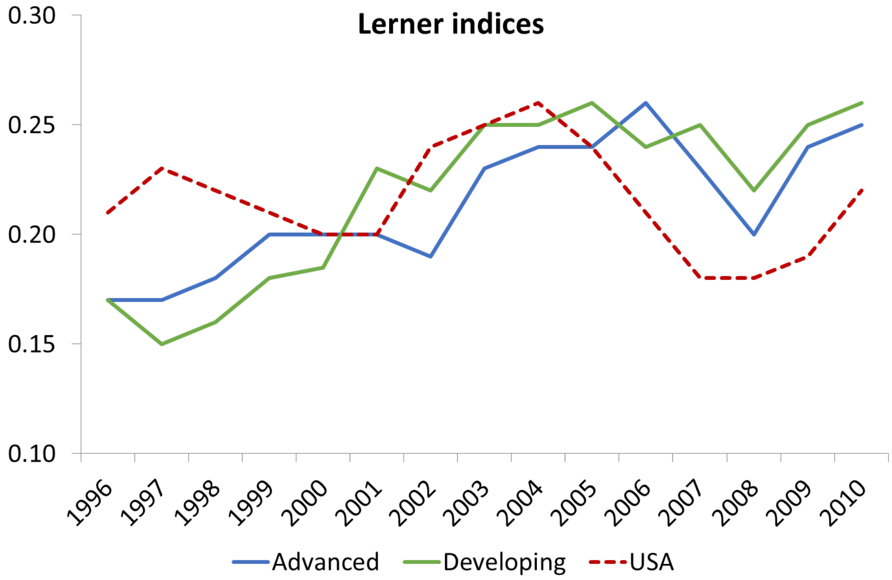
[9]The debate is a long-standing one. For a review, see Carletti (2008) and World Bank (2013). For a non-technical recent exchange, see http://www.economist.com/debate/overview/205.

To relate the theory to these empirical findings, recall that competition in the model takes place in a loan market with a fixed set of borrowers. By construction, there is no scope for broadening the borrower base or financial deepening. Bank competition is therefore necessarily associated with greater crowdedness in credit supply and consequently lower prices of credits. Competition in this sense is associated more directly with pricing power than market concentration. Less market concentration would lead to bank fragility in the model only if more banks were competing for the same borrower pool (for example, if more banks were populated on the Hotelling line $[0, 2]$). But, in general, lower concentration could also represent financial deepening if the newly entered banks were tapping new borrowers previously unserviced by the incumbents. Thus, the model predicts a positive relationship between pricing power and financial stability, but is silent on the role of bank concentration which depends on the degree of credit market segmentation. These predictions help explain the empirical findings of Fu et al. (2014).

To explain the heterogeneity observed by Beck et al. (2013), recall the key role of the parameter d in driving the degree of bank competition in equilibrium. A lower d is isomorphic to banks being closer to each other on the Hotelling line while holding transaction costs fixed. A decline in d can therefore be interpreted as the result of endogenous location choices made by the banks to compete over a smaller set of borrowers. Such location choices could be optimal in a regulatory regime where banks are prohibited from engaging in many activities deemed risky by the regulators, and are forced to compete more in a common segment of the market (which in fact ends up raising financial fragility). A more restrictive regulatory regime could then promote the competition-fragility outcome as Beck et al. (2013) find. Similarly, when banks share more credit information, the pool of borrowers over which a bank commands some market power diminishes in size. As the size of the common pool grows, each bank can attract more new borrowers for a given cut in interest rate, an isomorphism to a lower d which leads to more fragile banking system.

In addition to the cross-country perspectives discussed so far, the theory also proposes bank competition as a critical factor in predicting and driving credit booms over time in any given country. It also suggests that a structural decline in intermediation costs d, led for example by financial innovation, financial integration or regulatory changes, should be associated with a higher frequency of credit booms.

Consider the time-series of bank competition in Figure 7 based on the *Lerner index*, which measures the markup of output price over marginal cost. A lower Lerner index corresponds to a lower markup and less pricing power, indicating a higher degree of bank competition. As argued above, this pricing-power proxy may capture the notion of bank competition in the model more accurately than bank concentration.[10] The figure shows the median of country-level Lerner indices over the period 1996-2010, for advanced and developing economies, as well as the US.



Source: Global Financial Development Database (GFDD), April 2013, with original data from Bankscope. Higher Lerner index represents lower degree of bank competition. Group indices are calculated by authors as cross-country medians. *Advanced* includes 60 high-income countries, while *Developing* covers 52 upper middle income economies, using the GFDD definition.

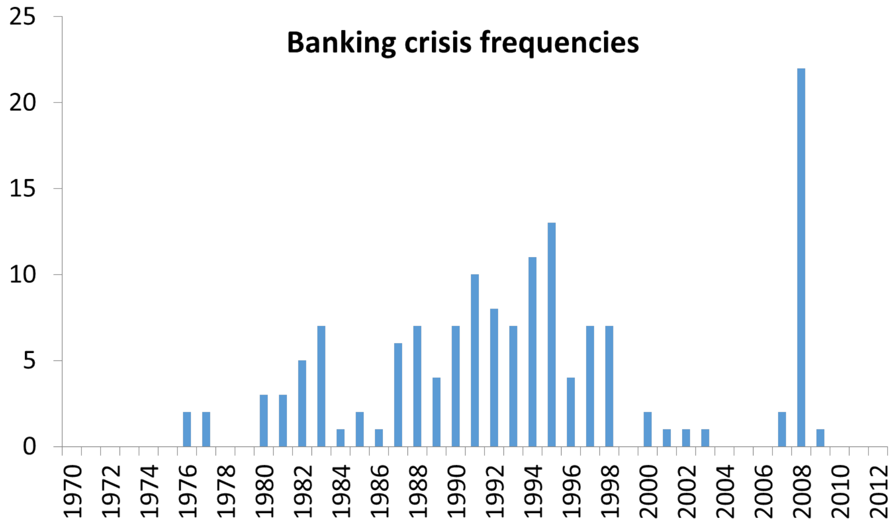
Figure 7: Degree of bank competition over time

The degree of bank competition in the United States started to intensify significantly from 2005 through to 2007. The upsurge in competition bucked the global trend of relatively stable competition, though by 2007 there was higher bank competition elsewhere too. It is well documented that the 2005-2007 period is associated with a widespread increase in risk-taking by US financial intermediaries, spanning the traditional lending, securitisation and shadow banking activities. While it remains contentious whether competitive behaviour or lax regulation is the root cause of the crisis, there is a broad consensus that the former factor is an integral part of the overall dynamics. The model supports the narrative that intensifying competition and higher risk-taking in the United States eventually led to asset quality deterioration, as cheaper credits found their way to subprime borrowers. The environment was supportive of the excessive

[10] Beck et al. (2013) argue that the Lerner index is a preferred measure of market power over other alternatives such as the Panzar-Rosse H-statistic, as there is meaningful variation over time, even at the bank level. It is also useful here for the same reason.

risk-taking, given low risk-free rates and financial innovation coupled with lax regulation that together enabled greater use of securitisation as a means to reach out to riskier borrowers (hence, lowering d).

Another notable feature from Figure 7 is that, excluding the United States, the degree of bank competition elsewhere in the world has been tracking a secular downward trend (an uptrend for the Lerner index). During 1997-2005, bank competition for both advanced and developing groups declined steadily.[11] Coincidentally, the period 1999-2006 is a remarkably calm period, and, as Figure 8 shows, the international frequency of banking crises dropped sharply relative to the past.



Source: Systemic Banking Crises Database, in Laeven and Valencia (2012).

Figure 8: Relative banking stability in 2000s before the crisis.

The global correlation of banking competition during 2007-2008 hints at the role of international factors in influencing the credit cycle. Recent works on the cross-border spillovers of financial conditions focus particularly on banking and capital flows. Monetary easing in a systemic economy, the story goes, induces capital inflows into other smaller economies, leading to higher asset prices and widespread easing in financial conditions in these capital-recipient economies. The theory based on bank competition, on the other hand, highlights changes in domestic banks' behaviour as a necessary condition in the credit creation process. Without changes

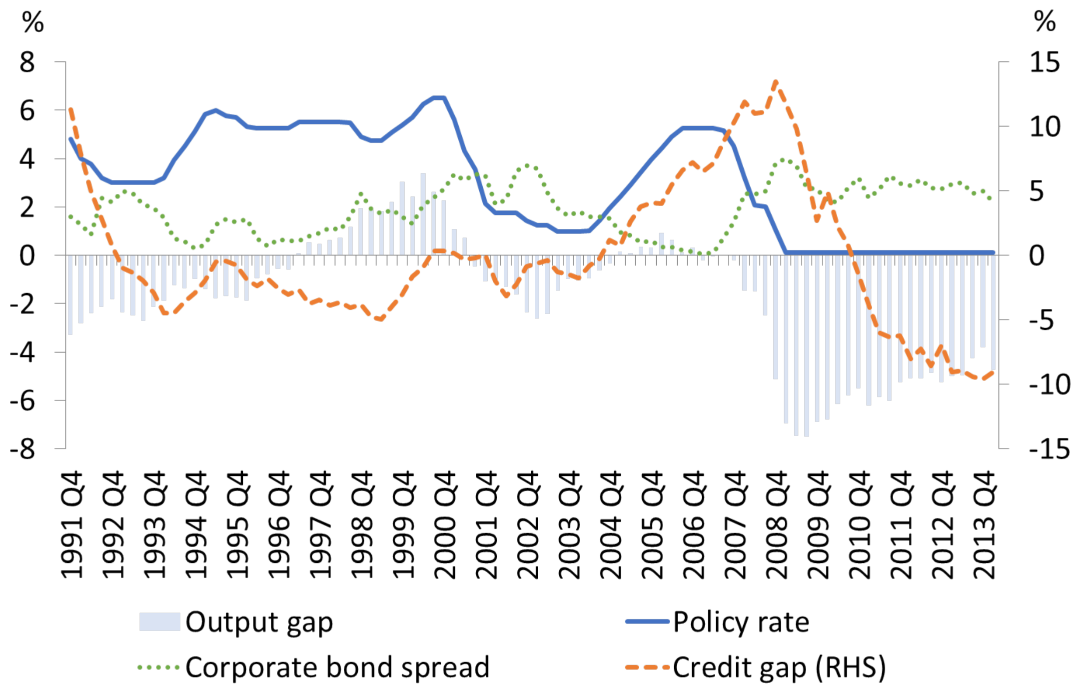
[11]World Bank (2013) cites the adoption of the European Monetary Union as one driver of this trend, as more integrated capital markets led to a shift in intermediation model towards more complex products with less price competition. Note also that in Asia, many banks had just recovered from a major credit boom-bust in 1997, and were in a mending phase subsequently.

in lenders' behaviour, the effects of cross-border spillovers will be limited to foreign-denominated credits and the asset price channel. But the model also suggests a channel through which domestic banks' behaviour could be influenced by greater competition from abroad. Against a secular rise in financial integration, banks' reach for customers increasingly transcends geographical bounderies. As domestic and international lenders compete to lend to the same group of borrowers, the parameter d falls, and banks' risk-taking increases in equilibrium as a result. With greater international financial integration, the cyclical correlation of banks' risk-taking could well become more synchronised, creating more amplified global credit cycle.

6.2 Estimating Finance-neutral Rate of Interest

It has been proposed that the prolonged monetary accommodation in the US may have contributed to the subsequent housing bubble and sowed the seed for the global financial crisis. Taylor (2009) argues that during this period, the Federal Reserve deviated from its past behaviour, the Taylor rule, that had served it well since the early 1980s. Had there been no deviation, Taylor (2009) estimates that the amplitude of the housing bubble would have been only half as big. Dokko et al. (2011), on the other hand, acknowledge that the US monetary policy did deviate from the Taylor rule, but found that the departure was too small to explain the subsequent boom in the housing market. They suggest that lax regulations had a larger role to play.

The model offers an alternative and somewhat stronger proposition in this debate. Even if monetary policy was consistent with the Taylor rule, there is no guarantee that financial stability would have been ensured. The issue is less about the cost of departing from the policy rule, and more about the basic conflict between the two policy objectives. Figure 9 plots the Fed funds rate against the output gap, the 'credit gap' (defined as the percentage difference between the credit-to-GDP ratio and its HP-filter trend, calculated using $\lambda = 400,000$ as in Borio and Lowe (2004)), and the 10-year AAA corporate bond spread. From the macro stability angle, a negative output gap in 2003-2004 may have lent some justifications to keeping interest rates low. However, the same period saw a falling risk premium and a steady rise in the credit gap, hinting at emerging risks to financial stability. Moreover, the compressed risk premium persists throughout 2004-2007 despite gradual policy normalisation, right up until the subprime blowup. This experience is consistent with the multiple equilibria property of the model, since the loan market was trapped in an excessively cheap finance equilibrium even as the risk-free interest rate moved up.



Source: BIS, Congressional Budget Office, FRED, and author's calculations.

Figure 9: Macro versus Financial Stability Objectives

In the world where there are no divine coincidences between financial and macroeconomic stability, the interest rate neutral for macroeconomic conditions needs not coincide with the finance-neutral interest rate that guarantees financial stability. Indeed, the definitions of the two are conceptually distinct. Suppose that financial stability is defined as the state of the world in which aggregate credit stays close to its natural stable trend. The dynamics of credit can be perturbed away from a stationary point by a departure of the interest rate from its finance-neutral value. The credit process is persistent (given the possibility of multiple equilibria), and therefore it takes time for changes in interest rate to have an impact. Specifcally, consider the following model:

$$\tilde{C}_t = \alpha_1 \tilde{C}_{t-1} + \alpha_2 \tilde{C}_{t-2} + \alpha_3 \sum_{i=1}^{N} (R_{t-i} - R^*_{t-i})/N + \varepsilon_{1t} \tag{6.1}$$

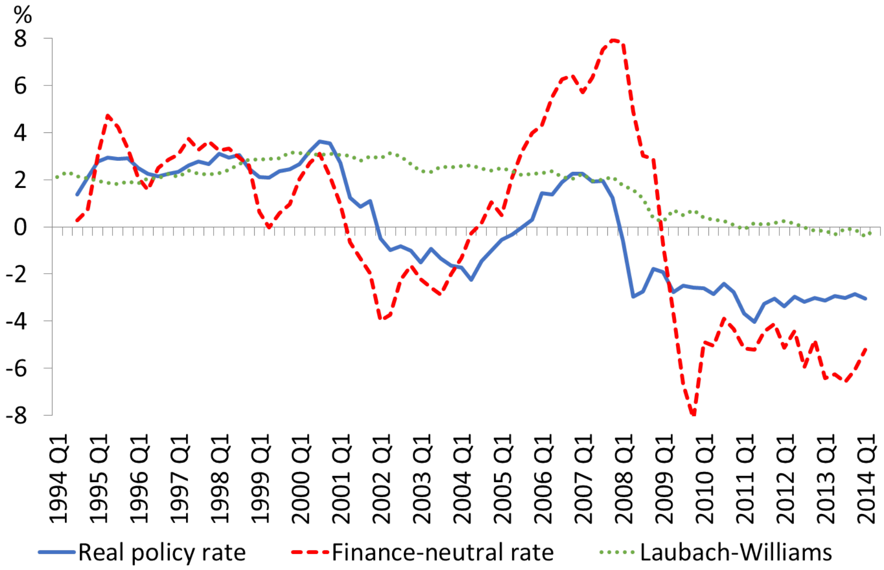
$$R^*_t = \beta_1 + \beta_2 R^*_{t-1} + \beta_3 R^*_{t-1} + \beta_4 d_t + \varepsilon_{2t} \tag{6.2}$$

where $\varepsilon_{1t} \sim N(0, \sigma_c^2)$ and $\varepsilon_{2t} \sim N(0, \sigma_r^2)$. The credit gap, $\tilde{C}_t$, follows an AR(2) process, and is influenced by the past N-period average of policy rate gap, that is, the deviation of the real policy interest rate R_{t-1} and the unobserved finance-neutral rate R^*_{t-1}. R^*_t is also an AR(2) process, and depends on an exogenous variable d_t, which, as proposed by the theoretical model, is a proxy for bank competition. Just as the conventional neutral rate of interest is structurally associated with fundamental variables such as trend GDP growth or the rate of households' time preference, the finance-neutral rate has a structural relationship counterpart.

The absence of macroeconomic variables such as output gap or inflation in equations 6.1 and 6.2 is intended to make clear the distinction between the finance-neutral rate R_t^* and the conventional natural rate. The former only concerns financial stability, which is a separate policy objective from macroeconomic stability. By assessing monetary policy purely in relation to its financial stability objective, one can appreciate the potential conflict involved when risks to financial stability must be weighed against macro considerations. One can of course imagine a more general credit process which justifies including macro variables in this empirical model (for example, if credit demand is modelled and allowed to depend on output). The credit process could even interact with the traditional macroeconomic block such as the Phillips and the IS curves, in a fully general equilibrium setting. In all these models, there remains a conceptual distinction between the finance-neutral rate and the conventional one, unless macroeconomic stability is assumed to guarantee stable credits. That is, unless the divine coincidence assumption is imposed.

The model in equations 6.1 and 6.2 can be written in a state-space form, and estimated in the standard way using a Kalman filter and a maximum likelihood method. Using the US quarterly data from 1991 Q4 to 2014 Q1, $\tilde{C}_t$ is the deviation of the credit-to-GDP from its HP trend ($\lambda = 400,000$), while R_t is the nominal Fed funds rate minus 1-year ahead inflation expectations from the University of Michigan survey. The spread between 10-year AAA corporate bonds and the 10-year US Treasury is used as a proxy for d_t. This price-based measure of competition is preferred due to its long time-series coverage and high frequency, although a direct measure such as the Lerner index is also a possible candidate. Credits are influenced by the past 3-year accumulated rate gap, so that $N = 12$. The model is estimated with identifying restrictions that variables are stationary ($\alpha_1 + \alpha_2 < 1, \beta_2 + \beta_3 < 1$), positive real rate gap reduces credit gap ($\alpha_3 < 0$), higher competition raises R_t^* ($\beta_4 < 0$), and the unconditional mean of R_t^* is the same as the sample average of R_t (β_1 is the adjust parameter). The ratio for σ_r/σ_c is bounded from above by 1.5 to alleviate the pile-up problem.

The results are shown in Figure 10, which plots the real policy interest rate R_t against the estimated finance-neutral interest rate R_t^*, together with the conventional natural rate of



Source: BIS, FRED, Laubach and Williams (2003), and author's calculations.
Note: *Finance-neutral rate* is the filtered series for R_t^*, estimated from the model in equations 6.1 and 6.2. *Laubach-Williams* series is the natural rate of interest estimated in Laubach and Williams (2003), using the conventional macroeconomic structural relationships.

Figure 10: No Divine Coincidences.

interest computed by Laubach and Williams (2003) for comparison. The estimates show how material the disconnect between the finance-neutral and the standard natural rate can be.[12] The finance-neutral rate started rising quickly as early as in 2004, and in the following years, the gap between the real policy rate and the finance-neutral rate grew increasingly negative despite the Fed's policy normalisation. The gap continued rising and reached its historical high in 2007. The trend only reversed when the crisis broke out, as a plunge in risk appetite induced a sharp drop in the finance-neutral rate. Since 2009, the monetary policy stance has become tighter than necessary for the financial stability objective amid persistently sluggish credit growth, despite being extraordinarily accommodative from the macroeconomic point of view.

The prohibitively high finance-neutral rate at certain points lessens the case for reacting to financial stability concerns, as macroeconomic consequences may be too costly. As discussed in Section 5.3, when a credit boom becomes an entrenched equilibrium fueled by fierce bank competition, the policy rate necessary to break such an equilibrium may be too high. In the late stage of the credit cycle, there are therefore strong justifications for resorting to other

[12] The estimated finance-neutral rate is noticeably more volatile than the conventional natural rate, since the determinant of finance-neutral rate is more variable relative to the determinants of conventional natural rate such as potential growth.

policy tools than policy interest rate alone. At the same time, monetary policy stance affects the credit evolution, and a preemptive earlier policy normalisation in 2004 may have helped prevent the credit boom from becoming entrenched. A successful preemptive policy plan would also imply lower finance-neutral interest rate subsequently, thus lessening the conflict with macro objective. Characterisation of the optimal dynamic policy plan, particularly when macro and financial variables evolve at different frequencies, is an important area of future research.

7 Conclusion

This paper offers a theory of credit booms based on the idea that bank competition increases the screening cost. Despite its simplicity, the model offers several insights into the nature of financial stability risks and role of policy. In particular, because banks' strategic interactions involve a coordination failure problem, the resulting credit boom equilibrium can be persistent and self-fulfilling. Monetary policy can play a role in preventing a credit boom, which can be summarised in terms of the finance-neutral rate of interest that is required for such a purpose. The burden on monetary policy grows, however, when the degree of competition is driven up in equilibrium from outside factors such as financial innovation or the degree of risk-taking (captured by d). This could lead to a conflict with broader macro stability in practice, as shown in an empircal exercise for the United States.

Since the model makes minimal institutional assumptions, it can be readily applied to understand risk-taking behaviour in financial markets more generally. For example, the US high-risk private debt market underwent a period of excessive exuberance in the run-up to the global financial crisis, not dissimilar to banking credit booms. In this instance, 'banks' could include international investors who chase after risky assets in the presence of low interest rates, and low availability of risk-free assets.

A possible extension is to take the model to a general equilibrium macroeconomic setting. Doing so would enable an optimal policy assessment in the presence of a trade-off between macroeconomic and financial stability. The main point of adding the banking model here is not to create a propagation mechanism, however. Low interest rate raises financial fragilities, which is negative for growth. The policymaker can recognise these implications by incorporating subsequent realisation of output losses into its objective, or penalise ex ante financial stability risks.

References

Aikman, D., A. G. Haldane, and B. D. Nelson (2014): "Curbing the Credit Cycle," *The Economic Journal (Forthcoming).*

Allen, F. and D. Gale (2004): "Competition and Financial Stability," *Journal of Money, Credit and Banking*, 36, 453–480.

Bank for International Settlements (2014): "84th Annual Report," Basel, Switzerland.

Beck, T., O. De Jonghe, and G. Schepens (2013): "Bank Competition and Stability: Cross-country Heterogeneity," *Journal of Financial Intermediation*, 22, 218–244.

Borio, C., P. Disyatat, and M. Juselius (2014): "A Parsimonius Approach to Incorporating Economic Information in Measures of Potential Output," *BIS Working Papers No. 442.*

Borio, C. and M. Drehmann (2009): "Assessing the Risk of Banking Crises - Revisited," *BIS Quarterly Review.*

Borio, C. and P. Lowe (2004): "Securing Sustainable Price Stability: Should Credit Come Back from the Wilderness," *BIS Working Papers No. 157.*

Borio, C. and H. Zhu (2012): "Capital Regulation, Risk-taking and Monetary Policy: A Missing Link in the Transmission Mechanism?" *Journal of Financial Stability*, 8, 236–251.

Boyd, J. H. and G. De Nicolo (2005): "The Theory of Bank Risk-Taking and Competition Revisited," *Journal of Finance*, 60, 1329–1343.

Carletti, E. (2008): "Competition and Regulation in Banking," in *Handbook of Financial Intermediation and Banking*, ed. by A. W. A. Boot and A. V. Thakor, Elsevier, 449–482.

De Nicolo, G. and M. Lucchetta (2011): "Bank Competition and Financial Stability: A General Equilibrium Exposition," *IMF Working Paper, No. 11/728.*

Dell'Ariccia, G. and R. Marquez (2006): "Lending Booms and Lending Standards," *Journal of Finance*, 61, 2511–2546.

Dokko, J., B. Doyle, M. T. Kiley, J. Kim, S. Sherlund, J. Sim, and S. V. den Heuvel (2011): "Monetary Policy and the Global Housing Bubble," *Economic Policy*, 26, 237–287.

Freixas, X. and J.-C. Rochet (2008): *Microeconomics of Banking*, The MIT Press, second ed.

Fu, X., Y. Lin, and P. Molyneux (2014): "Bank Competition and Financial Stability in Asia Pacific," *Journal of Banking and Finance*, 38, 64–77.

Gorton, G. B. and P. He (2008): "Bank Credit Cycles," *Review of Economic Studies*, 75, 1181–1214.

Keeley, M. (1990): "Deposit Insurance, Risk and Market Power in Banking," *American Economic Review*, 80, 1183–1200.

Laeven, L. and F. Valencia (2012): "Systemic Banking Crises Database: An Update," *IMF Working Paper, No. 12/163.*

Laubach, T. and J. C. Williams (2003): "Measuring the Natural Rate of Interest," *Review of Economics and Statistics*, 85, 1063–1070.

Levine, R. (2005): "Finance and Growth: Theory and Evidence," in *Handbook of Economic Growth*, ed. by P. Aghion and S. Durlauf, Elsevier, vol. 1, chap. 12, 865–934.

Rajan, R. G. (2005): "Has Financial Development Made the World Riskier," *NBER Working Paper No. 11728*.

Reinhart, C. M. and K. S. Rogoff (2009): *This Time is Different: Eight Centuries of Financial Follies*, Princeton University Press.

Schularick, M. and A. M. Taylor (2012): "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles and Financial Crises, 1870-2008," *American Economic Review*, 102, 1029–1061.

Stiglitz, J. E. and A. Weiss (1981): "Credit Rationing in Markets with Imperfect Information," *The American Economic Review*, 71, 393–410.

Taylor, J. B. (2009): "The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong," *NBER Working Paper No. 14631*.

World Bank (2013): "Global Financial Development Report: Rethinking the Role of State in Finance," Washington, D.C.

Yellen, J. E. (2014): "Monetary Policy and Financial Stability," Speech at the 2014 Michel Camdessus Central Banking Lecture, International Monetary Fund, Washington, D.C.

Appendix A Financial Stability and Social Welfare

From society's point of view, multiple equilibria are not Pareto rankable, since the bad firms always enjoy positive surplus under the pooling equilibrium regardless of banks' preferences. A pooling equilibrium could in fact be preferred by a social planner if, despite not observing firms' types a priori, she can still verify realised output and redistribute the surplus ex post. In such a case, the social planner is effectively an equity investor with access to both technologies, and may want to gamble more than a bank does. In particular, when $G(L)$ is sufficiently larger than $F(L)$ for $L > 1$, the social planner may well want to finance both types of firms even when a single bank would not. After production, the planner can then tax the successful bad firms in order to redistribute. Banks as a seller of debt contracts, on the other hand, do not enjoy such a privilege because they cannot extract any surplus from the bad firms without giving up the good customers.

The social cost of the pooling equilibrium therefore does not stem from productive inefficiency. Instead, the primary welfare consequence of financial instability has to do with the special intermediary function of banks, and the fact that their viability is critical for a well-functioning economy.[13] A simple way to introduce financial stability to welfare calculations in the current setting is to assume that, in spite of banks' risk neutrality, the society assigns some positive weight to the viability of banks, and trades off the risk of bank insolvency against the productive efficiency.

As an example, consider a social welfare function of the form

$$W = \pi + S - \lambda \sigma_\pi^2 \tag{A.1}$$

where π is the aggregate banks' profits, S is the total firms' surplus, σ_π^2 is the variance of π, and λ is the weight that the society places on financial stability. The variance of banks' payoff captures the probability of bank insolvency or its value-at-risk, in the event that banks lose too much capital from risky investment going bad.

Using equation A.1, social welfare with and without a financial stability objective can be

[13] There are well-known reasons why a decentralised allocation may be suboptimal according to this criterion. Banks that know they are 'too big to fail', for example, could undertake projects that pose risks to their viability, at social costs that far exceed private ramifications. A separation of origination and distribution of debt securities is another instance where moral hazard is made worse by increased product sophistication and diluted accountability, leading to allocative inefficiencies. In this model, the assumption that society may want banks to be more risk-averse could be motivated by reasons similar to these.

compared under the two symmetric equilibria. The parameters used for this exercise are given in Table 3, where the technological parameters are modified slightly from Table 1 (in order to illustrate a case where the social planner indeed wishes to take more risks than banks do). It is also temporarily assumed here that risks are perfectly correlated across firms of the same type, so that default risks are aggregate shocks. The assumption is needed so that banks cannot rely on the law of large number to avoid insolvency risks (equivalently, one could assume that banks only lend to a finite number of firms).

Table 3: Parameterisation 2

a_1	b_1	a_2	b_2	p	q	γ	C	d
0.3	4	0.9	4	0.9	0.1	0.2	10	2

Under these parameters, $\left[\underline{R}, \overline{R}\right] = [0.695, 0.915]$. Over this interval, there exists three subsets of interest rates as before: (1) for $R_f < 0.805$, there exists a unique credit boom equilibrium; (2) for $R_f > 0.895$, a unique credit rationing equilibrium obtains; and (3) there are multiple equilibria in the intermediate range. Banks strictly prefer the joint separating equilibrium of credit rationing when there is a multiplicity.

Figure 11 depicts social welfare under the two equilibria, when society does not care about financial stability ($\lambda = 0$) and when it does ($\lambda = 0.1$). When $\lambda = 0$, the social planner would prefer lending to both firms as in the credit boom equilibrium as long as $R_f < 0.865$ (thus, including when there are multiple equilibria in the decentralised allocation). This is an instance where the social planner would prefer to take more risks than banks. But as society places a larger penalty on the variability of banks' profits, the credit rationing equilibrium becomes socially optimal for a wider range of interest rates. In Figure 11, when $\lambda = 0.1$, it is socially desirable to attain the joint separating equilibrium for the entire relevant range of interest rates.

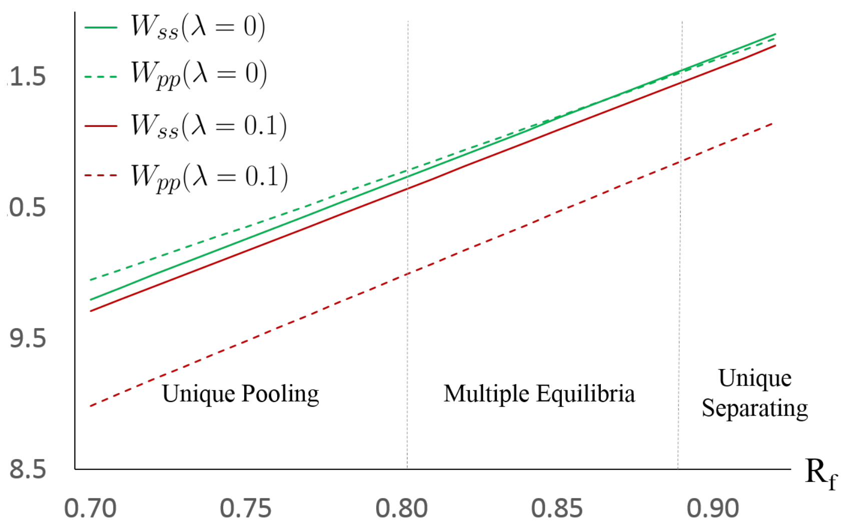


Figure 11: Social welfare with and without financial stability objective