ECONOMIC RESEARCH
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WORKING PAPER SERIES

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Working Paper Number	2018-018C
Revision Date	July 2019
Citable Link	https://doi.org/10.20955/wp.2018.018
Suggested Citation	Figueroa, N., Leukhina, O., Ramirez, C., 2019; Imperfect Information Transmission from Banks to Investors: Macroeconomic Implications, Federal Reserve Bank of St. Louis Working Paper 2018-018. URL https://doi.org/10.20955/wp.2018.018

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Imperfect Information Transmission from Banks to Investors: Macroeconomic Implications

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December 2019

Abstract

Our goal is to elucidate the interaction of banks' screening effort and strategic information production in loan-backed asset markets using a general equilibrium framework. Asset quality is unobserved by investors, but banks may purchase error-prone ratings. The premium paid on highly rated assets emerges as the main determinant of banks' screening effort. The fact that rating strategies reflect banks' private information about asset quality helps keep this premium high. Conventional regulatory policies interfere with this decision margin, thereby reducing signaling value of high ratings and exacerbating the credit misallocation problem. We propose a tax/subsidy scheme that induces efficiency.

Keywords: credit misallocation, information asymmetry, information production, screening effort, rising asset complexity, mandatory rating, mandatory ratings disclosure

JEL codes: G01, G24, G28

1. Introduction

The economic expansion leading up to the 2007-2008 financial crisis witnessed an unprecedented growth of markets for securitized products. Several empirical papers[1] suggested that the rise of securitization weakened loan originators' incentives to screen their borrowers, thereby lending support

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† *Acknowledgements:* We would like to thank Hengjie Ai, Anmol Bhandari, Philip Bond, Theo Eicher, Mark Flannery, Kristopher Gerardi, Jonathan Heathcote, Burton Hollifield, Markus Opp, Uday Rajan, William Roberds, Bryan Routledge, Chester Spatt, Venky Venkateswaran and the seminar participants at the University of Wisconsin, University of Washington, Pontificia Universidad Católica de Chile, the Federal Reserve Banks of Atlanta, Minneapolis and St. Louis, the 2019 Society for Economic Dynamics Meetings, the 2014 Midwest Macro Conference, the 2014 Midwest Economics Association Conference, the 2014 North American Meetings of the Econometric Society and the 2015 Carnegie Mellon University Conference entitled "The Economics of Credit Rating Agencies, Credit Ratings and Information Intermediaries." Figueroa acknowledges support of the Millennium Institute in Complex Engineering Systems (ICM: P05-004F; FONDECYT: FB016).

[1] See (Mian & Sufi, 2009), (Purnanandam, 2011), (Keys *et al.* , 2010), (Bord & Santos, 2015) and (Rajan *et al.* , 2018)).

to popular narrative, e.g. (Stiglitz, 2007) and (Blinder, 2007). Yet, our theoretical understanding of real implications of markets for loan-backed assets remains limited. In this paper, we examine macroeconomic implications of information asymmetry that plagues these market.

Our main premise is that *banks*, whose screening choices determine resource allocation in the economy, possess valuable information regarding their asset quality which is not available to *investors,* who provide the funds and bear the risk. Our specific goal is to elucidate the interaction of strategic information transmission by way of ratings and ratings' disclosures on the part of banks and their screening effort at the time of loan origination.

To this end, we develop a general equilibrium rational expectations framework with heterogeneous banks lending to heterogeneous borrowers and representative investors. In order to raise funds, banks must sell their loans to investors. Consistent with the classic role of intermediaries, banks are able to make sure, at a cost, that they extend high quality loans. The information available to banks about their asset is not observable by investors, but an imperfect rating technology, which reveals the true asset type with a fixed probability, is available to banks at a cost. Profit maximizing banks choose their screening effort, rating and ratings disclosure strategies. Employing the rating technology should be interpreted loosely as engaging in a costly process, which results, with some positive probability, in the enhancement of the perceived value of the asset. Investors observe the disclosed ratings and pay competitive prices in line with rational expectations regarding asset quality.

The following important insight immediately emerges from our model: It is the premium paid on assets with good ratings that disciplines the screening effort. In turn, this premium is directly proportional to *informativeness of a good rating*, $\Pr_{G|GR} - \Pr_{G|NR}$. This quantity describes the gain in investors' rational belief that the asset is of high quality, which results from observing a good rating. In the case of a perfectly accurate rating technology, rating informativeness is maximal as banks are aware of their asset quality, and their rating behavior reflects this information. However, an imperfect rating technology lowers the informational content of a good rating, both directly, by providing a less accurate signal, and indirectly, by encouraging strategic rating of low quality assets. As a result, the premium paid on highly rated assets is too low to induce the efficient level of screening.

The role of strategic ratings is also critical in helping the model interpret the variation in default rates across asset classes documented in (Cornaggia *et al.* , 2017) and explaining a number of puzzling trends seen in pre-crisis data. The presence of a strategic use/disclosure of error-prone ratings is well grounded in the data. (Benmelech & Dlugosz, 2009a) employ tranche-level CLO data to show that there is a significant mismatch between tranche ratings and the quality of underlying collateral. They also document that 70% of the dollar value of CLO tranches received a triple-A rating in 2000, while 23% did not have a published rating.

The fact that banks know their asset quality and produce ratings accordingly helps keep rating informativeness relatively high. Regulatory policies that dictate mandatory rating, certified review, and mandatory disclosure of ratings interfere with this decision margin. Under *mandatory rating*, sellers of low quality assets are dictated to rate, which makes good ratings less informative and discourages screening effort at the stage of loan origination. *Certified review* denotes a policy that eliminates availability of free bad ratings, making it possible for investors to distinguish between unrated and poorly rated assets. In this richer context, we also consider the policy of *mandatory ratings disclosure* which requires that all ratings are disclosed. Under both policies, strategic rating intensifies as poor ratings now serve as positive signals. This reduces the relevant premium and compounds resource misallocation. Thus, contrary to conventional wisdom, these policies are counterproductive, and the strategic rating decision is to blame.

We formally show that any policy that curtails strategic rating activity, whether it is through a direct mandate or through altering the model parameters that directly enter the rating decision, encourages screening activity and moves the economy closer to efficiency. This contrasts the current use of the issuer-pay model which typically requires pay for published ratings only – such a system does nothing to discourage strategic ratings.

Finally, our optimal policy analysis considers a policy maker that cannot directly enforce screening by banks, dictate the use of ratings, or observe the quality of extended loans, but has the ability to distort prices. We examine two policy schemes. The first is a tax on rating activity which raises the effective cost of ratings and works through discouraging strategic ratings. The second is a tax/subsidy scheme which directly distorts prices of rated and unrated assets. Both policies improve economic outcomes. However, full efficiency is possible to achieve only in the case of the tax/subsidy scheme, as it directly rewards the screeners and punishes the non-screeners.

Importantly, our welfare results stem from the presence of interplay between strategic ratings of assets and the ex-ante selection of projects underlying asset quality. Such feedback effect has not been modeled in related literature on information transmission in asset markets. This literature typically focuses on understanding why ratings fail to accurately reflect asset quality. Our paper is most closely related to (Skreta & Veldkamp, 2009) in that ratings inflation arises in the presence of unbiased rating agencies.[2] (Skreta & Veldkamp, 2009) and (Sangiorgi & Spatt, 2017) emphasize the role of ratings shopping. (Bolton *et al.* , 2012) highlight the role of investors' naiveté. Other papers focus on the role of strategic behavior of rating agencies, e.g. (Damiano *et al.* , 2008), (Mathis *et al.* , 2009), (Frenkel, 2015), (Kashyap & Kovrijnykh, 2016). We intentionally abstract from modeling behavior of rating agencies so as to isolate the effects of banks' strategic ratings on their ex-ante choice of project selection. However, our welfare analysis highlights the important role of rating accuracy, suggesting that future analysis can benefit from incorporating agencies' behavior into a framework like ours.

The paper is organized as follows. The model is described in Section 2. Section 3 contains equilibrium characterization and discussion of the role played by strategic ratings in generating inefficiency and explaining pre-crisis data patterns. Conventional regulatory policies are studied in Section 4. Optimal policy analysis is performed in Section 5, and conclusions appear in Section 6.

2. Model

We consider an economy with investors and heterogenous banks each facing a pool of informationally opaque heterogeneous projects/borrowers.[3] Borrowers are in need of funds, investors desire to save, and banks alone have the technology to screen and identify repaying borrowers. Banks need to raise funds by selling loans to investors. But investors do not possess information about the underlying quality of traded assets. (Gorton, 2009) discusses the severity of this type of asymmetric information.

The model period can be subdivided into three stages occurring in the following order.

1. **Screening of Projects.** Banks choose whether or not to engage in costly screening of projects when originating loans or choose them at random. Upon origination, loan quality is

[2](Skreta & Veldkamp, 2009) must assume that investors are unaware of the possibility of hidden information in order to avoid unraveling of trade. In our model, trade does not unravel because banks are in need of investors' funds. This allows us to model rational expectations.

[3]Borrowers/projects are meant to represent small businesses, startups, and first time home buyers.

revealed to the banks.

2. **Rating of Assets.** Banks choose whether or not to rate their assets.

3. **Asset Trade.** Banks and investors trade in competitive loan markets.

Note that we do not attempt to explain the rise of markets for loan-backed assets and defer to a separate body of work for that.[4] We simply assume their existence by postulating that banks are in need of investors' funds. This assumption is also what keeps trade from unravelling, see (Shavell, 1994), and makes the problem of information asymmetry relevant.[5]

Our equilibrium concept will require that, given asset prices, banks use optimal screening and ratings strategies, that asset prices reflect investors' beliefs regarding asset quality, and those beliefs are consistent with equilibrium outcomes.

2.1. Banks

There is a continuum of measure 1 of profit-maximizing banks, heterogeneous in their screening cost $k \sim F[0,1]$, which is unobserved to investors. F is continuous and represents the cumulative distribution function of banks' screening costs. Each bank faces its own pool of potential projects of unobserved types $\theta \in \{G, B\}$, represented in proportions μ_0 and $1-\mu_0$, respectively. Each project requires 1 unit of funds and repays W_θ on the loan, with $\Delta W := W_G - W_B > 0$.

Banks have the option of using the screening technology at the cost k, which guarantees financing of a good project. Otherwise, the borrower is chosen at random. Lending to a type θ borrower should be interpreted very generally, as standing in for extending a large basket of loans that generates W_θ in total proceeds.[6]

Once the borrower is financed, the asset type θ is revealed to the bank. This information regarding the quality of underlying loans is not available to investors. At a cost c, banks can employ a rating technology (i.e. an unbiased rating agency) that reveals the true asset type with probability $r \in (0.5, 1]$. Availability of this technology is needed to incentivize banks to issue high

[4] e.g. (Gorton & Pennacchi, 1995) and (Parlour & Plantin, 2008). This literature largely agrees on liquidity needs as underlying loan sales.

[5] In the absence of liquidity needs, the problem could be resolved if originating banks retained the most risky tranche of their loan basket, thereby sending a credible signal to asset buyers, e.g. (DeMarzo, 2005).

[6] This represents interest and principal repayment, or collections in case of default.

quality assets.[7] Rating an asset stands in for engaging in a costly process that results, with some positive probability, in the enhancement of the perceived value of the asset. Such process may involve hiring consultants to navigate the rating process and shopping for a favorable rating.[8] The assumption that $r > 0.5$ simply captures the idea that banks with better assets are more likely to succeed in this process. We also assume that bad ratings are available for free to all banks, which rules out the signaling value of poor ratings and ensures that only good ratings are revealed.

The following parametric assumptions are needed:[9]

Assumption 1 *We assume that $\Delta W > c$ and $\mu_0 W_G + (1 - \mu_0) W_B > 1 + c$.*

Let P_{GR} and P_{NR} denote prices on assets with good ratings and no ratings (or hidden poor ratings). Taking these prices as given, banks choose their screening and rating strategies to maximize profits.

Rating Strategy

Because asset prices are conditioned only on ratings, all banks holding an asset of a given type θ will make the same rating decision. Denote the probability of rating a type θ asset by f_θ. Type B assets are rated with certainty ($f_B = 1$) if the indifference condition (1) holds with "$>$", implying that the expected price gain, $\Delta P := P_{GR} - P_{NR}$, obtained with probability of a rating error, $1 - r$, strictly exceeds the cost of using the technology. They are not rated ($f_B = 0$) if the condition holds with "$<$", and the mixed strategy $f_B \in (0, 1)$ is played otherwise:

$$(1 - r)\,\Delta P \lesseqgtr c \tag{1}$$

We restrict attention to the range of parameter values, to be derived in Lemma 1, for which high quality assets are rated with certainty ($f_G = 1$):

$$r\Delta P > c. \tag{2}$$

[7] In the case of $r = 0.5$, there would be no premium paid on high ratings, and no bank would rate or screen their loans.

[8] We have also worked out a model with multiple rating draws, but did not find additional insight sufficient to justify the added complexity.

[9] The first assumption implies that, under full information, a bank would choose to rate a good project. The second guarantees that all banks participate in lending (see online appendix A).

Screening Strategy

Taking asset prices and optimal rating strategies as given, each bank decides whether or not to pay k to screen out bad projects. R_θ denotes the expected return to an asset of type θ :

$$R_G = rP_{GR} + (1-r)P_{NR} - c - 1, \tag{3}$$

$$R_B = (1-r)f_B P_{GR} + [1-(1-r)f_B]\, P_{NR} - f_B c - 1. \tag{4}$$

Consider returns to a type G asset, which is rated with certainty. With probability r, the bank obtains a high rating and sells the asset for P_{GR}. With probability $1-r$, this bank obtains a poor rating, hides it, and sells the asset for P_{NR}. The return is reduced by the rating cost and loan amount. A type B asset sells at a premium only in the case it is rated and a good signal is obtained in error, which happens with probability $(1-r)\, f_B$. Otherwise, the bank sells the asset for P_{NR}. The return is reduced by the expected rating cost and loan amount.

Banks that choose to screen finance high quality loans with certainty. The ex-ante expected return for these banks is given by $R_G - k$. Banks that draw projects at random finance high quality loans with probability μ_0. The ex-ante expected return for these banks is given by $\mu_0 R_G + (1-\mu_0) R_B$. It follows that, in order to maximize the ex-ante expected return to investment, a bank of type k should screen whenever

$$R_G - k \geq \mu_0 R_G + (1-\mu_0) R_B. \tag{5}$$

2.2. Investors

Investors save by buying loan-backed assets in competitive markets. Our assumption of competitive markets implies that investors make zero profits, i.e. that equilibrium asset prices $\{P_R\}_{R\in\{GR,NR\}}$ reflect expected returns, as perceived by investors:

$$P_R = W_G \Pr_{G|R} + W_B[1-\Pr_{G|R}] = \Pr_{G|R}\Delta W + W_B, \tag{6}$$

where $\left\{\Pr_{G|R}\right\}_{R\in\{GR,NR\}}$ denote investors' beliefs regarding asset quality, conditioned on observed ratings.

2.3. Model Equilibrium

Thus far, the banks' optimal screening and rating decisions have been described, for given asset prices. We have also discussed how asset prices are related to investors' beliefs regarding asset quality. To close our equilibrium definition, we also require that investors' beliefs are consistent with equilibrium outcomes.

Definition. *An equilibrium is given by the set of screening banks S^*, rating strategies f_G^* and f_B^*, the measure of good projects in the economy μ^*, investors' beliefs regarding asset quality $\left\{Pr^*_{G|R}\right\}_{R\in\{GR,NR\}}$ and asset prices $\{P^*_R\}_{R\in\{GR,NR\}}$ such that:*

1. *Given the asset prices, banks in set S^* find it optimal to screen their projects, while the rest of the banks pick projects at random: condition (5) holds only for banks in S^*.*
2. *Given the asset prices, banks that issued type θ assets find it optimal to rate them according to f_θ^*: conditions (1), (2) hold.*
3. *Given investors' beliefs, asset prices reflect expected returns: condition (6) holds.*
4. *Investors' beliefs are consistent with the equilibrium outcomes:*

$$Pr_{G|GR} = \frac{\mu r}{\mu r + (1-\mu) f_B (1-r)}, \tag{7}$$

$$Pr_{G|NR} = \frac{\mu(1-r)}{\mu(1-r) + (1-\mu)[(1-f_B) + f_B r]}. \tag{8}$$

5. *The measure of resource allocation in the economy $\mu^* \in (0,1)$ is determined according to*

$$\mu^* = \int_{S^*} dF(k) + \mu_0 \int_{S^{*\prime}} dF(k). \tag{9}$$

In belief consistency condition (7), investors' belief $\Pr_{G|GR}$ corresponds to the actual fraction of high quality assets, μr, among all highly rated assets, i.e. the sum of accurately rated high quality assets, μr, and poor quality assets that received a high rating in error, $(1-\mu) f_B (1-r)$. Similarly, $\Pr_{G|NR}$ defined in (8) corresponds to the actual fraction of high quality assets among all unrated assets. We will refer to the belief differential $\Delta\text{Pr}{:=}\text{Pr}_{G|GR}{-}\text{Pr}_{G|NR}$ as *rating informativeness*, precisely because it captures the increment in the equilibrium probability that the asset is of high quality implied by an observation of a high rating.

To the extent that loan payoffs W_θ are related to project productivity, the equilibrium object μ^* reflects average productivity in the sector that relies on bank financing.

3. Equilibrium Characterization

The optimal screening condition (5) allows us to characterize the set of screening banks in terms of the marginal screener

$$\bar{k} = (1 - \mu_0)\Delta R, \tag{10}$$

so that $S = \left\{k : k \leq \bar{k}\right\}$, where $\Delta R := R_G - R_B$. Banks with screening costs below $\bar{k}$ choose to screen, while the less productive banks draw projects at random. It follows that the measure of high quality projects in the economy, defined in (9), can also be written in terms of $\bar{k}$:

$$\mu = F(\bar{k}) + (1 - F(\bar{k}))\mu_0. \tag{11}$$

We proceed to solve for the equilibrium quantities and prices as follows. We first characterize the optimal rating strategy $f_B\left(\mu\right)$, which ensures that Conditions 2-4 in the definition above hold (Lemma 1). Beliefs and prices are then obtained as functions of μ. Given these prices, $\bar{k}\left(\mu\right)$ is obtained from (10), which allows for the equilibrium resource allocation μ^* to be found as a fixed point of (11).

3.1. Rating Strategy

The optimal rating strategy f_B, described in (1), depends on asset prices. In turn, asset prices depend on investors' beliefs through the zero profit condition (6), and beliefs depend on μ and f_B through the consistency conditions in (7) and (8). Therefore, by substituting consistent beliefs into prices and prices into ratings optimality, we can determine the equilibrium dependence of the rating strategy f_B on μ.

It is first helpful to describe how rating accuracy and the cost of screening relative to repayment differential, $\tilde{c} := \frac{c}{\Delta W}$, affect the rating decision. The lemma below characterizes the optimal rating strategy in the parameter space of r and $\tilde{c}$ (for a fixed μ).

Lemma 1 ***Rating Strategies for a Fixed Measure of Resource Allocation*** μ
For a fixed $\mu \in [0, \bar{\mu}]$, *where* $\bar{\mu} := \frac{r-\tilde{c}}{r(1-\tilde{c})}$, *rating strategies are given by* $f_G = 1$ *and*

$$f_B(\mu) = \begin{cases} 1 & \tilde{c} \leq \frac{\mu(1-\mu)(1-r)(2r-1)}{[r-\mu(2r-1)][\mu(2r-1)+(1-r)]} \\ f_B^{mix}(\mu) & \text{if } \frac{\mu(1-\mu)(1-r)(2r-1)}{[r-\mu(2r-1)][\mu(2r-1)+(1-r)]} < \tilde{c} < \frac{(1-r)(1-\mu)}{1-r\mu} \\ 0 & \frac{(1-r)(1-\mu)}{1-r\mu} \leq \tilde{c}. \end{cases}$$

where $f_B^{mix}(\mu)$ *is the solution to the rating indifference condition* (1).

The proof is given in the online appendix B. Figure 1 illustrates $f_B(\mu)$ in the space of r and $\tilde{c}$ for three levels of μ. Higher levels of $\tilde{c}$ clearly weaken the incentive to rate poor quality assets. However, the effect of r is non-monotone. On one hand, raising r increases rating accuracy, making it less likely that a poor quality asset sells at a premium, which discourages rating. On the other hand, raising r increases rating informativeness and the price premium, which tends to encourage rating activity. The latter effect dominates for low r because high ratings are largely uninformative and the premium is low. Conversely, the former effect dominates for large values of r where errors are unlikely.

The return to rating activity is disciplined by the premium $\Delta P(\mu)$, which, in turn, depends on rating informativeness $\Delta\Pr(\mu)$ through

$$\Delta P(\mu) = \Delta W \Delta\Pr(\mu), \tag{12}$$

derived from (6). $\Delta\Pr(\mu)$ is a hump-shaped. When μ is small, there are very few good assets in the economy, so a good rating does little to change investors' beliefs regarding asset quality. The same is true for high levels of μ when all traded assets are predominantly of high quality. For intermediate values of μ though, a good rating carries a lot of informational content – investors are willing to pay the highest premium on good ratings and banks are most likely to rate.

3.2. Screening Strategies and Resource Allocation

Given the equilibrium relationship $f_B(\mu)$ characterized in Lemma 1, it is straightforward to obtain the equilibrium dependence of investors' beliefs and prices on μ, using $(6)-(8)$. Given these prices, the marginal screener $\bar{k}(\mu)$ is determined according to (10) after substituting for the return differential:

$$\Delta R(\mu) = \Delta P(\mu)\left[r - (1-r) f_B(\mu)\right] - (1 - f_B(\mu)) c. \tag{13}$$

An important insight emerges. It is the price differential on assets with good ratings and assets with no ratings that disciplines the banks' screening effort at the stage of loan origination. In turn, as seen from (12), this premium is proportional to rating informativeness $\Delta\Pr(\mu)$. It can be shown that $\Delta\Pr(\mu)$ is high when r is high and when $f_B(\mu)$ is low. In that case, a good rating implies a large gain in the perceived quality of the asset, investors pay a large premium on assets with high ratings, and more banks screen their projects.

The fact that $f_B(\mu) < f_G(\mu)$ in the range of admissible μ is important for keeping rating informativeness high. In other words, asset issuers know the quality of their asset and this information is reflected in their rating behavior. Less frequent rating of low quality assets strengthens informativeness of good ratings and raises the premium paid on highly rated assets. This, in turn, encourages the screening effort.

Substituting the resulting marginal screener expression $\bar{k}(\mu)$ into the final equilibrium condition (11), we obtain the resource allocation in the economy μ^* as a fixed point of

$$\mu = F(\bar{k}(\mu)) + \left[1 - F(\bar{k}(\mu)\right] \mu_0. \tag{14}$$

To prove existence and uniqueness of equilibrium, it suffices to show that there is a unique solution μ^* to the above equation. The proof of equilibrium existence and uniqueness is formalized in the online appendix C. The remaining equilibrium quantities and prices have already been characterized as functions of μ.

3.3. *Inefficiency of Equilibrium Outcomes*

It is instructive to compare outcomes in the decentralized economy to the efficient ones. To define social welfare, suppose there is a representative agent that owns banks and rating agencies. Investors' payoffs are zero. We assume that the rating cost is a transfer from banks to rating agencies, standing in for extracted monopolistic rents. It follows that the total surplus of the economy is a function of the level of screening activity $\bar{k}$:

$$Y = F(\bar{k})W_G + (1 - F(\bar{k}))(\mu_0 W_G + (1 - \mu_0)W_B) - \int_0^{\bar{k}} k dF(k) - 1. \tag{15}$$

The first two terms give the total project payoff; the last two terms represent inputs involved in screening and financing of projects. As $\bar{k}$ goes up, more resources are used up in screening, but the total payoff increases.

The efficient allocation is given by screening activity $\bar{k}$ that maximizes Y. The social marginal gain of screening by any bank is $(1-\mu_0)\Delta W$, because good projects are financed with probability μ_0 even in the absence of screening. The marginal cost for a given bank is k. Therefore, it is socially optimal for a bank with the screening cost k to screen whenever $(1 - \mu_0)\Delta W \geq k$. The least productive bank faces the screening cost of 1. If $(1 - \mu_0)\Delta W > 1$, then even the least productive bank should screen. Otherwise, there exists a cutoff marginal screener $\bar{k}^{ef} \in (0, 1)$. Formally, the socially efficient marginal screener is given by

$$\bar{k}^{ef} = \min\{(1 - \mu_0)\Delta W, 1\}, \tag{16}$$

and the implied socially efficient measure of resource allocation is given by

$$\mu^{ef} = F(\bar{k}^{ef}) + \left[1 - F(\bar{k}^{ef})\right] \mu_0. \tag{17}$$

We find that, as long as $r < 1$, the level of screening in the decentralized economy falls short of the socially efficient level. In other words, as long as there is room for mistakes, the return differential ΔR which incentivizes individual banks to screen falls short of the social value differential ΔW. Intuitively, rating informativeness $\Delta \Pr^{*}$, and therefore the price differential ΔP, are inefficiently low because some good assets are rated low by mistake and because issuers of low quality assets are encouraged to try their luck at getting a high rating. The following proposition formalizes this intuition.

Proposition 1 ***Decentralized Outcomes vs. Constrained Efficient Outcomes***
Whenever $r < 1$, the equilibrium level of screening is less than efficient, and resources are misallocated:

$$\bar{k}^* < \bar{k}^{ef} \quad \textit{and} \quad \mu^* < \mu^{ef}.$$

Proof. First consider the case where $(1-\mu_0)\Delta W \geq 1$ and so $\bar{k}^{ef} = 1$. We want to show that $\bar{k}^* < \bar{k}^{ef} = 1$. Suppose not. If $\bar{k}^* = 1$ then $\mu^* = 1$, and it follows that investors pay $P_{GR}(\mu^*) = P_{NR}(\mu^*) = W_G$. These prices, in turn, imply that no bank will choose to engage in costly screening, i.e. $\bar{k}^* = 0$. This leads to a contradiction.

Now consider the case where $(1-\mu_0)\Delta W < 1$ and so $\bar{k}^{ef} = (1-\mu_0)\Delta W < 1$. Drawing on equilibrium conditions (10) and (13), we have

$$\begin{aligned} \bar{k}^* &= (1-\mu_0)\Delta R^* \\ &= (1-\mu_0)\left(\Delta W \Delta \mathrm{Pr}^*[r-(1-r)f_B^*] - (1-f_B^*)c\right) \\ &< (1-\mu_0)\Delta W r \Delta \mathrm{Pr}^* < (1-\mu_0)\Delta W = \bar{k}^{ef}, \end{aligned}$$

where the first inequality is due to $(1-f_B^*)c > 0$ and $r-(1-r)f_B^* < 1$, and the second inequality is due to r, $\Delta \mathrm{Pr}^* < 1$. Recognizing that $F\left(\bar{k}\right) + \left(1 - F\left(\bar{k}\right)\right)\mu_0$ increases in $\bar{k}$, the result that $\mu^* < \mu^{ef}$ follows immediately from (14) and (17). ■

An important message that emerges from this discussion is that the strategic rating component is partly to blame for the inefficiency. In fact, it is possible to show that any small exogenous change that effectively discourages ratings of bad assets, whether it is through a direct regulation or change in parameters that directly enter the rating decision (an increase in c or r , or a decrease in ΔW), always moves the economy closer to efficiency. Since we think of c as a monopolistic rent, a reduction in f_B would also redistribute resources from rating agencies to banks.

Proposition 2 ***Rating Activity and Efficiency at the Margin***
Suppose $f_B^* \in (0,1)$. The economy is weakly better off whenever f_B^* is reduced at the margin (while

$f_G^* = 1$ is maintained) as a result of the following small changes: (1) a direct mandate, (2) an increase in c or r, or a decrease in ΔW.[10]

One immediate implication is that a regulation that mandates rating of all assets would likely be counterproductive. To the extent that policy can influence model parameters, this result also suggests direction for optimal policy design. A tax on ratings, for example, would discourage rating activity by raising the effective cost of ratings. A regulation of liability limits, i.e. the amount W_B that lenders recover from bad projects, could discourage rating activity by lowering the premium paid on highly rated assets. Importantly, this result does not imply that all successful policies must necessarily reduce rating activity f_B.

3.4. Macroeconomic Effects of a Declining Rating Accuracy

We saw that rating inaccuracy, $r < 1$, is behind equilibrium inefficiency. In Lemma 2, we establish that a decline in r necessarily sends the economy farther away from efficiency.[11] This result immediately implies that policy design aimed at raising r, which could be accomplished by reducing asset complexity or regulating rating agencies, would help improve economic outcomes.

Lemma 2 ***Macroeconomic Effects of Rating Accuracy* r**

Screening effort $\bar{k}^*$ and measure of resource allocation μ^* are strictly increasing in r.

A change in r – through its effect on strategic ratings – can also generate an unexpected response of asset prices. In fact, if we associate the expansionary period that preceded the 2008 financial crisis with growing asset complexity and therefore declining rating accuracy ($r \downarrow$), then our model can help interpret a number of puzzling phenomena.

Figure 2 helps illustrate one informative comparative statics exercise. A decline in r is captured by movement along the x-axis towards the origin. All high quality assets are rated with certainty. We observe that the strategic rating on the part of lemon holders intensifies (panel b). For a sufficiently high rating accuracy, poor quality assets are never rated, and for a low enough level of rating precision, everyone engages in rating. Rating informativeness (panel f) decreases through the direct effect of ratings becoming more prone to error. Importantly, it falls faster in the region

[10] The proof is in the online appendix D.
[11] The proof is in the online appendix E.

where the mixed strategy is played. In this region, investors' beliefs regarding the relative quality of highly rated assets deteriorate due to both—the direct effect of less accurate ratings and the indirect effect of intensified rating activity. In the same region, the fraction of banks screening and the measure of high quality projects in the economy decline most rapidly (panels a and c). This is not surprising, because the screening decision depends on the premium paid on highly rated assets and on the probability of obtaining a good rating, both of which decline.

Most interestingly, the prevalence of highly rated traded assets rises despite declining average quality of extended loans (panels a and e). This happens in the (empirically relevant) region of mixed strategy. The reason for this regularity is the intensified rating of poor quality assets.

Therefore, our model is consistent with the following phenomena observed during the expansionary period leading up to the crisis: Laxer screening standards and rising delinquency rates (panels a and c); An intensified use of ratings (panel b); Rising default probability conditional on a high rating, i.e. rating inflation (panel d); (4) A decline in yield spreads between low rated and highly rated securities, or equivalently, a drop in the premium paid on highly rated assets (panel f); (5) An increased prevalence of highly rated assets despite the worsening pool of loans that back them (panels a and e).

Laxer screening standards are identified by the empirical papers cited in the Introduction. The upsurge in loan delinquency rates can be seen in aggregate data.[12] (Benmelech & Dlugosz, 2009b) and (Griffin & Tang, 2011) provide empirical evidence for the intensified rating activity and ratings inflation prior to the crisis. The decline in yield spreads is simply an upshot of ratings inflation. Finally, the rise in prevalence of triple-A rated assets to only result in massive downgrades is discussed in (Cornaggia *et al.* , 2017) and (Benmelech & Dlugosz, 2009b).

Moreover, our model is consistent with the following empirical regularity documented in (Cornaggia *et al.* , 2017): After conditioning on ratings, the more opaque asset classes (i.e. lower r) exhibit greater default rates. Our model would imply these assets are of lower average quality, and therefore would exhibit greater default rates, conditional on a given rating.

[12] Available at https://fred.stlouisfed.org/series.

4. Policy Experiments

We analyze several regulatory policies that aim to increase information production in financial markets so as to improve economic outcomes. Contrary to conventional wisdom, these policies are shown to worsen the degree of resource misallocation.

4.1. Mandatory Rating

Consider a policy that dictates that all assets are rated. In this economy, a lack of a rating will signal a hidden poor rating, which implies all ratings will be disclosed, and prices will be conditioned on good and bad ratings. Therefore, an introduction of mandatory ratings is equivalent to setting $f_B = f_G = 1$. By intensifying rating activity on the part of sellers of low quality assets, this policy introduces more confusion in the asset market. As the high rating premium declines – a result of policy intervention – banks curtail screening expenditures.

Denoting the measure of good assets in the economy under mandatory rating by μ^{mr}, we formalize our main findings in the proposition below.

Proposition 3 ***Macroeconomic Implications of Mandatory Rating Policy***
Rating intensifies, $f_B^{*,mr} = 1 \geq f_B^*$, *and resource misallocation worsens,* $\mu_{mr}^* \leq \mu^*$.

Proof. It suffices to show that the right hand side of (14) is lower in the case of mandatory ratings, which would imply a lower fixed point. Recognizing that the right hand side increases in $\bar{k}(\mu)$ and therefore in ΔR, it suffices to show that $\Delta R_{mr}(\mu) \leq \Delta R(\mu)$ for admissible μ. This result follows immediately from the definition of ΔR after substituting for prices and employing the expression of $f_B(\mu)$ given in Lemma 1. The inequality is strict in the range of μ where $f_B(\mu) \in (0, 1)$ in the benchmark model. ■

This policy experiment highlights the importance of distinct ratings of high quality and low quality assets, $f_B^* < f_G^*$, in the benchmark model. The fact that poor quality asset issuers know they have a lemon and act on that information translates into less frequent rating use on their part. This margin makes good ratings more informative and helps discipline screening activity. Mandatory ratings policy is counterproductive because it interferes with this margin.

4.2. Certified Review and Mandatory Ratings Disclosure

Consider a policy that eliminates availability of free bad ratings. We refer to this policy as *certified review,* as it may be implemented by a mandate that all ratings are obtained through one of a few certified agencies. In practice, these agencies would charge a hefty monopolistic rent for their review regardless of its nature or outcome. In particular, an issuer would not be able to obtain a bad rating for free, even if the cost incurred by the agency were negligible such as in the case of failure to provide information needed for review.

The *certified review* policy is designed to eliminate confusion between unrated and poorly rated assets. It eliminates the possibility of passing unrated assets off as hidden poorly rated assets. As a result, investors can potentially differentiate between assets with good ratings, assets with bad ratings, and unrated assets. In this richer context, we also consider the policy of *mandatory ratings disclosure* which requires that all ratings are disclosed but leaves the rating decision up to the issuer. Both policies are designed to produce more information in asset markets. Yet, both imply more intensified rating activity and inferior equilibrium outcomes.

4.2.1. Certified Review

The equilibrium definition needs to be adjusted to accommodate the possibility of three distinct signals in this economy: $R \in \{GR, BR, NR\}$. The equilibrium is now given by the set of screening banks S^*, rating strategies f_G^*, f_B^*, measure of good projects in the economy μ^*, investors' beliefs $\left\{\Pr_{G|R}\right\}_R$ and asset prices $\{P_R^*\}_R$ that satisfy the previously stated conditions, subject to the following adjustments.

High quality assets are now rated with certainty ($f_G = 1$) if and only if

$$rP_{GR} + (1-r)P_{BR} - c > P_{NR}.$$

Low quality assets are rated with certainty ($f_B = 1$) if the indifference condition (18) holds with "$>$", rated with probability $f_B \in (0,1)$ if the indifference condition applies, and never rated ($f_B = 0$) otherwise:

$$(1-r)\,P_{GR} + rP_{BR} - c \gtreqqless P_{NR}. \tag{18}$$

Expected returns to an asset of type $\theta \in \{B, G\}$ are now given by

$$R_G = rP_{GR} + (1-r)P_{BR} - c - 1, \tag{19}$$

$$R_B = f_B\left[(1-r)P_{GR} + rP_{BR} - c\right] + (1-f_B)P_{NR} - 1. \tag{20}$$

Investors' beliefs are restated as:

$$\Pr_{G|GR} = \frac{\mu r}{\mu r + (1-\mu) f_B (1-r)}, \tag{21}$$

$$\Pr_{G|BR} = \frac{\mu(1-r)}{\mu(1-r) + (1-\mu) f_B r}, \tag{22}$$

$$\Pr_{G|NR} = 0. \tag{23}$$

The last result holds because high quality assets are always rated and disclosed.

Because the introduction of this policy eliminates any confusion of poorly rated assets with unrated assets, bad ratings now serve as positive signals. It becomes optimal to disclose them. This is formalized in the lemma below.

Lemma 3 ***Ratings Disclosure under Certified Review***

All ratings, good or bad, are disclosed.

Proof. Because $f_G = 1$, it is clear that $\Pr_{G|NR} = 0$, and therefore $P_{NR} = W_B$. Is is also known that $\Pr_{G|BR} > 0$ due to $r < 1$. Therefore, $P_{BR} > W_B$, and the result follows. ■

This policy encourages rating of low quality assets. In fact, it is seen immediately that, for all admissible μ, rating strategy $f_B^{mix}(\mu)$, obtained by solving the indifference condition (18), is strictly greater than its benchmark counterpart (defined in Lemma 1).[13] In fact, it is clear that $f_B > 0$, i.e. it cannot be the case that low quality assets are never rated. The intuition is as follows. If low quality assets were never rated in the economy where good assets are always rated, then the disclosure of any rating, even a bad one, signals a high quality asset with certainty. The equilibrium asset prices generated by such beliefs would incentivize rating of poor quality assets, which implies a contradiction.

As a result of increased rating activity, this policy reduces the informational value of good

[13] In the online appendix F, we formally characterize rating strategies in the case of certified ratings policy, where we also show that no additional parametric restrictions (relative to the benchmark) are needed to ensure that $f_G = 1$.

ratings and the premium paid on highly rated assets. Banks reduce their screening effort and credit misallocation worsens, just as in the case of mandatory ratings. The result is formalized below, where we also compare outcomes implied by mandatory ratings and certified review policies. The proof is provided in the online appendix G.

Proposition 4 ***Macroeconomic Implications of Certified Review***
If $\mu^* \in \left(0, \frac{1-r-\tilde{c}}{1-r-r\tilde{c}}\right)$, *then* $f^*_{B,cr} \geq f^*_B$ *and* $\mu^*_{cr} \leq \mu^*$.
Moreover, $\mu^*_{mr} < \mu^*_{cr}$ *if* $W_G - c \geq (2r-1)\Delta W$.

The condition on the admissible range of μ applies in the empirically relevant case where $f^*_B \in (0,1)$, and it is more stringent than needed for the result. The last condition is quite weak, and therefore we expect mandatory ratings to be more detrimental than certified review. After all, all assets are rated under mandatory ratings, while $f^{cr}_B < 1$ ensues for a wide range of parameter values under certified review. Yet, if c is high relative to W_B, mandatory rating may fare better than certified review despite it inducing more ratings. The intuition comes from the fact that bad loans impose greater rating expenditures, which makes screening more attractive.

4.2.2. Mandatory Ratings Disclosure

In the context of a model with certified review, consider a policy that also mandates for all ratings to be disclosed. We find this policy makes no difference relative to certified review, as all ratings are already optimally disclosed.

Proposition 5 ***Macroeconomic Implications of Mandatory Ratings Disclosure***
If $\mu^* \in \left(0, \frac{1-r-\tilde{c}}{1-r-r\tilde{c}}\right)$, *then* $f^*_{B,md} = f^*_{B,cr} \geq f^*_B$ *and* $\mu^*_{md} = \mu^*_{cr} \leq \mu^*$.

Proof. Follows immediately from Lemma 3. ■

5. Optimal Policy Analysis

We consider a policy maker that cannot directly enforce screening by banks, dictate the use of ratings, or observe the quality of extended loans, but can distort prices via tax policy. The policy maker entertains two policies. The first is a tax on rating activity which distorts rating prices. The second is a tax/subsidy scheme which distorts prices of rated and unrated assets.

Both policies improve economic outcomes. However, full efficiency is attainable only in the case of the tax/subsidy scheme. In contrast to the tax on rating activity, which distorts rating costs for all banks, regardless of whether or not they screen, the tax/subsidy scheme directly rewards the screeners and punishes the non-screeners. It is therefore more effective.

5.1. Tax on Rating Activity

In light of Proposition 2, it seems reasonable that a tax on rating activity may help reduce strategic rating activity and move the economy closer to efficiency. We consider a policy that levies a tax τ_c on the use of a rating technology and redistributes the proceeds equally among all banks.

We find that a tax on rating activity is indeed successful in the empirically relevant space of parameter values – those that imply a mixed strategy in the benchmark model. Mechanically speaking, for the indifference condition (1) to continue to hold in response to an increase in the effective cost of ratings $\tau_c c$, the price differential ΔP must increase. This is obtained through a lower rating activity f_B. Thus, as τ_c increases rating costs and rating activity is reduced ($f_B \downarrow$). High ratings become more meaningful, and investors are willing to pay more for them, which incentivizes more banks to engage in screening. For a large enough $\tau_c^{\max}$, strategic rating activity is fully eliminated ($f_B = 0$), and further increases in the tax are counterproductive. This is because the only remaining marginal effect is on the sellers of high quality assets, which makes the ex-ante screening option less attractive. The result is formalized below. The proof, given in the online appendix H, closely follows our discussion.

Proposition 6 ***Macroeconomic Effects of the Ratings' Tax,*** τ_c
If $f_B(\mu^*) = 1$, *then* $\bar{k}^*$ *and* μ^* *are independent of* τ_c.
If $f_B(\mu^*) \in (0, 1)$ *(the empirically relevant case), then* f_B *is decreasing while* $\bar{k}^*$ *and* μ^* *are strictly increasing in* τ_c.
If $f_B(\mu^*) = 0$, *then* $\bar{k}^*$ *and* μ^* *are strictly decreasing in* τ_c.

As long as $f_B > 0$, which is the case for all $\tau_c < \tau_c^{\max}$, it is optimal to rate high quality assets with certainty and therefore no additional parametric assumptions are needed to ensure $f_G = 1$. Thus, an increase in τ_c can successfully eliminate strategic ratings. The question is whether or not full efficiency can be reached before the tax becomes counterproductive. The following result shows that is not the case.

Proposition 7 *A tax on ratings cannot achieve full efficiency.*

Proof. It follows from Proposition 6 that the highest level of screening is achieved with $\tau_c^{\max}$ which induces $f_B = 0$, and where prices also satisfy the rating indifference condition (1), $(1-r)\,\Delta P = \tau_c^{\max} c$. At this point,

$$\begin{aligned}\Delta R &= rP_{GR} + (1-r)P_{NR} - 1 - \tau_c^{\max} c - (P_{GR} - 1) \\ &= r\Delta P - \tau_c^{\max} c = (2r-1)\Delta P \\ &= (2r-1)\Delta W \Delta\,\mathrm{Pr} = (2r-1)\Delta W \frac{1-\mu}{1-\mu r} < \Delta W,\end{aligned}$$

where we substituted for $\tau_c^{\max} c$ from the indifference condition in the second line, and used $\Delta\,\mathrm{Pr} = \frac{1-\mu}{1-\mu r}$ in the last line. ■

5.2. Tax/subsidy policy

Now consider a policy intervention that combines a tax on transactions of loans with no ratings (τ_{NR}) and a subsidy on transactions of highly rated loans (τ_{GR}). We require that $\tau_{GR} > 0$ and $\tau_{NR} \in (0,1)$ and impose a budget constraint for the policy maker.

Proposition 8 *There exists a tax-subsidy scheme $\{\tau_{GR} > 0, \tau_{NR} \in (0,1)\}$ that induces the efficient level of resource allocation, provided the following parametric condition is satisfied:*

$$\frac{\min\{\Delta W, (1-\mu_0)^{-1}\} r\mu^{ef}}{2r-1} \leq \min\{\Delta W, (1-\mu_0)^{-1}\} r\mu^{ef} \Delta Pr + Pr_{NR},$$

where $\{Pr_R\}_{R\in\{GR,NR\}}$ are evaluated at μ^{ef}.

The above result shows this simple scheme attains efficiency if ΔW is not too high. However, if ΔW is very high, the stakes are high and efficiency dictates that nearly all banks screen, which would require unaffordable subsidies. The optimal tax/subsidy rates are derived in the proof (see the online appendix I).

It is important to emphasize that if efficiency cannot be achieved with the tax/subsidy scheme, it is because it is *impossible* to do so even through the general mechanism design approach that conditions banks' payoffs on their declared screening costs. In the online appendix J, we formally show that all outcomes attainable by the general mechanism can also be achieved by a pooling mechanism that specifies only two payoffs, one for having financed each type of loan. Moreover, it can be done without changing the implementation cost for the policy maker. It is precisely this pooling mechanism that our policy maker implements by distorting prices in asset markets.

6. Conclusion

We developed a general equilibrium model that allowed us to study the interaction of information transmission in secondary markets for loans, via ratings and their disclosure, and screening intensity at the stage of loan origination. The model provides insight into what determines screening effort at the stage of loan origination and explains why it is less than optimal. Because rating technology is imperfect, strategic rating activity ensues in equilibrium, reducing the premium paid on highly rated assets and weakening the incentive to screen. Nonetheless, the fact that banks know their asset quality helps curtail strategic ratings and keep the premium high. Several conventional regulatory policies interfere with this margin and move the economy farther from efficiency. Our optimal policy analysis considers a policy maker that cannot directly enforce screening by banks or dictate the use of ratings. We show this policy maker can restore efficiency by introducing a tax/subsidy scheme in asset markets. A tax on rating activity can also improve outcomes but cannot restore full efficiency.

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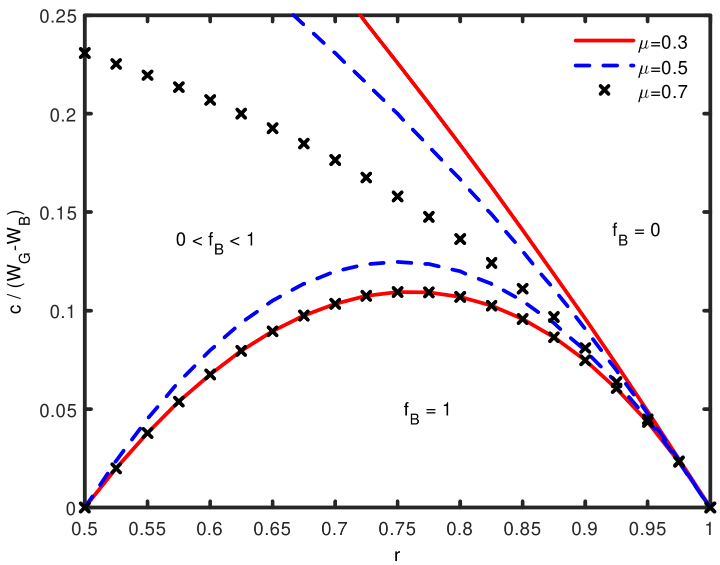

Figure 1. Equilibrium Rating Strategy

Notes: This figure helps visualize Lemma 1. For a given resource allocation μ^*, this figure reports the optimal rating strategy by holders of type B assets in the space of two exogenous quantities: the rating accuracy r and the rating cost c normalized by the repayment differential $W_G - W_B$.

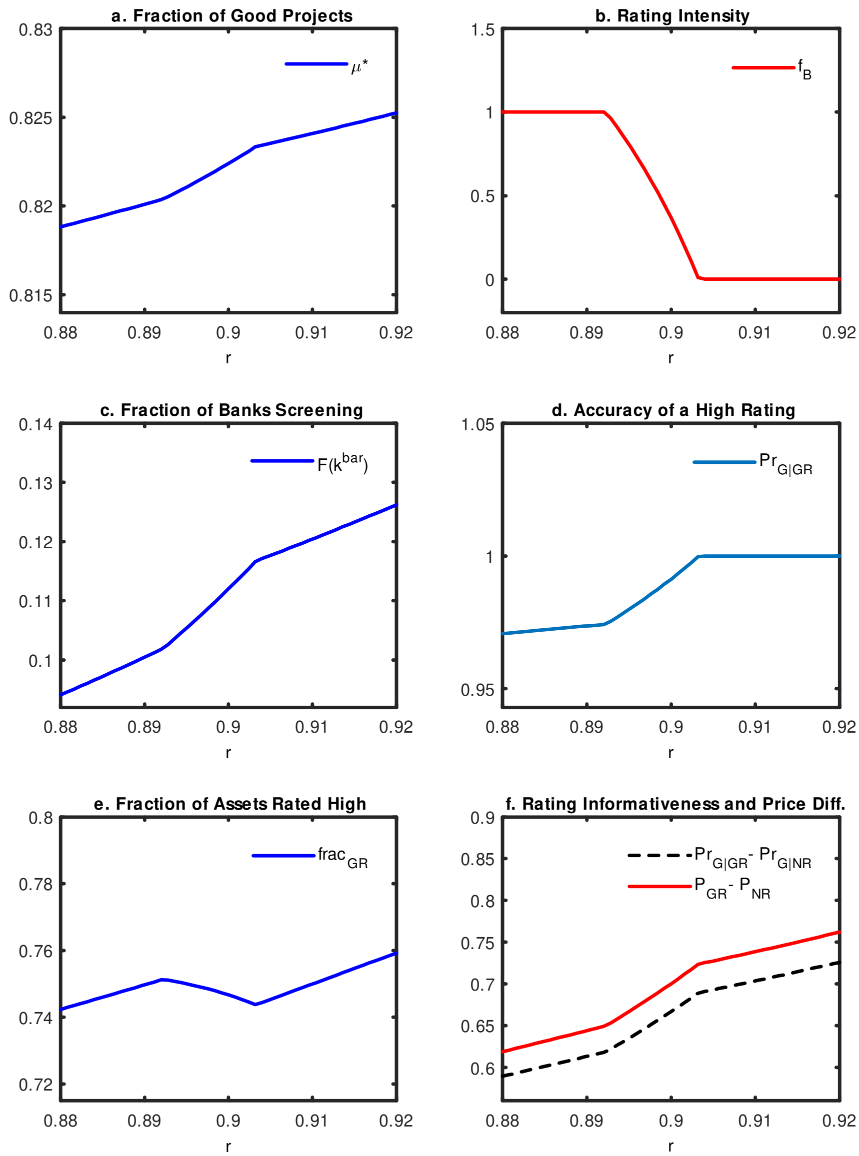

Figure 2. Equilibrium Effects of Decreasing the Rating Precision

Notes: This figure illustrates possible equilibrium effects of changing the rating accuracy parameter r.

Online Appendix

to

Imperfect Information Transmission from Banks to Investors:

Macroeconomic Implications

by

Nicolás Figueroa[a], Oksana Leukhina[b], Carlos Ramírez[c]

The included material is intended for online appendix only.
The material references equations from the main text.

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A Bank Participation

Proposition. *Assumption 1 guarantees that all banks participate in lending.*

Proof

All banks have the option of not screening. Therefore, the ex-ante profits are at least $\mu_0 R_G + (1-\mu_0)R_B$. Moreover, denoting by $\bar{R}_i$ the profits net of investment and rating costs, we conclude that ex-ante profits for all banks are at least $\mu_0 \bar{R}_G + (1-\mu_0)\bar{R}_B - 1 - c$, which assumes maximum rating costs.

Investors make zero profits when they buy loans from the *average* distribution in the economy, i.e. $\mu \bar{R}_G + (1-\mu)\bar{R}_B = \mu W_G + (1-\mu)W_B$.

Because non-screeners have a project that is worse than average ($\mu_0 < \mu$), investors lose money when trading with them: $\mu_0 \bar{R}_G + (1-\mu_0)\bar{R}_B > \mu_0 W_G + (1-\mu_0)W_B$. Therefore, all banks expect to earn at least $\mu_0 W_G + (1-\mu_0)W_B - c - 1$, which is positive by Assumption 1. □

B Proof of Lemma 1

Rating strategy f_B.

Case 1. $f_B = 1$. From (1), this strategy is optimal whenever $(1-r)\Delta P > c$. Substituting for prices from the zero profit condition (6), we have

$$(1-r)\Delta W \Delta \Pr > c.$$

Substituting for beliefs from the consistency condition (6) and from $f_B = 1$ gives the necessary and sufficient condition for the above inequality:

$$\begin{aligned} (1-r)\Delta W \left[\frac{\mu r}{\mu r + (1-\mu)(1-r)} - \frac{\mu(1-r)}{\mu(1-r) + r(1-\mu)}\right] &> c, \text{ or} \\ (1-r)\frac{\mu(1-\mu)(2r-1)}{(r-\mu(2r-1))(\mu(2r-1)+(1-r))} &> \frac{c}{\Delta W}. \end{aligned} \tag{B.1}$$

Case 2. $f_B = 0$. Following the same steps as in Case 1, we find this strategy is optimal whenever

$$(1-r)\Delta W \Delta \Pr < c.$$

Substituting for beliefs from the consistency conditions and for $f_B = 0$, we obtain

$$\begin{aligned} (1-r)\Delta W \left[1 - \frac{\mu(1-r)}{\mu(1-r) + (1-\mu)}\right] &< c, \text{ or} \\ (1-r)\left[\frac{1-\mu}{1-r\mu}\right] &< \frac{c}{\Delta W}. \end{aligned} \tag{B.2}$$

Case 3. $f_B \in (0,1)$. The mixed strategy is optimal whenever

$$(1-r)\Delta W \Delta \Pr = c.$$

Substituting into the above equality for ΔPr from (7) and (8) gives

$$(1-r)\left[\frac{\mu r}{\mu r + (1-\mu) f_B (1-r)} - \frac{\mu(1-r)}{\mu(1-r) + (1-\mu)[(1-f_B) + f_B r]}\right] = \frac{c}{\Delta W}.$$

It is straightforward to show that the positive solution to this equation is given by

$$f_B^{mix} = \frac{\tilde{c}\,(1-2\mu r) + \mu\,(1-r) - \sqrt{(\tilde{c}+\mu)^2 - \mu^2 r\,(2-r) - (6-4r)\,\tilde{c} r \mu}}{2\tilde{c}\,(1-r)\,(1-\mu)}. \tag{B.3}$$

The optimal strategy f_B is given by f_B^{mix} derived above, but bounded by 0 from below and 1 from above. Thus we have $f_B \in (0,1)$ whenever

$$(1-r)\frac{\mu(1-\mu)(2r-1)}{(r-\mu(2r-1))(\mu(2r-1)+(1-r))} < \frac{c}{\Delta W} < (1-r)\left[\frac{1-\mu}{1-r\mu}\right].$$

The first inequality appearing in the expression above is derived by setting $f_B^{mix} < 1$, and the second inequality is derived by setting $f_B^{mix} > 0$.

Rating strategy f_G**.**
To ensure that $f_G = 1$, we must impose that

$$r\Delta W \Delta \Pr > c.$$

This inequality holds whenever $f_B > 0$ as in that case $r\Delta W \Delta \Pr > (1-r)\,\Delta W \Delta \Pr \geq c$.

However, an additional restriction is needed in the space of parameters that imply $f_B = 0$. Substituting for $\Delta \Pr$ in the case of $f_B = 0$ and simplifying, we obtain

$$r\Delta W \Delta \Pr = r\Delta W \left[\frac{1-\mu}{1-r\mu}\right] > c.$$

The result follows. □

C Existence and Uniqueness of Equilibrium

Proposition.
Denote the right hand side of the equilibrium condition (11) *by* $H : \left[0, \frac{r(1-\mu)}{1-r\mu}\right] \to [\mu_0, 1]$,

$$H(\mu) := F(\bar{k}(\mu)) + \left[1 - F(\bar{k}\,(\mu)\right]\mu_0. \tag{C.1}$$

Assume $\mu_0 < \bar{\mu}$*. If parameter values satisfy* $\tilde{c} \leq (1-r)\,(2r-1)$*, then also assume*

$$\bar{f}(1-\mu_0)^2 \Delta W \frac{(2r-1)^2}{r\,(1-r)}\sqrt{\frac{1-r-\tilde{c}/\,(2r-1)}{1-r-\tilde{c}\,(2r-1)}}\Big/\left(\frac{1-r}{1-r-\tilde{c}\,(2r-1)}\right)^2 < 1, \tag{C.2}$$

where $\bar{f} := \sup_{k\in[0,1]} F'(k)$*.*
Then $H'(\mu) \leq 1$ *and there exists a unique equilibrium.*

Proof
Note that the condition $(C.2)$ imposed to ensure uniqueness is quite weak. In fact, this condition is not needed for parameterizations that imply that the equilibrium measure of high quality assets is over a half.[14] Because $H(\cdot)$ is continuous, there exists at least one fixed point of $H(\cdot)$ whenever

[14] We show that $H\,(\mu)$ is weakly decreasing for $\mu \in (0.5, \bar{\mu})$ without any restriction on parameter values.

$H(0) > 0$ and $H(\bar{\mu}) < \bar{\mu}$. The fixed point is unique if $H'(\mu) < 1$ on the entire range of $\mu \in (0, \bar{\mu})$. Define constants μ_1,μ_2,μ_3 as follows: μ_1 and μ_2 denote the lower and higher solutions of $f_B^{mix} = 1$ and μ_3 solves $f_B^{mix} = 0$.

Step 1. Existence

Recall the definition of $H : [0, \bar{\mu}] \rightarrow [\mu_0, 1]$ given in $(C.1)$:

$$H(\mu) = F(\bar{k}(\mu)) + \left[1 - F(\bar{k}(\mu)\right] \mu_0.$$

Substituting for $\Delta R(\mu)$ into (10), we obtain the marginal screener $\bar{k}(\mu)$:

$$\bar{k}(\mu) = (1 - \mu_0)\left[\Delta W \Delta \Pr(\mu)\left[r - (1 - r) f_B(\mu)\right] - (1 - f_B(\mu)) c\right], \tag{C.3}$$

where the rating informativeness

$$\Delta \Pr(\mu) = \frac{\mu r}{\mu r + (1 - \mu) f_B(\mu)(1 - r)} - \frac{\mu(1 - r)}{\mu(1 - r) + (1 - \mu)[(1 - f_B(\mu)) + f_B(\mu) r]}$$

was derived from (7) and (8).

We use the resulting expression to find $H(0)$. We know from Lemma 1 that $f_B(0) = 0$ and $f_G(0) = 1$. Hence, $\Delta \Pr(0) = 1$ and $\bar{k}(0) = (1 - \mu_0)[\Delta W r - c] > 0$. It follows that

$$H(0) = F((1 - \mu_0)[\Delta W r - c]) + [1 - F((1 - \mu_0)[\Delta W r - c])]\mu_0 > F(0) + [1 - F(0)]\mu_0 > 0.$$

Our next objective is to find $H(\bar{\mu})$. By Lemma 1, $f_B(\bar{\mu}) = 0$ and $f_G(\bar{\mu}) = 1$. Hence, $\Delta \Pr(\bar{\mu}) = \frac{1-\bar{\mu}}{1-r\bar{\mu}}$ and

$$\begin{aligned}
\bar{k}(\bar{\mu}) &= (1 - \mu_0)\left[\Delta W \Delta \Pr(\bar{\mu})\left[r - (1 - r) f_B(\bar{\mu})\right] - (1 - f_B(\bar{\mu})) c\right] = \\
&= (1 - \mu_0)\left[\Delta W r \frac{1 - \bar{\mu}}{1 - r\bar{\mu}} - c\right] \\
&= (1 - \mu_0)\left[\Delta W r \frac{1 - \frac{r - \tilde{c}}{r(1 - \tilde{c})}}{1 - \frac{r - \tilde{c}}{1 - \tilde{c}}} - c\right] \\
&= (1 - \mu_0)\left[\Delta W r \frac{\tilde{c}}{r} - c\right] = (1 - \mu_0)[c - c] = 0.
\end{aligned}$$

Hence,

$$H(\bar{\mu}) = F(0) + [1 - F(0)]\mu_0 = \mu_0.$$

The assumption $\mu_0 < \bar{\mu}$ then implies that $H(\bar{\mu}) < \bar{\mu}$. We showed that $H(0) > 0$ and $H(\bar{\mu}) < \bar{\mu}$, which implies that equation $\mu = H(\mu)$ has at least one solution.

Step 2. Uniqueness

Now we move on to discuss uniqueness. Differentiating $H(\mu)$, we obtain

$$H'(\mu) = (1 - \mu_0) F_{\bar{k}} \frac{\partial \bar{k}}{\partial \mu}.$$

Range 1. First, consider the highest admissible range of $\mu \in (\mu_3, \bar{\mu})$, where $f_B = 0$ by Lemma

1. Substituting for f_B into $(C.3)$ and differentiating, we obtain $\frac{\partial \bar{k}}{\partial \mu} = \frac{-(1-\mu_0)r(1-r)\Delta W}{(1-r\mu)^2}$ and therefore

$$H'(\mu) = -F_{\bar{k}}(1-\mu_0)^2\left(\frac{r(1-r)\Delta W}{(1-r\mu)^2}\right) \leq 0.$$

Range 2. If parameters satisfy $\tilde{c} \leq (1-r)(2r-1)$, consider $\mu \in (0, \mu_1)$ and $\mu \in (\mu_2, \mu_3)$. If instead parameters satisfy $\tilde{c} > (1-r)(2r-1)$, consider the entire range of $\mu \in (0, \mu_3)$. By Lemma 1, we have $f_B \in (0,1)$ for these values of μ, and therefore $\Delta \Pr = \frac{c}{(1-r)\Delta W}$. Substituting this into $(C.3)$ and differentiating gives us $\frac{\partial \bar{k}}{\partial \mu} = 0$ and therefore

$$H'(\mu) = 0.$$

Range 3. It remains to consider the range $\mu \in (\mu_1, \mu_2)$, relevant only if parameters satisfy $\tilde{c} \leq (1-r)(2r-1)$. By Lemma 1, $f_B = 1$. Substituting that into $\bar{k}$ and differentiating, we obtain

$$\frac{\partial \bar{k}}{\partial \mu} = (1-\mu_0)\Delta W \frac{r(2r-1)^2(2\mu-1)(r-1)}{(r-\mu(2r-1))^2(\mu(2r-1)+(1-r))^2},$$

which then implies

$$\begin{aligned} H'(\mu) &= F_{\bar{k}}(1-\mu_0)^2\Delta W \frac{(2r-1)^2(1-2\mu)r(1-r)}{(r-\mu(2r-1))^2(\mu(2r-1)+(1-r))^2} = \\ &= F_{\bar{k}}(1-\mu_0)^2\Delta W \frac{(2r-1)^2(1-2\mu)}{r(1-r)\left(1+\mu(1-\mu)\left(\frac{r^2+(1-r)^2}{r(1-r)}-2\right)\right)^2}. \end{aligned} \tag{C.4}$$

The resulting derivative is a decreasing function of μ, with a zero at $\mu = 0.5$.
If $\mu \geq 0.5$, then $H'(\mu) \leq 0$. If $\mu < 0.5$, then $H'(\mu) > 0$, and it is maximized out at μ_1. Therefore, we can bound $H'(\mu)$ on the range of $\mu \in (\mu_1, 0.5)$ by setting $H'(\mu_1) < 1$.

Substituting the expression for μ_1 into the expression for $H'(\mu)$, given in $(C.4)$, and noting that $\mu_1(1-\mu_1)$ simplifies to $\frac{\tilde{c}r(1-r)}{(2r-1)(1-r-\tilde{c}(2r-1))}$, we obtain

$$\begin{aligned} H'(\mu) &< H'(\mu_1) = F_{\bar{k}}(1-\mu_0)^2\Delta W \frac{\frac{(2r-1)^2}{r(1-r)}\sqrt{\frac{(1-r)(2r-1)-\tilde{c}}{(2r-1)(\tilde{c}+1-2\tilde{c}r-r)}}}{\left(1+\frac{\tilde{c}r(1-r)}{(2r-1)(1-r-\tilde{c}(2r-1))}\left(\frac{r^2+(1-r)^2}{r(1-r)}-2\right)\right)^2} = \\ &= \bar{f}(1-\mu_0)^2\Delta W \frac{(2r-1)^2}{r(1-r)}\sqrt{\frac{(1-r)-\tilde{c}/(2r-1)}{(1-r-\tilde{c}(2r-1))}} / \left(\frac{1-r}{(1-r-\tilde{c}(2r-1))}\right)^2 < 1, \end{aligned}$$

where $\bar{f} = \sup_{k\in[0,1]} F'(k)$, and the last inequality is satisfied by the premise.

To summarize, we found that $H(\mu)$ is weakly decreasing in the entire range of $\mu \in (0, \bar{\mu})$ if $\tilde{c} > (1-r)(2r-1)$. It is also weakly decreasing in the range of $\mu \in (0.5, \bar{\mu})$ if $\tilde{c} \leq (1-r)(2r-1)$. In all cases, $H'(\mu) < 1$, which ensures that equation $\mu = H(\mu)$ has exactly one solution.

It follows that the equilibrium exists, and it is unique. □

D Proof of Proposition 2

Consider a regulation that directly lowers f_B and does not affect any parameters. To understand marginal changes in $\bar{k}$, we differentiate (10) with respect to f_B and evaluate it at the original equilibrium: $\frac{\partial \bar{k}^*}{\partial f_B}\Big|_{f_B=f_B^*} = (1-\mu_0)\left[-\Delta W \Delta \Pr^* (1-r) + c + \frac{\partial \Delta \Pr^*}{\partial f_B}(r-(1-r) f_B^*) \Delta W\right] < 0$. This inequality follows from the fact that $(1-r)\Delta W \Delta \Pr(\mu) = c$ in the original equilibrium and $\frac{\partial \Delta \Pr^*}{\partial f_B} < 0$. It follows that $\bar{k}$ increases. Because $F(\bar{k}) + (1-F(\bar{k}))\mu_0$ increases in $\bar{k}$, condition (14) implies the same qualitative response in μ^*.

Next consider changing parameters that directly enter the rating decision. Substituting for prices into the indifference condition (1) obtains $(1-r)\Delta W \Delta \Pr(\mu) = c$. Note that $\Delta \Pr(\mu)$ decreases in $f_B(\mu)$. Consider an increase in c or r, or a decrease in ΔW that raise $\Delta \Pr(\mu)$ and lower $f_B(\mu)$. Note this condition will continue to hold exactly as long as f_B remains interior, i.e. for small parameter changes. Substituting it into (10) obtains $\bar{k} = (1-\mu_0)\frac{c(2r-1)}{1-r}$. It follows that $\bar{k}^*$ is independent of ΔW but increases with an increase in c or r. Because $F(\bar{k}) + (1-F(\bar{k}))\mu_0$ increases in $\bar{k}$, condition (14) implies the same qualitative response in μ^*. □

E Proof of Lemma 2

Defining H as the right hand side of condition (11), $\mu^*(r) = H(\mu^*(r), r)$, we obtain

$$\frac{\partial \mu^*}{\partial r} = \frac{H_r}{1-H_\mu}.$$

and we showed that $1-H_\mu > 0$. Therefore, the sign of $\frac{\partial \mu^*}{\partial r}$ is determined by the sign of H_r.

Recalling the definition of H,

$$H(\mu, r) = F(\bar{k}(\mu, r)) + (1-F(\bar{k}(\mu, r)))\mu_0,$$

we see that $H(\mu, \cdot)$ is increasing in r if and only if $\bar{k}(\mu, \cdot)$ is increasing in r. Recalling the expression for the marginal screener,

$$\begin{aligned} \bar{k}(\mu, r) &= (1-\mu_0) dR(\mu, r) \\ &= (1-\mu_0)\{(r-(1-r) f_B(\mu, r))\Delta W \Delta \Pr(\mu, r) - (1-f_B(\mu, r))c\}, \end{aligned} \tag{E.1}$$

we see that r enters through two channels. An increase in the rating precision directly increases the payoff to screening by increasing the probability that holders of high quality assets will receive a good rating and sell their assets at a premium and by decreasing the probability that holders of poor quality assets will receive a good rating in error and sell at a premium. There is also an indirect effect working through f_B which influences the actual premium paid on a highly rated asset. There are two cases to consider.

Case 1. Suppose that $f_B \in (0,1)$. Then $\Delta \Pr = \frac{c}{\Delta W(1-r)}$. This means that rating informativeness and hence the premium paid on high quality assets also increase in r. Both effects work in the same direction. Formally, we substitute for $\Delta \Pr$ into $(E.1)$ to obtain $\bar{k} = (1-\mu_0)\frac{2r-1}{1-r}c$, which is clearly increasing in r. Hence, $\frac{\partial \bar{k}^*}{\partial r} > 0$ and $\frac{\partial \mu^*}{\partial r} > 0$.

Case 2. Suppose that $f_B \in \{0,1\}$. Then f_B is constant in the neighborhood of μ^*, and therefore

$$\frac{\partial (R_G - R_B)}{\partial r} = (1+f_B)\Delta W \Delta \Pr + (r-(1-r) f_B)\Delta W \frac{\partial \Delta \Pr}{\partial r} > 0,$$

which implies that $\frac{\partial \bar{k}^*}{\partial r} > 0$ and $\frac{\partial \mu^*}{\partial r} > 0$. □

F Rating Strategies Under Certified Review

Lemma. *Rating Strategies Under Certified Review (for a fixed μ).*
For a given measure of resource allocation $\mu \in (0,1]$, we have $f_G = 1$ and f_B is summarized as

$$f_B^{cr}(\mu) = \begin{cases} 1 & \tilde{c} < \kappa(\mu) \\ f_B^{mix,cr}(\mu) \in (0,1) & \text{if } \kappa(\mu) \leq \tilde{c} < 1, \end{cases}$$

where the mixed rating strategy $f_B^{mix,cr}(\mu)$ is a solution to the indifference condition (18)[15] and $\kappa(\mu) = \frac{\mu r(1-r)}{[\mu r + (1-\mu)(1-r)][\mu(1-r)+(1-\mu)r]}$.

Proof

In light of $r > 0.5$, the rating decision rules imply that $f_G \geq f_B$, and we consider the space of parameters that imply $f_G = 1$. We first rule out the case of $f_B = 0$. Suppose that $f_B = 0$. The beliefs expressions (21) - (23) then imply that $\Pr_{G|GR} = \Pr_{G|BR} = 1$ and $\Pr_{G|NR} = 0$. Substituting these into asset prices, we get $P_{GR} = P_{BR} = W_G$ and $P_{NR} = W_B$. Substituting for these prices into (18), we see that it is optimal to rate poor quality assets as long as $\Delta W > c$, which holds by Assumption 1. This implies a contradiction.

The remaining cases are: (a) $f_G = f_B = 1$ and (b) $f_G = 1$ and $f_B \in (0,1)$. Both cases imply $\Pr_{G|NR} = 0$ and therefore $P_{NR} = W_B$.

Case a For both types of assets to be rated, it must be the case that $P_{GR} + (1-r)P_{BR} > W_B + c$ and $(1-r)P_{GR} + rP_{BR} > W_B + c$. The latter condition is sufficient to ensure that both hold. Substituting for prices and beliefs in that condition and using $f_B = 1$ in the resulting expression, we obtain

$$\tilde{c} < \frac{\mu r(1-r)}{[\mu r + (1-\mu)(1-r)][\mu(1-r) + (1-\mu)r]}.$$

Case b The indifference condition (18) holds. Substituting for prices and beliefs, we obtain

$$\frac{(1-r)\mu r}{\mu r + (1-\mu) f_B (1-r)} + \frac{(1-r)\mu r}{\mu(1-r) + (1-\mu) f_B r} = \tilde{c}. \tag{F.1}$$

The mixed strategy f_B^{mix} is the positive root of the above expression. Setting $f_B^{mix} > 0$ simplifies to $\tilde{c} < 1$, while setting $f_B^{mix} < 1$ simplifies to $\tilde{c} > \frac{\mu r(1-r)}{[\mu r + (1-\mu)(1-r)][\mu(1-r)+(1-\mu)r]}$.

Noting that $\frac{\mu r(1-r)}{[\mu r + (1-\mu)(1-r)][\mu(1-r)+(1-\mu)r]}$ equals 0 at $\mu = 0$ and increases in μ in the interval $\mu \in (0,1)$, this lemma allows us to characterize the shape of $f_B(\mu)$ under certified review. For low μ, $f_B(\mu) \in (0,1)$. As μ increases, f_B switches to 1 and stays there. For all $\mu \in (0,1]$, we have $f_B > 0$, which we know implies $f_G = 1$, and therefore no additional restriction is needed to guarantee that $f_G = 1$. □

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[15] $f_B^{mix} = \mu \frac{(1+2\tilde{c})\left(r-r^2\right) - \tilde{c} + \sqrt{10\tilde{c}r^2 - (16\tilde{c}+2)r^3 + (8\tilde{c}+1)r^4 + 4\tilde{c}^2\left(r^2-r\right) + (\tilde{c}-r)^2}}{2\tilde{c}r(1-\mu)(1-r)}$.

G Proof of Proposition 4

Comparison of Certified Review to the Benchmark Model

To show that $\mu^*_{cr} \leq \mu^*$, it suffices to show that $H^{cr}(\mu) \leq H(\mu)$. Because $H(\mu)$ increases in $\bar{k}(\mu) = (1-\mu_0)\,\Delta R(\mu)$, it suffices to show that

$$\Delta R(\mu) \geq \Delta R^{cr}(\mu).$$

We will drop the dependence of quantities and prices on μ for notational clarity. We will employ the following expressions from the benchmark model: ΔR given in (13) and ΔP given in (12). The relevant quantities for the certified review economy are:

$$\begin{aligned}
\Delta R^{cr} &= \left(r-(1-r)\,f_B^{cr}\right)P_{GR}^{cr} + \left(1-r-f_B^{cr}r\right)P_{BR}^{cr} - \left(1-f_B^{cr}\right)P_{NR}^{cr} - c\left(1-f_B^{cr}\right),\\
P_{GR}^{cr} &= \frac{\mu r}{\mu r+(1-\mu)f_B^{cr}(1-r)}\Delta W + W_B,\\
P_{BR}^{cr} &= \frac{\mu(1-r)}{\mu(1-r)+(1-\mu)f_B^{cr}r}\Delta W + W_B,\\
P_{NR}^{cr} &= W_B.
\end{aligned}$$

It is clear from Lemma 1 and appendix F that $f_B^{cr}(\mu) \geq f_B(\mu)$. Hence, we have to consider three cases.

Case 1. $f_B(\mu)\,,\, f_B^{cr}(\mu)$ are both mixed.

In the benchmark economy, $\triangle R = c\frac{2r-1}{1-r}$, obtained by substituting from the indifference condition (1) into ΔR.

In the certified review economy,

$$\begin{aligned}
\triangle R^{cr} &= (2r-1)\left(P_{GR}^{cr} - P_{BR}^{cr}\right)\\
&= (2r-1)\,\Delta W\left[\frac{\tilde{c}}{(1-r)} - \frac{\mu}{\mu(1-r)+(1-\mu)f_B^{cr}r}\right],
\end{aligned}$$

obtained by substituting from the indifference condition (18) into ΔR^{cr}.

It follows that $\triangle R^{cr} < \triangle R$ because $\frac{\mu}{\mu(1-r)+(1-\mu)f_B^{cr}r} > 0$.

Case 2. $f_B(\mu) = f_B^{cr}(\mu) = 1$.

In the benchmark economy, $\triangle R = (2r-1)\left(\frac{\mu r}{\mu r+(1-\mu)(1-r)} - \frac{\mu(1-r)}{\mu(1-r)+(1-\mu)r}\right)\Delta W$, obtained by substituting for prices into $\triangle R$ and using $f_B = 1$.

In the certified review economy, $\triangle R^{cr} = (2r-1)\left[\frac{\mu r}{\mu r+(1-\mu)(1-r)} - \frac{\mu(1-r)}{\mu(1-r)+(1-\mu)r}\right]\Delta W$, obtained by substituting for the relevant prices into $\triangle R^{cr}$ and using $f_B^{cr} = 1$.

It follows that $\triangle R = \triangle R^{cr}$.

Case 3. $f_B(\mu)$ is mixed and $f_B^{cr}(\mu) = 1$.

We already showed that $\triangle R = c\frac{2r-1}{1-r}$ in the benchmark economy (case 1).

We also found the relevant $\triangle R^{cr}$ (case 2), which is a symmetric inverted parabola centered at 0.5.

Define constants μ_1, μ_2, μ_3 as follows: μ_1 and μ_2 denote the lower and higher solutions of $f_B^{mix} = 1$ and μ_3 solves $f_B^{mix} = 0$ in the benchmark economy.

If $c > (1-r)(2r-1)\Delta W$ then the relevant range is $\mu \in (0, \mu_3)$. In this range of μ, $\triangle R^{cr}$ is maximized at 0.5 where it is valued at $(2r-1)^2 \Delta W$. It follows that

$$\triangle R = \frac{c(2r-1)}{(1-r)} > (2r-1)^2 \Delta W = \max_{\mu \in (0,\mu_3)} \triangle R^{cr} \geq \triangle R^{cr}.$$

If instead $c \leq (1-r)(2r-1)\Delta W$, then this case is in the range of $\mu \in (0, \mu_1) \cup (\mu_2, \mu_3)$. In this range, $\triangle R^{cr}$ is maximized at μ_2 and μ_3 where it is valued at $c\frac{2r-1}{1-r}$. It follows that

$$\triangle R^{cr} \leq \max_{\mu \in (0,\mu_1)\cup(\mu_2,\mu_3)} \triangle R^{cr} = c\frac{2r-1}{1-r} = \triangle R.$$

Comparison of Certified Review to Mandatory Ratings

Next, we need to show that $\mu^*_{mr} < \mu^*_{cr}$. It suffices to prove that the operator H is higher under certification. This amounts to showing that $\triangle R$ is higher under certification. Note that under mandatory ratings, $\triangle R = (2r-1)\Delta W \Delta Pr|_{f_B=1}$.

Moreover, $R^{cr}_G - R^{cr}_B$ is minimal when $f_B = 0$. At $f_B = 0$, we have $P^{cr}_{NR} = W_B$, $P^{cr}_{GR} = P^{cr}_{BR} = W_G$. Therefore $R^{cr}_G - R^{cr}_B = W_G - c$. Since $\Delta Pr|_{f_B=1} \leq 1$, the inequality follows from the assumption $W_G - c \geq (2r-1)\Delta W$. □

H Proof of Proposition 6

Because τ_c multiplies c and the lump-sum transfer has no effect on banking decisions, it suffices to perform the comparative statics on c. Consider H defined as the right hand side of equilibrium condition (11): $\mu^*(c) = H(\mu^*(c), c)$. We obtain

$$\frac{\partial \mu^*}{\partial c} = \frac{H_c}{1 - H_\mu}.$$

We also showed that $1 - H_\mu > 0$. Therefore, the sign of $\frac{\partial \mu^*}{\partial c}$ is determined by the sign of H_c.

Recalling the definition of H,

$$H(\mu, c) = F(\bar{k}(\mu, c)) + (1 - F(\bar{k}(\mu, c)))\mu_0,$$

we see that $H(\mu, \cdot)$ is increasing in c if and only if $\bar{k}(\mu, \cdot)$ is increasing in c.

Recalling the expression for the marginal screener,

$$\begin{aligned} \bar{k}(\mu, c) &= (1-\mu_0)(R_G(\mu, c) - R_B(\mu, c)) \\ &= (1-\mu_0)\{(r - (1-r)f_B(\mu, c))\Delta W \Delta \Pr(\mu, c) - (1-f_B)c\}, \end{aligned}$$

we see that c enters through several channels, directly by raising the cost of high quality baskets and indirectly through $f_B(\mu, c)$ and $\Delta \Pr(\mu, c)$. There are three cases to consider.

Case 1. Suppose that $f_B = 0$. Then f_B remains constant at 0 in the neighborhood of μ^*, and we have

$$\bar{k} = (1-\mu_0)[(2r-1)\Delta W \Delta \Pr - c],$$

which is strictly decreasing in c, so the result follows.

Case 2. Suppose $f_B \in (0,1)$. Then $\Delta W \Delta \Pr = \frac{c}{(1-r)}$. Substituting into the above expression, we obtain $\bar{k} = (1-\mu_0)\frac{2r-1}{1-r}c$, which is increasing in c. The result follows.

Case 3. Suppose that $f_B = 1$. Then f_B remains constant at 1 in the neighborhood of μ^*, and we have

$$\bar{k} = (1-\mu_0)(2r-1)\Delta W \Delta \Pr .$$

Because $\Delta \Pr$ depends on c only through f_B, which is fixed at 1, we have that $\bar{k}$ is independent of c. □

I Proof of Proposition 8

Step 1. Recall from Section 3.3. that the efficient marginal screener is given by $\bar{k}^{ef} = \min\{(1-\mu_0)\Delta W, 1\}$. To simplify notation, we will drop stars when talking about equilibrium outcomes. In a decentralized equilibrium, the marginal screener is given by $\bar{k} = \min\{(1-\mu_0)\Delta R, 1\}$. Therefore, the policy needs to induce prices that imply $\Delta R = \Delta W$.

Step 2. With such prices, all banks will participate. It suffices to show that the marginal screener $\bar{k}$, whose payoff is $R_G - \bar{k}$, chooses to participate. Indeed, all non-screeners face the same payoff, and the payoff is strictly greater for all other screeners because they face a lower k. The marginal screener will choose to participate if payoff $R_G - \bar{k} \geq 0$. This is implied by $\bar{k} = (1-\mu_0)\Delta R$ after substituting for $R_B \geq 0$, which we know holds due to our parametric assumption on the pool of projects (Assumption 1).

Step 3. We now derive the tax/subsidy scheme that implements the desired ΔR. Consider a tax rate τ_{NR} applied to transactions of unrated loans, and a subsidy rate τ_{GR} applied to transactions of highly rated loans. Suppose in the economy with no taxes, we have $f_B = 0$. From Lemma 1, we can see that as taxes and subsidies increase, f_B increases. Our preference is to suppose the benchmark economy is in the empirical relevant case where $f_B \in (0,1)$. We show that the policy has no effect on ΔR if a mixed strategy is played. In this region, the indifference condition (1) implies $\Delta R = c\frac{2r-1}{1-r}$, which is independent of the tax level. In other words, any tax change intended to increase the effective premium $(1+\tau_{GR})P_{GR} - (1-\tau_{NR})P_{NR}$ is offset by an increase in f_B.

However, once $f_B = 1$ is reached, further increases in tax and subsidy moves the economy towards efficiency. Substituting for $f_B = 1$ we have

$$\Delta R = (2r-1)[(1+\tau_{GR})P_{GR} - (1-\tau_{NR})]P_{NR},$$

with $P_{GR} = \frac{\mu r}{\mu r + (1-\mu)(1-r)}\Delta W + W_B$ and $P_{NR} = \frac{\mu(1-r)}{\mu(1-r)+(1-\mu)r}\Delta W + W_B$. In order to attain full efficiency ($\Delta R = \Delta W$) and satisfy the policy maker's budget constraint, (τ_{GR}, τ_{NR}) must satisfy the following two conditions:

$$\min\{(1-\mu_0)\Delta W, 1\} = (1-\mu_0)(2r-1)[(1+\tau_{GR})P_{GR} - (1-\tau_{NR})P_{NR}], \quad (I.1)$$

$$\tau_{GR}\mu r P_{GR} \leq \tau_{NR}P_{NR}(1-\mu r). \quad (I.2)$$

Step 4. For a policy to be feasible, we must have $\tau_{GR}, \tau_{NR} \in (0,1)$. The bound is given by setting $\tau_{NR} = 1$. Therefore, obtaining τ_{GR} from equation (I.1) and imposing inequality (I.2) we conclude that an efficient allocation can be achieved if the following parametric condition holds:

$$\frac{\min\{\Delta W, (1-\mu_0)^{-1}\}r\mu^{ef}}{2r-1} \leq \min\{\Delta W, (1-\mu_0)^{-1}\}(Pr_{GR} - Pr_{NR})r\mu^{ef} + Pr_{NR}, \quad (I.3)$$

where $Pr_{GR} = \frac{\mu^{ef}r}{\mu^{ef}r+(1-\mu^{ef})(1-r)}$, $Pr_{NR} = \frac{\mu^{ef}(1-r)}{\mu^{ef}(1-r)+(1-\mu^{ef})r}$ and $\mu^{ef} = F(k^{ef}) + (1-F(k^{ef}))\mu_0$.

For the inequality to be satisfied, ΔW cannot be too high. When is ΔW is high, we go to the case where $\mu^* = 1$ and $\min\{\Delta W, (1-\mu_0)^{-1}\} = (1-\mu_0)^{-1}$. The inequality becomes $\frac{r}{2r-1} \leq 1-\mu_0$, which is never satisfied.

Step 5. Note that f_G is non-decreasing in $\tau' s$ and, therefore, no additional conditions are needed to ensure $f_G = 1$ under this policy scheme. □

J A Note on Optimal Policy: the Mechanism Design Approach

This note formalizes the claim made in Section 5.2.. We show that all outcomes attainable by a general mechanism which conditions payoffs on declared k's can also be achieved by a pooling mechanism which offers only two contracts: one for the screeners and one for the non-screeners. The latter can be implemented with the tax/subsidy policy studied in Proposition 8.

Definition 1 *A mechanism is given by* $\{P_{GR}(k), P_{NR}(k)\} : [0,1] \Longrightarrow \mathbb{R}^2$*, indicating banks' payoffs to trading a highly rated and an unrated asset, conditional on declaring a screening cost* k*.*

This mechanism can be equivalently specified in terms of $\{R_G(k), R_B(k)\} : [0,1] \longrightarrow \mathbb{R}^2$ indicating payoffs associated with having made good/bad loans. The equivalence is given by $R_G(k) = rP_{GR}(k) + (1-r)P_{NR}(k) - c - 1$ and $R_B(k) = (1-r)P_{GR}(k) + rP_{NR}(k) - f_B c - 1$. We want to show that it is without loss of generality that we can restrict attention to a pooling mechanism, where all banks are offered the same menu (R_G, R_B).

Proposition
Any outcome attained by the general mechanism can be also attained by a pooling mechanism that offers the same menu (R_G, R_B) *to all banks, without changing the implementation cost to the policy maker.*

Proof
Step 1. First, we show we can restrict attention to a simpler mechanism with a menu of two options, one designed as a recommendation to screen, and another as a recommendation not to screen: $(R_G^S, R_B^S), (R_G^{NS}, R_B^{NS})$.

By additive separability of screening costs, any mechanism $\{R_G(k), R_B(k)\}$ that induces a bank of type k to screen also induces a bank of type $k' < k$ to screen. Analogously, if a bank of type k does not screen, any bank of type $k' > k$ will not screen. Moreover, incentive compatibility implies that all screening (non-screening) banks will select the same contract regardless of k.

Step 2. Next, we want to show we can further restrict attention to a pooling mechanism (R_G, R_B). Consider the mechanism $(R_G^S, R_B^S), (R_G^{NS}, R_B^{NS})$. There is a $\hat{k}$ such that

$$R_G^S - [\mu_0 R_G^{NS} + (1-\mu_0) R_B^{NS}] = \hat{k}.$$

Banks choose the recommendation to screen iff $k \leq \hat{k}$.

It is clear that any pooling mechanism $(\hat{R}_G, \hat{R}_B)$ such that

$$(1-\mu_0)(\hat{R}_G - \hat{R}_B) = \hat{k}$$

induces the same behavior.

Step 3. Moreover, the pooling mechanism can be chosen in a way that implies the same implementation cost for the planner. The mechanism $(R_G^S, R_B^S), (R_G^{NS}, R_B^{NS})$ costs

$$\begin{aligned} F(\hat{k})R_G^S + (1-F(\hat{k}))(\mu_0 R_G^{NS} + (1-\mu_0)R_B^{NS}) &= F(\hat{k})R_G^S + (1-F(\hat{k}))(R_G^S - \hat{k}) \\ &= R_G^S - (1-F(\hat{k}))\hat{k}, \end{aligned}$$

while the pooling mechanism costs $\hat{R}_G - (1 - F(\hat{k}))\hat{k}$. In order to keep the implementation cost the same, we choose (R_G, R_B) that satisfy $R_G = R_G^S$, and $(1 - \mu_0)(R_G^S - R_B) = \hat{k}$. $\square$