Does Financial Innovation Increase Inequality?: A Competitive Search Approach*

BongGeun Choi†, Hyun Lee‡

This Version: June 14, 2017

Abstract

In this paper, we study the impact of financial innovation on wealth distribution and welfare, using a novel framework that embeds banking sector into the Aiyagari (1994) incomplete market heterogeneous agent model. The banking sector consists of the savings banks that have direct access to household savings but has no access to firms, and investment banks that can directly invest in firms but do not have direct access to household savings. Investment banks are heterogeneous in terms of their intermediation skills and their level of skills is private information. This creates an adverse selection problem in the interbank market and we assume that the market has a competitive search structure à la Guerrieri, Shimer, and Wright (2010). We first show that our model endogenously generates three different interest rates: savings rate, borrowing rate, and the rate of return on equity. Then, we show that the impact of financial innovation on the welfare of heterogeneous households will depend on whether the innovation is affecting the intensive or the extensive margin of the adverse selection problem. This is because the two margins have an opposite effect on the net interest spread.

JEL Classification: E13, E21, E44

Keywords: financial innovation, competitive search, financial friction, adverse selection, heterogeneous agent model, welfare, wealth inequality

---

*We would like to thank Rob Shimer and Harald Uhlig for their valuable inputs at the early stages of the project. We also would like to thank Junsang Lee, and participants at the 2017 Asian Meeting of the Econometric Society (Chinese University of Hong Kong), 2017 China Meeting of the Econometric Society (Wuhan University), International Conference on Recent Trends in Economics (Sungkyunkwan University), Fall 2016 Midwest Macro Meeting (Kansas City Fed), 51st Annual Conference of the Canadian Economics Association, and 2017 MEA Annual Meeting (Cincinnati, OH) for their thoughts and comments.

†Department of Economics, University of Chicago, 5757 S. University Ave, Chicago, IL 60637; webpage: http://b-choi.com/; email: bchoi@uchicago.edu.

‡Department of Economics, University of Connecticut, 365 Fairfield Way, Unit 1063, Storrs, CT 06269-1063; webpage: https://sites.google.com/site/paulhyunlee; email: hyun.2.lee@uconn.edu.

1 Introduction

In light of the Great Recession, there has been a renewed interest on analyzing the impact of financial markets on the macroeconomy. To better understand the importance of financial markets, many papers in the literature have incorporated financial frictions to dynamic stochastic general equilibrium (DSGE) models in order to study important issues such as the impact of frictions in the financial market on monetary transmission, optimal monetary policy and/or macroprudential policies, and the impact of financial shocks to the real economy.[1] Another strand of literature have focused on how deregulation led to an explosion of new and complex financial products which ultimately contributed to the recession and on what macroprudential tools should be implemented as a preventive measure.[2] Thus far, the macroeconomic literature has been mostly silent about how financial innovation has the potential to reduce information frictions in the banking sector and what subsequent implications that would have about household welfare and wealth inequality. This paper fill that gap and in doing so, offers a novel way of incorporating financial market and financial friction to a macro model.

In this paper, we develop a novel general equilibrium model that embeds the banking sector into a standard Aiyagari (1994) incomplete-markets economy with heterogeneous households. We then use the model to assess the impact of financial innovation in the banking sector on household welfare and wealth inequality. We model the banking sector as a financial intermediary between the households and the firms, composed of savings banks and investment banks. The savings banks have direct access to household savings but do not have direct access to firms. On the other hand, the investment banks can directly invest in firms but do not have the direct access to the household savings. Hence, the savings banks and the investment banks have the incentive to meet in an interbank market so that the

[1] Gertler and Kiyotaki (2010), Iacoviello and Neri (2010), Meh and Moran (2010), Gerali, Neri, Sessa, and Signoretti (2010), Carlstrom, Fuerst, and Paustian (2010), Gertler and Karadi (2011), Christiano, Trabandt, and Walentin (2011), Calza, Monacelli, and Stracca (2013), Brunnermeier and Sannikov (2014), and Cúrdia and Woodford (2016) are some of the examples.

[2] Refer to Hanson, Kashyap, and Stein (2011), Hoshi (2011), and Galati and Moessner (2013) for details.

aggregate savings from the household can be intermediated to the firms.

The key complication in the interbank market is that the investment banks are heterogeneous in terms of their intermediation skills and that this is private information. This creates an adverse selection problem in the interbank market. To simplify our analysis, we assume that the interbank market has a competitive search structure à la Guerrieri, Shimer, and Wright (2010) and use their key result that a unique separating equilibrium exists under this setting. In particular, the savings banks in our model freely enter the interbank market and bilaterally match with the investment banks by posting incentive compatible contracts specifically designed to screen and attract an investment bank with specific level of intermediary skills. We show that the inclusion of the banking sector with information friction endogenously generates three different interest rates—rate of return on household savings, rate of return on household lending (the interest on household borrowing), and the rate of return on equity—and we quantitatively show that decoupling the rate of return on household savings and the rate of return on household lending has meaningful implications about household welfare and inequality.

We compartmentalize the adverse selection problem in our model to two different margins: the extensive and the intensive. The extensive margin of our adverse selection deals with the relative mass of "good" investment banks compared to the mass of "bad" investment banks. The intensive margin of our adverse selection deals with the magnitude of the skill gap across the different types of investment banks. We then use the model to assess the macroeconomic effect of two types of financial innovation. First, we analyze the effect of financial innovation undertaken by the industry leader. We interpret this financial innovation to be of the type that makes the "good" investment banks even better than before compared to its worse counterparts. In other words, the magnitude of the adverse selection problem increases through its intensive margin. We show that this decreases both the rate of return on household savings and the net interest spread. Overall, such financial innovation decreases household welfare and increases wealth inequality. If instead, if the financial innovation is undertaken by the industry follower, we would obtain the exact opposite: welfare increases and wealth inequality decreases.

Second, we analyze the effect of financial innovation that causes technological diffusion from "good" banks to "bad" banks, thus decreasing the magnitude of the adverse selection problem through the extensive margin. We find that this increases the rate of return on household savings but decreases the net interest spread. Overall, household welfare increases and wealth inequality decreases.

The key result from our welfare analysis is that even though reducing adverse selection—regardless of whether it originates from the extensive or the intensive margin— categorically improves the welfare of all households, the magnitude of the welfare change is quite heterogeneous across households and is very much dependent on which of the two margins is being affected by the financial innovation. If the financial innovation reduces the overall adverse selection through the intensive margin, the welfare of the households with low level of wealth increase less in magnitude compared to their richer counterparts. On the other hand, if the financial innovation is reducing the adverse selection problem through the extensive margin, the welfare of the poor households increase more relative to their richer counterparts. This is because each of the two margins have opposite effect on the net interest spread, which is the difference between the rate on household borrowing and the return on household savings. We show that an improvement of adverse selection through the intensive margin increases the net interest spread, which will hamper the ability of the poor households to borrow from the savings bank. However, this effect is of second order compared to the first order effect of increasing the rate of return on household savings, and that causes the overall direction of the welfare change to be positive for all households. On the other hand, when the adverse selection is improved through the extensive margin, the net interest spread decreases, which in turn allows the poor households to borrow at a lower rate. In this case, the second order effect reinforces the first order effect, which is why the poor households gain much more compared to their richer counterparts.

The key contribution of our paper is that we fill the gap in the literature by quantitatively assessing the impact of financial innovations on household welfare and wealth inequality. On the topic of financial innovation, the macro literature has primarily focused on how deregulation led to an explosion of new and complex financial products which ultimately contributed to the recession and on what macroprudential tools should be implemented as a preventive measure (Hanson, Kashyap, and Stein (2011), Hoshi (2011), and Galati and Moessner (2013)). Other papers in the literature have focused on the diffusion process of financial innovations and the consequences of innovation for firm profitability (Frame and White (2004) and Lerner and Tufano (2011)). The papers that do address the impact of financial innovation on welfare either focus on how it empirically increased the value of our economy through various channels such as increasing venture capital and leveraged buyout funds to finance businesses (Allen (2012)) or examine the impact on welfare of financial innovation in the form of introducing a new asset to an incomplete market economy (Elul (1999)). In this paper, we take a different approach and define financial innovation to be anything that impacts the technology (or skill) of the investment banks to engage in efficient corporate lending. The changes to their skill levels and/or the distribution of the skill across the heterogeneous investment banks will impact the magnitude of information friction in the banking sector, which subsequently has impact on wealth distribution and welfare.

The second contribution of this paper is that our model endogenously generates three different interest rates—rate of return on household savings, rate of return on household lending (the interest on household borrowing), and the rate of return on equity—in a heterogeneous agent model and is able to generate a Gini coefficient on wealth distribution that is much higher than the standard Aiyagari (1994) model. We also quantitatively show why it is important to model the rate of return on household lending to be different from the rate of return on household savings. As surveyed by De Nardi (2015), there have been many variations of the Aiyagari (1994) model, yet ours—to our knowledge—is the first to generate the aforementioned three different endogenous rates. This is significant not only because it allows us to match the empirical fact that these three rates each have a different value in data, but also because the model is able to solve the equity premium puzzle without using the recursive utility. In addition, our paper adds yet another mechanism to a long list (preference heterogeneity, transmission of bequests and human capital across generations, entrepreneurship, and high earnings risk for the top earners) that helps the heterogeneous agent model to better match the magnitude of wealth inequality observed in the data.

This paper is related to the extensive literature that incorporates financial frictions into DSGE models to better analyze the interaction between the macroeconomy and the financial sector. The two most popular approaches in this literature is to use collateral constraints (as in Kiyotaki and Moore (1997) and Iacoviello (2005)) or costly state verification (as in Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), and Bernanke, Gertler, and Gilchrist (1999)) as the microfoundation for generating the financial friction. Our paper is related to the latter approach in that we also create an endogenous wedge between the lending rate and the rate of return on savings, but we do so using adverse selection with competitive search in the banking sector instead of costly state verification. Our use of competitive search to model the interbank market follows the convention that the literature has established in describing the over-the-counter (OTC) markets with a competitive search framework, such as in Duffie, Gârleanu, and Pedersen (2005), Vayanos and Weill (2008), Lagos and Rocheteau (2009), and Afonso and Lagos (2015). Last but not least, our paper is also related to the extensive literature on using contracts as screening device to deal with adverse selection (Rothschild and Stiglitz (1976); Rosenthal and Weiss (1984); Bisin and Gottardi (2006); Lester, Shourideh, Venkateswaran, and Zetlin-Jones (2017)) and various papers that utilize competitive search as the means to screen across different types (Guerrieri, Shimer, and Wright (2010); Kim (2012); Guerrieri and Shimer (2014); Guerrieri and Shimer (2015); Chang (2012)).

The rest of the paper is as follows. In Section 2, we describe the model and its recursive stationary equilibrium. We also discuss how we compute the solution of the model. In

Section 3, we conduct a comparative statics exercise to understand how the model behaves with respect to each of the two margins of adverse selection. In Section 4, we calibrate a benchmark specification using moment matching and then do a series of welfare analysis. The last section concludes.

2 Model

In this section, we describe our model. First, we describe in detail the problems faced by the household and the firm. Then, we describe the banking sector and then describe the relationship between savings banks and investment banks. Finally, we characterize the equilibrium of the model.

2.1 Household

Let c, a, l denote household's consumption, assets, and the labor endowment. As in Aiyagari (1994), there is a continuum of atomless households that are ex-ante homogeneous but ex-post heterogeneous, depending on the history of realizations of idiosyncratic shocks. Specifically, we assume that households are subject to labor endowment shocks (equivalently, earnings) in the following form:

$$\log l' = \rho \log l + \sigma \left(1-\rho^2\right)^{\frac{1}{2}} \epsilon, \qquad \epsilon \sim N(0,1)$$

The labor endowment in the next period equals l', the coefficient of variation equals σ, and the serial correlation coefficient equals ρ. In other words, we assume that the logarithm of the labor endowment shock is first-order autoregressive. Households have a constant relative risk aversion utility of the form

$$u(c) = \frac{c^{1-\mu}}{1-\mu}$$

Let β be the discount factor. All households receive endogenously determined market wage W from their labor. As for assets a, savers—households with positive a—receive a gross rate of return R^A on their asset holdings, whereas borrowers—households with negative a—must payback at the gross rate of interest R^B. Both R^A and R^B will be endogenously determined at the general equilibrium.

Hence, the household that starts the period with a asset and l labor endowment solves the following Bellman equation:

$$V(l,a) = \max_{c\geq 0,a'} u(c) + \beta \mathbb{E}\left[V(l',a')|l\right] \tag{1}$$

subject to

$$\begin{aligned} c + a' &= \begin{cases} Wl + R^A a & \text{if } a \geq 0 \\ Wl + R^B a & \text{if } a < 0 \end{cases} \\ \log l' &= \rho \log l + \sigma \left(1-\rho^2\right)^{\frac{1}{2}} \epsilon, \qquad \epsilon \sim N(0,1) \\ a' &\geq -\phi \end{aligned}$$

where $\phi > 0$ is the natural borrowing limit as in Aiyagari (1994).

2.2 Firm

There is a unit measure of a continuum of homogeneous firms which have access to the following common CRS technology:

$$Y = ZF(K,L)$$

where K is the capital input, L is the labor input, and Z is the total factor productivity. Letting δ be the capital depreciation rate, the firm's profit maximization problem is the following:

$$\Pi = \max_{K,L} \left\{ZF(K,L) + (1-\delta)K - RK - WL\right\} \tag{2}$$

where $R \neq R^A$ is the endogenously determined market rental rate of capital.

2.3 Banking Sector

There are two types of banks: savings banks and investment banks. There is a unit measure of each of the two types and both types last for only one-period. In other words, in each period, a new set of savings and investment banks are introduced into the economy.

The savings banks are homogeneous and have access to household savings (assets). They funnel a portion of these funds to the investment banks, who have access to firm's investment opportunity. Savings banks do not have direct access to the firms, which implies that investment banks serve as an intermediary between savings banks and firms. On the other hand, investment banks do not have direct access to the households, thereby implying that savings banks act as an intermediary between investment banks and households. Hence, both the savings banks and the investment banks have strong incentives to lend and borrow with each other in the interbank market.

Investment banks are heterogeneous in terms of their investment skills, which can be interpreted as the ability of the investment bank in recovering their investment. Specifically, let $s \in \{0, 1\}$ denote the level of skill in an investment bank, where skill s is drawn from an i.i.d. distribution with $\Pr(\{s = 1\}) = \eta \in (0, 1)$. An investment bank with skill s is able to collect a profit of $g(s) RK$ from the firm, with $g(s) \in [0, 1]$ and $g(0) < g(1)$. They do not have access to households, so their only means of generating a positive payoff is to match up with a savings bank that is willing to intermediate the household savings to them through the interbank market, which will eventually be used to invest in firms.

Savings banks have access to two payoff generating mechanisms. First, they can lend to the household and earn endogenous gross rate of return R^B as long as there are households who find it optimal to borrow. Second, they can participate in the interbank market and purchase investment opportunity from investment banks that it bilaterally matches with via competitive search. Unfortunately, investment banks' type s is private information. As in Guerrieri, Shimer, and Wright (2010), the uninformed savings banks try to attract certain type of investment banks and screen out others through contracts that they post in the interbank market, in the hopes of matching bilaterally with their desired type. Specifically, savings banks—after paying a fixed cost τ—post a menu of contracts $\Xi = \{\xi_s\}_{s\in\{0,1\}}$, where $\xi_s = (p_s, q_s)$ is a specific contract designed to attract investment banks of type s with $p_s \in [0,1]$ denoting the fraction of savings bank's fund spent to purchase type s investment bank's cash flow and $q_s \in [0,1]$ denoting the fraction of type s investment bank's cash flow that the savings bank will receive in return. Once the investment banks observe the menu of contracts Ξ, they choose where to direct their search.[3] As previously mentioned, all the matches between the principals (savings banks) and agents (investment banks) are bilateral, but failing to match is a possibility.

As in Guerrieri, Shimer, and Wright (2010), we assume without loss of generality that each savings bank posts a single contract ξ_s designed to only attract a type s investment bank, rather than the entire menu Ξ offering a different contract to each type s investment bank. Let $\Theta(\xi_s)$ define the market tightness—the principal-agent ratio—which in our case would simply be the measure of savings banks posting contract ξ_s divided by the measure of investment banks applying to ξ_s. We define $\gamma_i(\xi_s)$ to be the share of skill $i \in \{0,1\}$ investment banks among all investment banks that apply to contract ξ_s that is designed to attract the type s investment bank.[4] Let $\Gamma(s) = \{\gamma_0(\xi_s), \gamma_1(\xi_s)\}$ denote the set of all shares, with $\gamma_0(\xi_s) + \gamma_1(\xi_s) = 1, \forall \xi_s \in \Xi$. An investment bank that applies to contract ξ_s faces matching probability of $\mu(\Theta(\xi_s))$, in which the matching function μ is nondecreasing with respect to the market tightness $\Theta(\xi_s)$. Conversely, a savings bank that posts contract ξ_s faces probability of $\frac{\mu(\Theta(\xi_s))}{\Theta(\xi_s)}$ of matching with any investment bank, and conditional on matching, the probability that the investment bank it is matched with is indeed the desired skill type s is $\gamma_s(\xi_s)$.

Let $u_i(p_s, q_s; R, A)$ denote the payoff of a type i investment bank matched with a savings bank offering contract ξ_s, in which A and R are respectively the aggregate household savings

[3] There potentially can be many more contracts, but by revelation principle it is suffice to consider $\Xi = \{\xi(s)\}_{s\in\{0,1\}}$ as long as it is incentive compatible.

[4] For example, $\gamma_0(\xi_1)$ would represent the share of type $s = 0$ investment banks that have applied for the contract designed to attract type $s = 1$ investment bank.

and the return on firm's equity that the investment bank takes as given. After a successful match, the type i investment bank receives a fraction p_s of the household savings A from the savings bank, which is then invested into the firm. After the firm's production, the investment bank is able to extract a cash flow of $g(i)\, Rp_sA$ from the representative firm, of which it is able to keep fraction $(1-q_s)$ as its payoff, while the fraction q_s is paid back to the savings bank. Hence, $u_s(p_s, q_s; R, A)$ takes the following form:

$$u_i(p_s, q_s; R, A) = (1-q_s)\, g(i)\, Rp_sA$$

Let $v_i\left(p_s, q_s; R, R^B, A\right)$ denote the payoff of a savings bank offering contract ξ_s, conditional on a successful match with a type i investment bank, in which it takes R, R^B, and A as given. The savings bank is able to generate payoffs from two sources. First, it collects what it invested through the interbank market in which it gave the matched investment bank a fraction p_s of its asset, in return for a fraction q_s of the cash flow extracted from the firm. Second, they can lend whatever they did not spend on the interbank market—which would be $(1-p_s)\, A$— to the households for additional payoff. Hence, $v_i\left(p_s, q_s; R, R^B, A\right)$ takes the following form:

$$v_i\left(p_s, q_s; R, R^B, A\right) = q_s g(i)\, Rp_sA + R^B(1-p_s)\, A$$

2.4 Optimal Contract in the Interbank Market

Our characterization of the banking sector is very similar to the description of the economy with adverse selection and frictions in competitive search in Guerrieri, Shimer, and Wright (2010). We use their key result that a unique separating equilibrium always exists under mild assumptions, and construct the optimal contracts between the savings banks and the investment banks using their algorithm.

In equilibrium, the savings banks post profit maximizing contract $\xi_s = (p_s, q_s)$ and earn zero profit. Each type s investment bank directs its search toward contract ξ_s. The optimal contract is defined as the following.

Definition 1. Optimal contract in the interbank market consists of the set $\{\bar{U}_0, \bar{U}_1, \Theta, \Gamma, \lambda\}$ with $\bar{U}_s \in R_+$, $\Theta : \Xi \mapsto [0, \infty]$, $\Gamma : \Xi \mapsto \Delta^2$, and λ being a measure on Ξ with support $\Xi^P \subset \Xi$ satisfying

1. Savings Bank's Profit Maximization and Free Entry: $\forall \xi_s \in \Xi$
$$\left[\frac{\mu(\Theta(\xi_s))}{\Theta(\xi_s)} \cdot \left(\sum_{i=0,1} \gamma_i(\xi_s) \cdot \left\{q_s g(i) R p_s A + R^B (1-p_s) A\right\}\right) + \left(1 - \frac{\mu(\Theta(\xi_s))}{\Theta(\xi_s)}\right) R^B A\right] \leq \tau$$
with equality if $\xi_s \in \Xi^P$. The first term of the left hand side of the condition above
$$\frac{\mu(\Theta(\xi_s))}{\Theta(\xi_s)} \cdot \left(\sum_{i=0,1} \gamma_i(\xi_s) \cdot \left\{q_s g(i) R p_s A + R^B (1-p_s) A\right\}\right)$$
represents profit from successfully matching with an investment bank, and the second term
$$\left(1 - \frac{\mu(\Theta(\xi_s))}{\Theta(\xi_s)}\right) R^B A$$
represents profit from failing to match and only engaging in household lending. The sum of these two terms has to be less than or equal to the fixed cost τ of posting the contract ξ.

2. Investment Bank's Optimal Search: $\forall \xi_s \in \Xi$ and $\forall s \in \{0, 1\}$
$$\mu(\Theta(\xi_s)) u_s(p_s, q_s; R, A) \leq \bar{U}_s(R, A)$$
with equality if $\Theta(\xi_s) < \infty$ and $\gamma_s(\xi_s) > 0$, where
$$\bar{U}_s(R, A) = \max_{\xi_s \in \Xi} \mu(\Theta(\xi_s)) \cdot u_s(p_s, q_s; R, A)$$

3. Market Clearing
$$\begin{aligned}
\int_{\Xi^P} \frac{\gamma_1(\xi_s)}{\Theta(\xi_s)} d\lambda(\{\xi_s\}) &\leq \eta \\
\int_{\Xi^P} \frac{\gamma_0(\xi_s)}{\Theta(\xi_s)} d\lambda(\{\xi_s\}) &\leq 1 - \eta
\end{aligned}$$
with equality if $\bar{U}_s > 0$

As in Guerrieri, Shimer, and Wright (2010), the optimal contract described in Definition 1 can be characterized as the solution to the following set of optimization problems. For skill type $s = 0$, consider the following problem:

$$\begin{aligned} \bar{U}_0(R, A) &= \max_{p_0, q_0, \theta_0} \left[\mu(\theta_0) u_0(p_0, q_0; R, A)\right] \\ \text{subject to} & \quad \left[\frac{\mu(\theta_0)}{\theta_0}\left\{q_0 g(0) R p_0 + R^B(1 - p_0)\right\} + \left(1 - \frac{\mu(\theta_0)}{\theta_0}\right) R^B\right] A \geq \tau \end{aligned} \tag{3}$$

The optimization problem (3) chooses market tightness $\theta_0 \equiv \Theta(\xi_0)$ and contract $\xi_0 = (p_0, q_0)$ to maximize the expected profit of skill type $s = 0$ investment bank subject to a savings bank offering contract ξ_0 making non-negative profits.

For skill type $s = 1$, the optimization problem is as follows:

$$\begin{aligned} \bar{U}_1(R, A) &= \max_{p_1, q_1, \theta_1} \left[\mu(\theta_1) u_s(p_1, q_1; R, A)\right] \\ \text{subject to} & \quad \left[\frac{\mu(\theta_1)}{\theta_1} \cdot \left\{q_1 g(1) R p_1 + R^B(1 - p_1)\right\} + \left(1 - \frac{\mu(\theta_1)}{\theta_1}\right) R^B\right] A \geq \tau \\ & \quad \mu(\theta_1) u_0(p_1, q_1; R, A) \leq \bar{U}_0(R, A) \end{aligned} \tag{4}$$

The optimization problem (4) chooses market tightness $\theta_1 \equiv \Theta(\xi_1)$ and contract $\xi_1 = (p_1, q_1)$ to maximize the expected utility of skill type $s = 1$ investment bank, subject to a savings bank offering contract ξ_1 making non-negative profits only when type $s = 1$ investment bank applies, in addition to the incentive compatibility condition that lower type investment banks do not search for this contract.

The solution that solves the optimization problems (3) and (4) is the least-cost separating equilibrium contracts consistent with Definition 1. The proof of this follows the logic laid out in Guerrieri, Shimer, and Wright (2010).

2.5 Recursive Stationary Equilibrium

Here, we define the recursive stationary equilibrium of the model that includes the banking sector partial equilibrium defined in the previous subsection. For the purpose of aggregation and defining the recursive stationary equilibrium of the model, it is necessary to describe the position of individuals across states. Let $\Omega^H(l, a)$ represent the mass of households with labor endowment l and asset a.

The recursive stationary equilibrium of the model consists of the following.

1. **Households' optimization** : Given prices R^A, R^B, and W, the value function $V(l,a)$ is the solution to the household's optimization problem described in equation (1), and $a'(l,a)$ is the associated optimal decision rule with respect to asset next period.

2. **Firm's optimization** : Prices R and W satisfy the optimization problem described in equation (2). The following marginal conditions must hold:

$$R = ZF_K(K,L) + (1-\delta)$$
$$W = ZF_L(K,L)$$

where K and L are aggregate capital and labor, respectively.

3. **Optimal Contracts in the Interbank Market** : Savings banks post contract ξ_s that solves the optimization problems (3) and (4).

4. **Consistency** : $\Omega^H(l,a)$ is the stationary distribution of the household.

5. **Aggregation** : Asset deposited into savings banks by heterogeneous households are aggregated appropriately as follows:

$$A' = \int_{a' \geq 0} a'(l,a)\, d\Omega^H(l,a)$$

Total borrowing by the households from the savings banks are aggregated appropriately as follows:

$$B' = \int_{a' < 0} a'(l,a)\, d\Omega^H(l,a)$$

Labor endowment of the heterogeneous households are aggregated appropriately as follows:

$$L = \int_{(l,a)} l \cdot d\Omega^H(l,a)$$

6. **Asset Market Clearing** : Savings banks can use its deposit of households' aggregate savings for either investing into the representative firm's production through the

interbank market or lending to the household such that

$$A = K + B \tag{5}$$

7. **Zero Profit in the Banking Sector** : The overall profit in the banking sector, which is the sum of profits of the savings banks and both types of investment banks, equals zero.

2.6 Model Solution

We solve for the recursive stationary equilibrium of the model in two steps. First, we analytically solve for the optimal contracts in the interbank market. Then, we utilize the analytical solution for the optimal contracts to computationally solve for the stationary general equilibrium.

For simplicity, we assume that the matching function between the savings bank and the type s investment bank $\mu(\theta_s)$ takes the form $\mu(\theta_s) = \min\{\theta_s, 1\}$ which is nondecreasing in θ_s. We also normalize $g(1) = 1$, which means that the type $s = 1$ investment bank is the "good" type that always extracts the entirety of their investment into the representative firm. Then, we have the following proposition.

Proposition 2. *Provided that* $\forall s$, $g(s)RA > \tau$, $g(s)R > R^B$, $g(1) = 1$ *and* $\mu(\theta_s) = \min\{\theta_s, 1\}$, *the analytical solution to the optimal contract in the interbank market defined in Definition 1 and characterized by the two optimization problems (3) and (4) is that* $\xi_0 = (p_0, q_0) = \left(1, \frac{\tau}{g(0)RA}\right)$, $\xi_1 = (p_1, q_1) = \left(1, \frac{\tau}{RA}\right)$, $\theta_0 = 1$, *and* $\theta_1 = \frac{g(0)RA-\tau}{g(0)RA-g(0)\tau} < 1$.

The proof of Proposition 2 is in the Appendix A.1. The intuition behind this result is the following. First, the condition $g(s)RA > \tau$ is necessary such that the savings banks have the incentive to partake in the interbank lending with an investment bank. Guerrieri, Shimer, and Wright (2010) established that an economy with adverse selection and frictions in competitive search—as in our model—has a unique separating equilibrium under mild assumptions. That means the savings bank must have the incentive to offer a separate contract for the type $s = 0$ investment bank, and that only happens when a profit it would receive from the interbank market $g(0)R$ is greater than the fixed cost τ of posting a contract in the search market. Second, provided that the condition $g(0)R > R^B$ holds—which implies that $g(1)R = R > R^B$ holds—the savings bank that successfully matches with any type s investment bank would find it optimal to intermediate all the savings that the households have deposited to the investment banks, rather than lend it to the household. Hence, $p_0 = p_1 = 1$. Third, with full information, we would have that $\theta_0 = \theta_1 = 1$. However, the presence of asymmetric information causes adverse selection in which the number of savings banks posting ξ_1 is small compared to the number of investment banks looking for ξ_1.

Notice from Proposition 2 that the savings banks—once successfully matched with an investment bank—will intermediate the entirety of the household savings they have aggregated to the investment banks ($p_0 = p_1 = 1$). However, the presence of adverse selection causes market failure for the contracts designed to attract the "good" investment banks ($\theta_1 < 1$), whereas all "bad" investment banks are perfectly matched with a savings bank ($\theta_0 = 1$). Since the savings banks use the aggregated household savings either for household lending or intermediation to the investment banks, Proposition 2 implies that in equilibrium, there will be a total mass of $(1 - \theta_1)\,\eta$ of savings banks that engage solely in household lending, while the rest of the savings banks are solely engaged in the interbank market with the investment banks. This means that the total borrowing by the household B will satisfy the following condition

$$B = (1 - \theta_1)\,\eta A \tag{6}$$

In other words, smaller value of θ_1 and/or bigger value of η means that more "good" investment banks are unable to match with savings banks, because not enough savings banks post contract ξ_1 due to adverse selection. Because the only option left for the savings banks who declined to participate in the interbank market is to use the aggregated household savings to lend it back to those households that are credit constrained, smaller value of θ_1 and/or bigger value of η means greater supply for the households that are looking to borrow. This mechanism will have a big implication for our comparative statics and welfare results.

With the analytical solution of the optimal contracts in the interbank market, we solve for the recursive stationary equilibrium of the model using a much complicated version of the Aiyagari (1994) algorithm for solving heterogeneous agent model. Specifically, our algorithm is as follows:

1. Guess the aggregate demand value for the aggregate household savings A. There is no need to make a guess on L since L can be computed separately using stationary distribution of the labor endowment shock.

2. Given A, calculate what the implied aggregate capital K used in firm's production must be, using the relationship (14) described in the Appendix A.2.

3. Calculate what the aggregate household borrowing B must be using the asset market clearing condition (5).

4. Prices R and W are calculated from the representative firm's optimization problem (2).

5. Analytically calculate the optimal contracts in the interbank market using Proposition 2.

6. Guess what the savings bank's rate of return on lending to household R^B should be.

7. Given R^B, calculate what R^A should be using the banking sector's zero profit condition. Mathematical representation of this condition can be seen in the Appendix A.3.

8. Given R^B and R^A, calculate the natural borrowing constraint, and use that to calculate the value functions and optimal decision rules for the households.

9. Compute the stationary distribution using the calculated optimal decision rules.

10. Use the stationary distribution and the optimal decision rules to compute the aggregate supply values for A and B.

11. Compare the simulated value of B to its derived value in Step 3. If they are the same, go to the next step. If not, go back to Step 6 and update your guess of R^B and then repeat.

12. Compare the simulated value of A to its guessed value in Step 2. If they are the same, the stationary distribution has been found. If not, go back to Step 2 and update your guess of A and then repeat.

The algorithm is fairly more involved than the standard Aiyagari (1994) because of the fact that the model delivers three different endogenous rates—the gross rate of return on household savings R^A, the gross rate of return on household lending R^B, and the gross rate of return on firm equity R—and that there is no closed-form solution to deliver R^B. For value function iteration, we use the standard discretized value function iteration method, but rely on Howard's improvement method to fasten the convergence. The shock to labor endowment are approximated by a seven-state Markov chain using the Rouwenhorst (1995) method.[5] We use a step function to approximate the CDF of the stationary distribution.

3 Comparative Statics

Despite the inclusion of the banking sector, our model adds only four additional parameters to the standard Aiyagari (1994) framework. First, we add $g(0)$ and $g(1)$, which represent the skill level of the "bad" and "good" investment banks, respectively. These two parameters together control the magnitude of the skill gap across the two types of investment banks. Second, we add η, which represents not only the investment bank's probability of drawing

[5] We can also use the Tauchen (1986) procedure. The difference is very minimal. However, we use this method as our baseline based on the recommendation in Kopecky and Suen (2010) that Rouwenhorst method is more reliable than others in approximating highly persistent processes and generating accurate model solutions.

Table 1: Parameter Values

Category	Symbol	Parameter Value
Preferences	β	0.96
	μ	3
Production Technology	α	0.36
	δ	0.08
Total Factor Productivity	Z	1
Labor Endowment Shocks	σ	0.4
	ρ	0.6
Ability of Investment Bank of Skill Type $s = 1$	$g(1)$	1

$s = 1$ at the beginning of the period but also the mass of type $s = 1$ investment bank at the equilibrium. Finally, we add τ, which is the savings bank's fixed cost of posting contract ξ_s.

In this section, we discuss how these "new" parameters affect the stationary equilibrium of the model through a series of comparative statics exercises in which we compute and compare various aggregate moments generated from the stationary equilibrium of the model. This exercise will help us to think about how various forms of financial innovation will impact the households through its impact on the adverse selection problem in the banking sector. We also quantitatively show the significance of allowing for the rate of return on household borrowing R^B to be different from the rate of return on household savings R^A.

3.1 Calibration

Table 1 summarizes the value choices for parameters that will be fixed throughout the comparative statics exercise and welfare calculations. All the parameter values listed in Table 1, except for $g(1)$, are those from the standard Aiyagari (1994) framework, and hence, we take their values directly from Aiyagari (1994). We set β—the discount factor—to be 0.96 and μ—the parameter of the constant relative risk aversion utility function—to be 3. The capital share in the Cobb-Douglas production function α is set as 0.36, while the

Table 2: Parameters for Comparative Statics Exercise

Symbol	Definition	Interpretation
$g(0)$	Ability of Investment Bank of Skill Type $s = 0$	Impacts the intensive margin of the adverse selection problem
η	Probability of Drawing $s = 1$ = Mass of Type $s = 1$ IB	Impacts the extensive margin of the adverse selection problem
τ	Savings Bank's Transaction Cost for Posting Contract	

depreciation rate δ is set at 0.08. Total factor productivity Z is set at 1, while σ and ρ—the two parameters that control the labor endowment shock—are respectively set to 0.4 and 0.6. As mentioned previously, we assume that $g(1) = 1$ for simplicity. Hence, $g(0) < 1$ will be the sole parameter that controls the intensive margin of the adverse selection problem.

Table 2 summarizes the parameters that we have chosen for the comparative statics exercise. $g(0)$ represents the ability of investment bank of skill type $s = 0$ to recuperate its investment into firms. Because we have normalized $g(1) = 1$, $g(0)$ effectively tells us the gap in the ability between the "good" and the "bad" investment banks. Hence, we interpret that if $g(0)$ increases, the ability gap between the two types are narrowing, whereas if $g(0)$ decreases, then the ability gap between the two is widening. We label this ability gap as the intensive margin of the adverse selection in the banking sector.

η is the investment bank's probability of drawing $s = 1$ at the beginning of the period. Since η also represents the mass of type $s = 1$ investment bank, increasing η implies the economy has relatively more of "good" investment banks compared to their worse counterparts than before. In other words, η is the parameter that impacts the extensive margin of the adverse selection in the banking sector, which we define as the relative mass between the two types of investment banks. Lastly, τ is the savings bank's fixed cost of posting contract ξ_s.

3.2 Results from Comparative Statics Exercises

Section B of the Appendix shows the figures generated from the comparative statics exercises, in which we compare the aggregate moments generated from the recursive steady states of various model specifications, where each specification represents a unique set of values from the parameter set $\{g(0), \eta, \tau\}$. Specifically, we show how the aforementioned parameters impact the following six endogenous objects: 1) the return on household savings R^A; 2) the net interest spread $R^B - R^A$, which is the difference between the interest on household borrowing and the return on household savings; 3) the return on firm equity R; 4) the aggregate household savings A; 5) the pass-through rate of household savings through the banking sector $\frac{K}{A}$; and 6) the Gini coefficient of the household wealth distribution.

Figure (1) shows how $g(0)$—the ability of investment bank of skill type $s = 0$ to recuperate its investment into firms—impacts the six aforementioned endogenous model moments. Every point on each of the six plots correspond to a specific set of values for $g(0)$, η, and τ. Each line in each of the six plots are created by connecting the points that share common η and τ. In other words, each connected line represents how an endogenous model moment changes as $g(0)$ changes, while holding the other two parameters η and τ constant. For example, each colored line in the top left plot represents how R^A changes as $g(0)$ increases, while holding η and τ fixed.

Now, suppose that the financial innovation in the banking sector improves the adverse selection problem through the intensive margin. This means that the skill gap between the "good" investment banks and "bad" investment banks have decreased, which in our model is interpreted as $g(0)$ increasing since $g(1)$ is normalized to equal 1. Information friction is less severe than before, which means the banking sector is able to intermediate a greater percentage of the aggregated household savings to the firm as can be seen in the bottom middle plot of Figure (1). The overall increased efficiency in the economy increases the rate of return the savings banks can provide to the household savings (top left plot), which creates the incentive for the households to save more (bottom left plot). This means greater $g(0)$

will also increase the amount of capital used in firm's production, so we have the rental rate of capital R decreasing in $g(0)$ (top right plot).

The top middle plot of Figure (1) shows that the net interest spread $R^B - R^A$ changes in the same direction as $g(0)$. This is because—as shown in Equation (6)—the total amount B that the savings banks make available for lending to households depends negatively on θ_1, which is the market tightness for the contract designed to attract the "good" investment bank in the interbank market. In Proposition 2, we showed that the equilibrium $\theta_1 = \frac{g(0)Ra-\tau}{g(0)Ra-g(0)\tau}$, which means that $\frac{\partial \theta_1}{\partial g(0)} > 0$. In other words, reduction in the skill gap across the two investment banks causes more "good" investment banks to be able to successfully match up with a savings bank, which means there is less B available for household lending. Hence, the reduction in supply causes the price R^B to increase, which ultimately leads to the increase in the net interest spread and creates less incentive for the households to borrow. This reinforces the already strong incentive for precautionary savings due to higher R^A, and consequently, reduces wealth inequality (bottom right plot).

Figure (2) shows how η—the investment bank's probability of drawing $s = 1$ at the beginning of the period —impacts the six aforementioned endogenous objects. Each line in each of the six plots represents how an endogenous model moment changes as η changes, while holding $g(0)$ and τ constant. As η increases, the mass of investment banks with "good" ability is increasing compared to their worse counterparts, which we interpret as improving the magnitude of the adverse selection problem through the extensive margin.

The key difference between Figure (2) and Figure (1) is that whereas reducing adverse selection through the intensive margin—by increasing $g(0)$—increases the net interest spread $R^B - R^A$, reducing adverse selection through the extensive margin—by increasing η—decreases the net interest spread. This is because the supply for the household borrowing depends positively on how many savings banks are unable to be matched with "good" type investment banks, due to the market failure caused by the presence of adverse selection problem in the banking sector. Since Equation (6) tells us that the magnitude of market failure increases as the relative mass of "good" investment banks η increases, we see that the supply of B increases with η. The increased supply causes the price R^B to decrease, which ultimately leads to the decrease in the net interest spread.

However, it is still the case that the banking sector is able to intermediate a greater percentage of the aggregated household savings to the firm as can be seen in the bottom middle plot of Figure (2). This is because of the fact that the overall increased efficiency in the banking sector increases the rate of return the savings banks can provide to the household savings (top left plot), which creates the incentive for the households to save more (bottom left plot). Since $\frac{\partial \theta_1}{\partial (RA)} > 0$ and it is always the case that RA changes in the same direction as η, we observe that increasing η increases θ_1 indirectly through its impact on RA. The fraction of household savings that the savings banks do not intermediate to the investment banks and instead use for household lending equals

$$\frac{B}{A} = (1 - \theta_1)\,\eta$$

Hence, η has a positive direct effect on this fraction, whereas it also has a negative indirect effect through θ_1. This indirect effect is quite strong at low values of η such that increasing η has the effect of increasing the passthrough rate (intermediation rate), but at high values of η, the direct effect is strong enough to negate the indirect effect. Hence, we see that the passthrough rate $\frac{K}{A}$ is not as sensitive to η as it was to $g(0)$. Since both the aggregate household savings A and the intermediation rate $\frac{K}{A}$ respond positively to η, it must be that K also responds positively to η, which in turn decreases the price of capital R (top right plot).

The effect of the extensive margin of the adverse selection problem on household's wealth inequality is a bit more nuanced compared to that of the intensive margin. As the economy is populated more by the "good" investment banks, we observe that the rate of return on household savings R^A increases, but the net interest spread $R^B - R^A$ decreases. This implies that the households face greater incentive to save, but also greater incentive to borrow. In other words, higher R^A lowers the wealth inequality by providing credit constrained households the means to climb out of the hole relatively faster, but lower net interest spread would increase the wealth inequality by making it easier to borrow and decumulate wealth. As can be seen in the bottom right plot of Figure (2), the former effect is stronger than the latter, so we observe that increasing η lowers the Gini coefficient of the wealth distribution. Comparing this plot to the bottom right plot of Figure (1), it is clear that both $g(0)$ and η reduce wealth inequality. However, the magnitude of the impact is much more pronounced for $g(0)$, since—in contrast to η—both the rate of return on household savings and the net interest spread impact the wealth inequality in the same direction.

To sum up, the impact of $g(0)$ and η on various model moments is remarkably similar. In both cases, an increase in its value reduces the overall magnitude of adverse selection, which increases the aggregate household savings A, increases the pass-through rate $\frac{K}{A}$, and decreases the Gini coefficient of household wealth distribution.[6] The key difference between the two is that their impact on the net interest spread $R^B - R^A$ is different.[7] This is the key insight that will allow us to do moment matching and then the subsequent welfare analysis.

Figure (3) quantitatively shows why it is important to incorporate the net interest spread into the model. This figure shows that τ—the savings bank's transaction cost for posting contract—has a huge impact on the net interest spread, but not on the return on household savings. Nonetheless, we observe a huge impact on the Gini coefficient of the household wealth distribution. In addition to the fact that the two rates are empirically different from each other, this figure provides the quantitative justification for why we believe it is important to expand the ordinary Aiyagari type model to include a different rate of return on household borrowing compared to that of household saving.

[6] Figures (4) and (6) are three-dimensional figures that respectively show how R^A and R change as the intensive and the extensive margins change. These two figures show that a financial innovation that decreases the magnitude of the adverse selection through the extensive margin would be almost indistinguishable from a financial innovation that decreases the magnitude of the adverse selection through the intensive margin when we only focus on R^A and R.

[7] This can also be seen in Figure (5), which is a three-dimensional figure that show how the net interest spread is affected simultaneously by the two margins.

4 Welfare Analysis

In this section, we calculate how the welfare of the household changes as a result of financial innovation. First, we discuss how we use moment matching to choose the baseline specification and use the key insight from the previous section that the two margins of the adverse selection problem have the opposite impact on the net interest spread $R^B - R^A$. Then, we us the model to run two policy experiments. We start by studying the macroeconomic effects of a financial innovation taken by the leading firm in the banking industry. Then, we analyze the effects of a financial innovation that causes diffusion of technology from the "good" investment bank to the "bad" investment bank.

4.1 Moment Matching

As mentioned in Section 3, we have computed the stationary distribution of many different specifications by varying three parameters: $g(0), \eta, \tau$. Since the impact of $g(0)$ and η on model generated moments differ only by the net interest spread, it is clear that R^B has to be one of the moments used in moment matching. For the two other moments, we choose R^A and R. Since the past 10 year average of return on household savings has been close to 1%, we set the target for R^A as 1.01. For the return on household borrowing R^B, we set the target as 1.0435 based on the past 10 year average of interest on car loans. For the return on firm equity R, we set the target as 1.12 based on the annualized return of S&P 500 from 1980 to 2013. Table (3) sums up how our model generated moments match to the data, and the values for the three parameters that delivers those moments.

Table 3: Moment Matching

Moment	Target	Model
R^A	1.01	1.015
R^B	1.0435	1.0466
R	1.12	1.17
Model Parameter	Values	
$g(0)$	0.9	
η	0.6	
τ	0.21	

4.2 Analysis of Financial Innovation by the Industry Leader

First, we study the macroeconomic effects of a cutting-edge type of financial innovation initiated by the leader of the banking industry. Through the lens of our model, this type of financial innovation is the one that would lower $g(0)$ and increase the ability gap across the two types of investment banks. Specifically, $g(0)$ is reduced from 0.9 to 0.87, which implies that this financial innovation exacerbates the adverse selection problem in the banking sector through the intensive margin by making "good" banks even better than before. Table 4 shows how the various model moments change due to this financial innovation.

For the welfare measure, we use the concept from Krusell, Mukoyama, and Şahin (2010). Suppose that each of the specifications represent a different "country", each with its unique value of $g(0), \eta, \tau$, depending on how developed its financial sector is. One of these countries is the US, which we calibrate to be our benchmark specification as shown in Table 3. Now imagine moving each of the households in the benchmark specification, along with its current labor and asset holdings, into each of the other countries and then comparing utilities. Our welfare measure in these comparisons, ω, is defined from

$$\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t u\left((1+\omega)\,c_t\right)\right]=\mathbb{E}_0\left[\sum_{t=0}^{\infty}\beta^t u\left(\tilde{c}_t\right)\right]$$

Table 4: Moment Comparisons: Decreasing $g(0)$ from 0.9 to 0.87

Moment	Old Steady State	New Steady State
R^A	1.015	1.010
$R^B - R^A$	0.0321	0.0133
R	1.17	1.21
A	1.91	1.51
$\frac{K}{A}$	0.9938	0.9892
Wealth Gini	0.4684	0.4983

where c_t is the consumption under the benchmark specification and $\tilde{c}_t$ is the consumption under a particular experiment.

Figure (7) shows the welfare calculation in which the households were moved from the baseline specification to a different country that possesses a banking sector with a greater magnitude of adverse selection with respect to its intensive margin. Specifically, $g(0)$ is reduced from 0.9 to 0.87, because the financial innovation taken by the industry leader caused the ability gap to widen across the two types. In Figure (7), x-axis denotes the percentile of asset holding and y-axis denotes the percentile of labor earnings among all households at the steady state. The bar on the far right shows the range of ω in this particular exercise. It is clear that the increase in the intensive margin of adverse selection in the banking sector reduces the welfare of all the households regardless of their labor and asset positions. However, one can easily see that households with bad labor shocks (low period labor earnings) and households with low level of wealth suffer relatively less compared to others. This is because the net interest spread decreases as $g(0)$ decreases, as we have previously seen during the comparative statics exercises. This implies that although increasing the intensive margin of the adverse selection has a negative first order effect on welfare since it decreases the rate of return on household savings, the second order effect is that the households will find it easier to borrow which would increase the welfare. This

Table 5: Moment Comparisons: Increasing η from 0.6 to 0.65

Moment	Old Steady State	New Steady State
R^A	1.015	1.017
$R^B - R^A$	0.0321	0.0131
R	1.17	1.16
A	1.91	2.06
$\frac{K}{A}$	0.9938	0.9924
Wealth Gini	0.4684	0.4671

second order effect is particularly strong among those that are wealth-constrained. Hence, we observe that the households at the lower left quadrant of Figure (7) suffer relatively less compared to others.

4.3 Analysis of Financial Innovation that Causes Technology Diffusion

Here, we study the macroeconomic effects of a type of financial innovation that facilitates diffusion of technology from the "good" investment banks to "bad" investment banks. We are agnostic about what form of financial innovation this would be, but anything that would allow many "bad" banks to catch up to the "good" banks will do. Through the lens of our model, this type of financial innovation is the one that would increase η and thus increase the relative mass of "good" banks compared to "bad" banks. Specifically, η is increased from 0.6 to 0.65, which implies that this financial innovation lessens the adverse selection problem in the banking sector through the extensive margin by allowing "bad" banks to become "good" banks by adopting their technology. Table 5 shows how the various model moments change due to this financial innovation.

Figure (8) shows the welfare calculation in which the households were moved from the baseline specification to a different country that possesses a banking sector with a lesser magnitude of adverse selection with respect to its extensive margin. Specifically, η is increased from 0.6 to 0.65, such that there is a greater mass of "good" investment banks and less of "bad" investment banks. As in Figure (7), x-axis denotes the percentile of asset holding and y-axis denotes the percentile of labor earnings among all households at the steady state. Comparing this figure against Figure (7), it is clear that lessening the magnitude of the adverse selection in the banking sector through the extensive margin improves the welfare of all the households regardless of their labor and asset positions. This is mainly because the rate of return on household savings R^A increases due to technology diffusion. However, we also observe in Table 5 that the net interest spread decreases, which means the borrowers have more incentive to borrow than before. This is why we observe that poorer households gain relatively more compared to their richer counterparts in Figure (8). In other words, the first order effect of increase in R^A and the second order effect of decrease in $R^B - R^A$ are both positive, and since the second order effect is particularly strong among the poor households, we observe that the welfare of the poor households increase relatively more compared to their wealthier counterparts.

5 Conclusion

In this paper, we studied the impact of financial innovation on wealth distribution and welfare, using a novel framework that embeds banking sector as a financial intermediary within the Aiyagari (1994) framework. Using this model, we examine the macroeconomic impact of two types of financial innovation in the banking sector. First, we find that a financial innovation undertaken by the industry leader would actually exacerbate the magnitude of the adverse selection problem in the banking sector through the intensive margin. This decreases the rate of return in household savings but also decreases the net interest spread. The former results in the first order effect of decreasing the welfare of all households, but the latter results in the second order effect of increasing the ability of the poor to borrow, which ultimately results in the poor households losing less equivalent consumption compared to their wealthier counterparts. We find that wealth inequality increases overall. Second, we find that a financial innovation that causes technological diffusion from the "good" bank to "bad" bank would lessen the magnitude of the adverse selection problem in the banking sector through the extensive margin. This increases the rate of return in household savings but decreases the net interest spread. In this case, the second order effect reinforces the first order effect, which means that the poor households benefit more compared to their wealthier counterparts. We find that wealth inequality decreases overall. We conclude the paper by drawing attention to two potentially important issues that this paper has abstracted from.

First, all the analysis in this paper are steady state analysis. We have yet to compute the transition path between the economy before and after a financial innovation. There can potentially be large transitional costs that we simply are not able to capture through our steady state analysis, which one might argue gives at best a partial picture of the true macroeconomic effects of financial innovation in the banking sector.

Second, this paper does not consider any aggregate shocks to the economy. Since the banking and financial sectors tend to be procyclical, it would be interesting to see how the aggregate shocks impact the magnitude of the adverse selection problem in the banking sector, and quantify how much the impact on household is amplified as a result. For now, we leave this up for future research.

References

Afonso, G. and R. Lagos (2015). Trade dynamics in the market for federal funds. *Econometrica 83*(1), 263–313.

Aiyagari, S. R. (1994). Uninsured idiosyncratic risk and aggregate saving. *The Quarterly Journal of Economics 109*(3), 659–684.

Allen, F. (2012). Trends in financial innovation and their welfare impact: an overview. *European Financial Management 18*(4), 493–514.

Bernanke, B. and M. Gertler (1989). Agency costs, net worth, and business fluctuations. *The American Economic Review*, 14–31.

Bernanke, B. S., M. Gertler, and S. Gilchrist (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of macroeconomics 1*, 1341–1393.

Bisin, A. and P. Gottardi (2006). Efficient competitive equilibria with adverse selection. *Journal of political Economy 114*(3), 485–516.

Brunnermeier, M. K. and Y. Sannikov (2014). A macroeconomic model with a financial sector. *The American Economic Review 104*(2), 379–421.

Calza, A., T. Monacelli, and L. Stracca (2013). Housing finance and monetary policy. *Journal of the European Economic Association 11*(s1), 101–122.

Carlstrom, C. T. and T. S. Fuerst (1997). Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *The American Economic Review*, 893–910.

Carlstrom, C. T., T. S. Fuerst, and M. Paustian (2010). Optimal monetary policy in a model with agency costs. *Journal of Money, credit and Banking 42*(s1), 37–70.

Chang, B. (2012). Adverse selection and liquidity distortion. *Mimeo*.

Christiano, L. J., M. Trabandt, and K. Walentin (2011). Introducing financial frictions and unemployment into a small open economy model. *Journal of Economic Dynamics and Control 35*(12), 1999–2041.

Cúrdia, V. and M. Woodford (2016). Credit frictions and optimal monetary policy. *Journal of Monetary Economics 84*, 30–65.

De Nardi, M. (2015). Quantitative models of wealth inequality: A survey. Technical report, National Bureau of Economic Research.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2005). Over-the-counter markets. *Econometrica 73*(6), 1815–1847.

Elul, R. (1999). Welfare-improving financial innovation with a single good. *Economic Theory 13*(1), 25–40.

Frame, W. S. and L. J. White (2004). Empirical studies of financial innovation: lots of talk, little action? *Journal of Economic Literature 42*(1), 116–144.

Galati, G. and R. Moessner (2013). Macroprudential policy–a literature review. *Journal of Economic Surveys 27*(5), 846–878.

Gerali, A., S. Neri, L. Sessa, and F. M. Signoretti (2010). Credit and banking in a dsge model of the euro area. *Journal of Money, Credit and Banking 42*(s1), 107–141.

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of monetary Economics 58*(1), 17–34.

Gertler, M. and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. *Handbook of monetary economics 3*(3), 547–599.

Guerrieri, V. and R. Shimer (2014). Dynamic adverse selection: A theory of illiquidity, fire sales, and flight to quality. *The American Economic Review 104*(7), 1875–1908.

Guerrieri, V. and R. Shimer (2015). Markets with multidimensional private information. *Mimeo*.

Guerrieri, V., R. Shimer, and R. Wright (2010). Adverse selection in competitive search equilibrium. *Econometrica 78*(6), 1823–1862.

Hanson, S. G., A. K. Kashyap, and J. C. Stein (2011). A macroprudential approach to financial regulation. *The Journal of Economic Perspectives 25*(1), 3–28.

Hoshi, T. (2011). Financial regulation: Lessons from the recent financial crises. *Journal of Economic Literature 49*(1), 120–128.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. *The American economic review 95*(3), 739–764.

Iacoviello, M. and S. Neri (2010). Housing market spillovers: evidence from an estimated dsge model. *American Economic Journal: Macroeconomics 2*(2), 125–164.

Kim, K. (2012). Endogenous market segmentation for lemons. *The RAND Journal of Economics 43*(3), 562–576.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of political economy 105*(2), 211–248.

Kopecky, K. A. and R. M. Suen (2010). Finite state markov-chain approximations to highly persistent processes. *Review of Economic Dynamics 13*(3), 701–714.

Krusell, P., T. Mukoyama, and A. Şahin (2010). Labour-market matching with precautionary savings and aggregate fluctuations. *The Review of Economic Studies 77*(4), 1477–1507.

Lagos, R. and G. Rocheteau (2009). Liquidity in asset markets with search frictions. *Econometrica 77*(2), 403–426.

Lerner, J. and P. Tufano (2011). The consequences of financial innovation: a counterfactual research agenda. *Annu. Rev. Financ. Econ. 3*(1), 41–85.

Lester, B., A. Shourideh, V. Venkateswaran, and A. Zetlin-Jones (2017). Screening and adverse selection in frictional markets. *Mimeo*.

Meh, C. A. and K. Moran (2010). The role of bank capital in the propagation of shocks. *Journal of Economic Dynamics and Control 34*(3), 555–576.

Rosenthal, R. W. and A. Weiss (1984). Mixed-strategy equilibrium in a market with asymmetric information. *The Review of Economic Studies 51*(2), 333–342.

Rothschild, M. and J. Stiglitz (1976). Equilibrium in competitive insurance markets: An essay on the economics of imperfect information. *The quarterly journal of economics*, 629–649.

Rouwenhorst, K. G. (1995). Asset pricing implications of real business cycle models. In T. F. Cooley (Ed.), *Frontiers of business cycle research*, pp. 53–84. Princeton University Press.

Tauchen, G. (1986). Finite state markov-chain approximations to univariate and vector autoregressions. *Economics letters 20*(2), 177–181.

Vayanos, D. and P.-o. Weill (2008). A search-based theory of the on-the-run phenomenon. *The Journal of Finance 63*(3), 1361–1398.

A Mathematical Detail

A.1 Proof of Proposition 2

With $\mu(\theta_s) = \min\{\theta_s, 1\}$, two optimization problems (3) and (4) become the following:

$$\begin{aligned} \bar{U}_0(R,A) &= \max_{p_0,q_0,\theta_0} \left[\min\{\theta_0,1\}(1-q_0)\,g(0)\,Rp_0A\right] \qquad (7) \\ \text{subject to} \quad & \left[\min\left\{\frac{1}{\theta_0},1\right\}\left\{q_0g(0)\,Rp_0 + R^B(1-p_0)\right\} + \left(1-\min\left\{\frac{1}{\theta_0},1\right\}\right)R^B\right]A \geq \tau \end{aligned}$$

and

$$\begin{aligned} \bar{U}_1(R,A) &= \max_{p_1,q_1,\theta_1} \left[\min\{\theta_1,1\}(1-q_1)\,g(1)\,Rp_1A\right] \qquad (8) \\ \text{subject to} \quad & \left[\min\left\{\frac{1}{\theta_1},1\right\}\left\{q_1g(1)\,Rp_1 + R^B(1-p_1)\right\} + \left(1-\min\left\{\frac{1}{\theta_1},1\right\}\right)R^B\right]A \geq \tau \\ & \min\{\theta_1,1\}(1-q_1)\,g(0)\,Rp_1A \leq \bar{U}_0(R,A) \end{aligned}$$

First, note that the participating constraints in the optimization problems (7) and (8) should hold with equality $\forall s$, such that

$$\begin{aligned} \tau &= \left[\min\left\{\frac{1}{\theta_s},1\right\}\left\{q_sg(s)\,Rp_s + R^B(1-p_s)\right\} + \left(1-\min\left\{\frac{1}{\theta_s},1\right\}\right)R^B\right]A \\ \Longrightarrow \quad \tau &= \left[\min\left\{\frac{1}{\theta_s},1\right\}\left\{q_sg(s)\,Rp_s - R^Bp_s\right\} + R^B\right]A \\ \Longrightarrow \min\left\{\frac{1}{\theta_s},1\right\}q_sg(s)\,Rp_sA &= \min\left\{\frac{1}{\theta_s},1\right\}R^Bp_sA + \tau - R^BA \\ \Longrightarrow \quad q_s &= \frac{1}{g(s)\,Rp_sA}\left[R^Bp_sA + \frac{\tau - R^BA}{\min\left\{\frac{1}{\theta_s},1\right\}}\right] \qquad (9) \end{aligned}$$

Then, we can simplify $u_s(p_s,q_s;R,A) = (1-q_s)\,g(s)\,Rp_sA$ using equation (9):

$$\begin{aligned} u_s(p_s, q_s; R, A) &= (1 - q_s)\, g(s)\, Rp_sA \\ &= \left(1 - \frac{1}{g(s)\, Rp_sA}\left[R^B p_sA + \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_s}, 1\right\}}\right]\right) g(s)\, Rp_sA \\ &= \left(g(s)\, Rp_sA - \left[R^B p_sA + \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_s}, 1\right\}}\right]\right) \\ &= \left(g(s)\, R - R^B\right) p_sA - \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_s}, 1\right\}} \end{aligned}$$

Plugging this back to the optimization problems (7), we obtain

$$\bar{U}_0(R, A) = \max_{p_0, \theta_0}\left[\min\{\theta_0, 1\}\left[\left(g(0)\, R - R^B\right) p_0A - \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_0}, 1\right\}}\right]\right] \tag{10}$$

in which the participating constraint is embedded into the objective function and q_0 is eliminated. Suppose that $\theta_0 \leq 1$. Then, optimization problem (10) becomes

$$\bar{U}_0(R, A) = \max_{p_0, \theta_0}\left[\theta_0 \cdot \left[\left(g(0)\, R - R^B\right) p_0A - \left(\tau - R^B A\right)\right]\right] \tag{11}$$

It is easy to see that as long as the condition $g(0)\, R > R^B$ holds, the solution to the optimization problem (11) is $p_0 = 1$ and $\theta_0 = 1$. Now, suppose that $\theta_0 \geq 1$. Then, optimization problem (10) becomes

$$\bar{U}_0(R, A) = \max_{p_0, \theta_0}\left[\left(g(0)\, R - R^B\right) p_0A - \theta_0 \cdot \left(\tau - R^B A\right)\right] \tag{12}$$

It is easy to see that as long as the condition $g(0)\, R > R^B$ holds, the solution to the optimization problem (12) is $p_0 = 1$ and $\theta_0 = 1$. Hence, it must be that the solution to the optimization problem (10) is $p_0 = 1$ and $\theta_0 = 1$.

Plugging these into the equation for q_0 and the optimization problem (10), we obtain that

$$q_0 = \frac{\tau}{g(0)\, RA}$$

and

$$\bar{U}_0(R, A) = g(0)\, RA - \tau$$

Similarly, we obtain $p_1 = 1$.[8] Because the participating constraint of problem (8) has to hold with equality, we obtain that

$$
\begin{aligned}
& \min\{\theta_1, 1\}(1-q_1)\, g(0)\, RA = g(0)\, RA - \tau \\
\implies \quad & \min\{\theta_1, 1\}\left(1 - \frac{1}{RA}\left[R^B A + \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_1}, 1\right\}}\right]\right) g(0)\, RA = g(0)\, RA - \tau \\
\implies \quad & \min\{\theta_1, 1\}\left(RA - R^B A - \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_1}, 1\right\}}\right) g(0) = g(0)\, RA - \tau
\end{aligned}
$$

Since $\theta_0 = 1$, it has to be true that $\theta_1 \leq 1$ since the mass of savings banks and investment banks are one, respectively. So, the expression above simplifies to

$$\theta_1 g(0)(RA - \tau) = g(0)\, RA - \tau$$

which further simplifies to

$$\theta_1 = \frac{g(0)\, RA - \tau}{g(0)\, RA - g(0)\tau}$$

Notice that $\theta_1 < 1$ since $g(0) < 1$.

Substitute this equation—along with the fact that $p_1 = 1$ and $g(1) = 1$—into the equation (9) for q_1 to obtain

$$q_1 = \frac{\tau}{RA}$$

A.2 Solving for K

The ultimate source of the firm's capital K is the aggregate household savings A intermediated through the banking sector. Because of the adverse selection in the banking sector,

[8] Sellers can be rationed through the market tightness θ (extensive margin) instead of the terms of trade q (intensive margin). Given that there is a positive τ of posting a contract, buyers will never decide optimally to ration ex-post using q.

$K \neq A$. The exact relationship between the two is the following:

$$K = \underbrace{\min\{\theta_0, 1\}}_{\text{probability of matching with a SB for type 0 IB}} \cdot \underbrace{p_0 A}_{\text{fund received from SB conditional on matching}} \cdot \underbrace{(1-\eta)}_{\text{mass of type 0 IB}}$$
$$+ \underbrace{\min\{\theta_1, 1\}}_{\text{probability of matching with a SB for type 1 IB}} \cdot \underbrace{p_1 A}_{\text{fund received from SB conditional on matching}} \cdot \underbrace{\eta}_{\text{mass of type 1 IB}}$$

Using the analytical solution from Proposition 2, this becomes

$$K = (1 - \eta + \theta_1 \eta) A \tag{13}$$

Since $\theta_1 < 1$, we obtain that $A > K$.

It may be easy to conclude that once we have a guess for A, we will be able to obtain K easily using relationship (13). Unfortunately, because θ_1 has an analytical solution that involves R, which in turn needs to know what the value of K is, K cannot be solved directly from (13). Instead, we use the following procedure. First, by rearranging (13), we obtain that

$$\theta_1 = \frac{1}{\eta}\left(\frac{K}{A} - 1\right) + 1$$

Then, we set the expression above equal to the analytical solution of θ_1 from Proposition 2, to obtain that

$$\frac{1}{\eta}\left(\frac{K}{A} - 1\right) + 1 = \frac{g(0) RA - \tau}{g(0) RA - g(0)\tau}$$

which can be rearranged to

$$\frac{K}{A} = 1 - \frac{(1 - g(0)) \eta\tau}{g(0)(RA - \tau)}$$

Since the aggregate production function is Cobb-Douglas, we obtain that $R = Z\alpha \left(\frac{L}{K}\right)^{1-\alpha} + (1-\delta)$, which means the expression above for $\frac{K}{A}$ can be written as

$$\frac{K}{A} = 1 - \frac{(1 - g(0)) \eta\tau}{g(0)\left(\left[Z\alpha\left(\frac{L}{K}\right)^{1-\alpha} + (1-\delta)\right] A - \tau\right)} \tag{14}$$

Note that the left hand side of the expression above is strictly increasing in K holding all else constant, while the right hand side of the expression is decreasing in K. Hence, there exists a unique K for a given value of A. In our computation, we use the relationship (14) to solve for K.

A.3 Banking Sector Profit

In order to calculate the profit for the entire banking sector, it is easier to calculate the profit of each of the components that make up the entire banking sector. First, we know from Appendix A.1, that the savings banks will always earn zero payoff from the interbank market due to their participation constraints binding at the equilibrium. So, the only positive profit that the savings banks at the equilibrium is through household lending. Because $\theta_0 = 0$ and $\theta_1 < 1$ in equilibrium, we know that there exists a total mass of $(1 - \theta_1)\,\eta$ of savings banks that engage solely in household lending, while the rest of the savings banks are solely involved with interbank market with the investment banks. This implies that it must be true that $(1 - \theta_1)\,\eta A = B$

As for the investment bank, we know that the the expected payoff π_{IB}^0 for a type $s = 0$ investment bank is

$$\pi_{\text{IB}}^0 = \min\{\theta_0, 1\}\,(1 - q_0)\,g\,(0)\,Rp_0A$$

and the expected payoff π_{IB}^1 for a type $s = 1$ investment bank is

$$\pi_{\text{IB}}^1 = \min\{\theta_1, 1\}\,(1 - q_1)\,g\,(1)\,Rp_1A$$

We also have that the savings bank must pay back the households $R^A A$ in assets every period. Hence, the overall banking sector profit π can be calculated as the following

$$\pi = \eta\pi_{\text{IB}}^1 + (1 - \eta)\,\pi_{\text{IB}}^0 + R^B\,(1 - \theta_1)\,\eta A - R^A A$$

Setting this profit to equal zero and then solving for R^A, we obtain that

$$R^A = \frac{\eta\pi_{\text{IB}}^1 + (1 - \eta)\,\pi_{\text{IB}}^0 + R^B\,(1 - \theta_1)\,\eta A}{A}$$

This is the expression we use to obtain the endogenous R^A.

B Figures

Figure 1: Comparative Statics: Changing $g(0)$

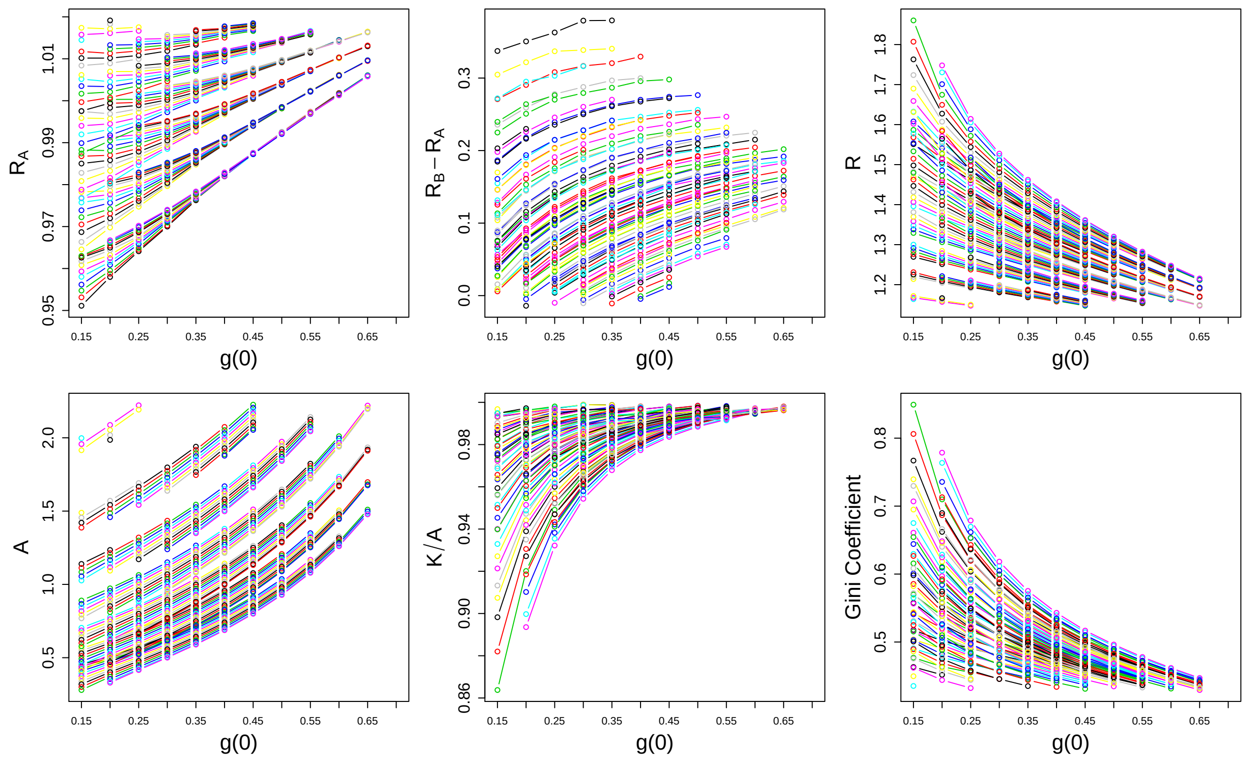

Figure 2: Comparative Statics: Changing η

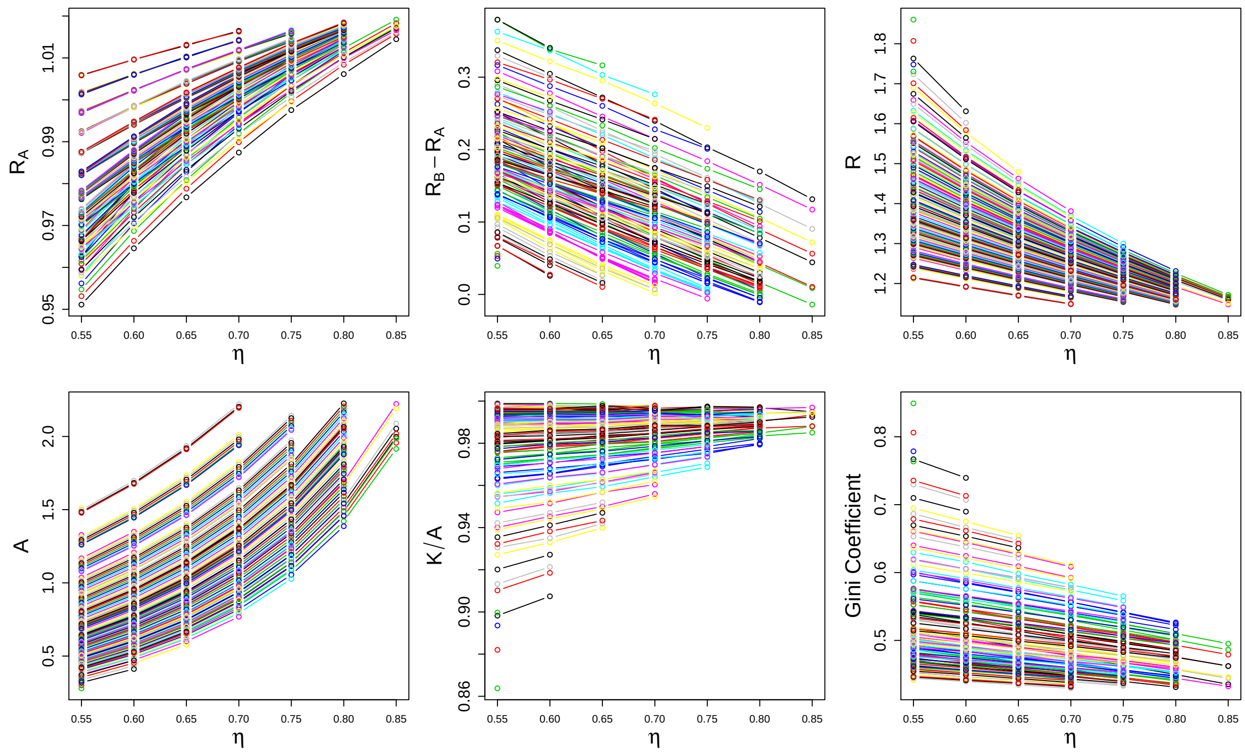

Figure 3: Comparative Statics: Changing τ

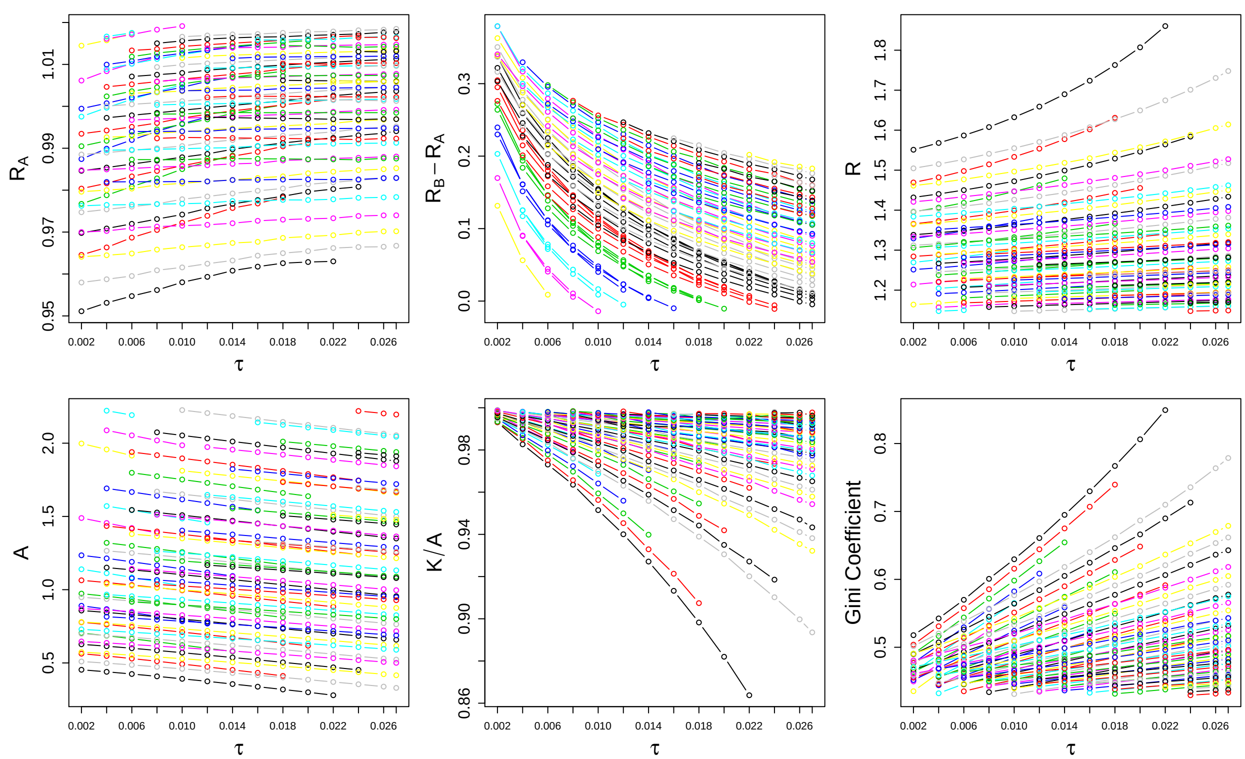

Figure 4: Impact of the Two Margins of Adverse Selection on R^A

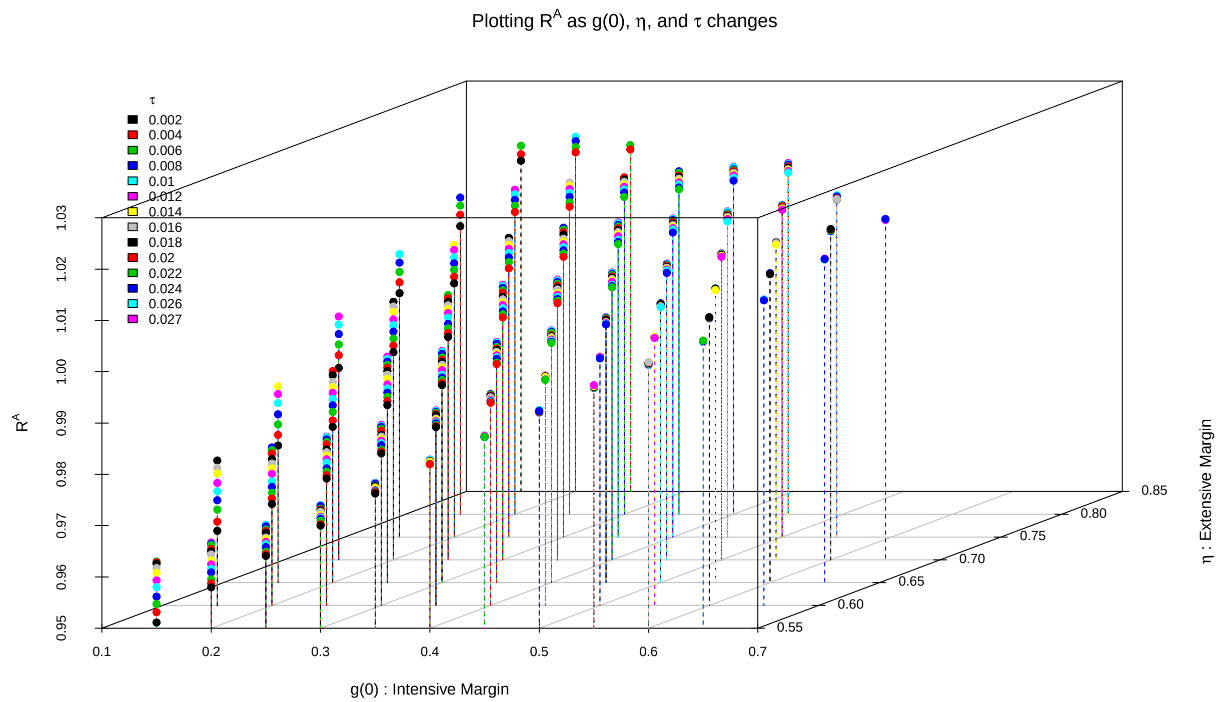

Figure 5: Impact of the Two Margins of Adverse Selection on Net Interest Spread

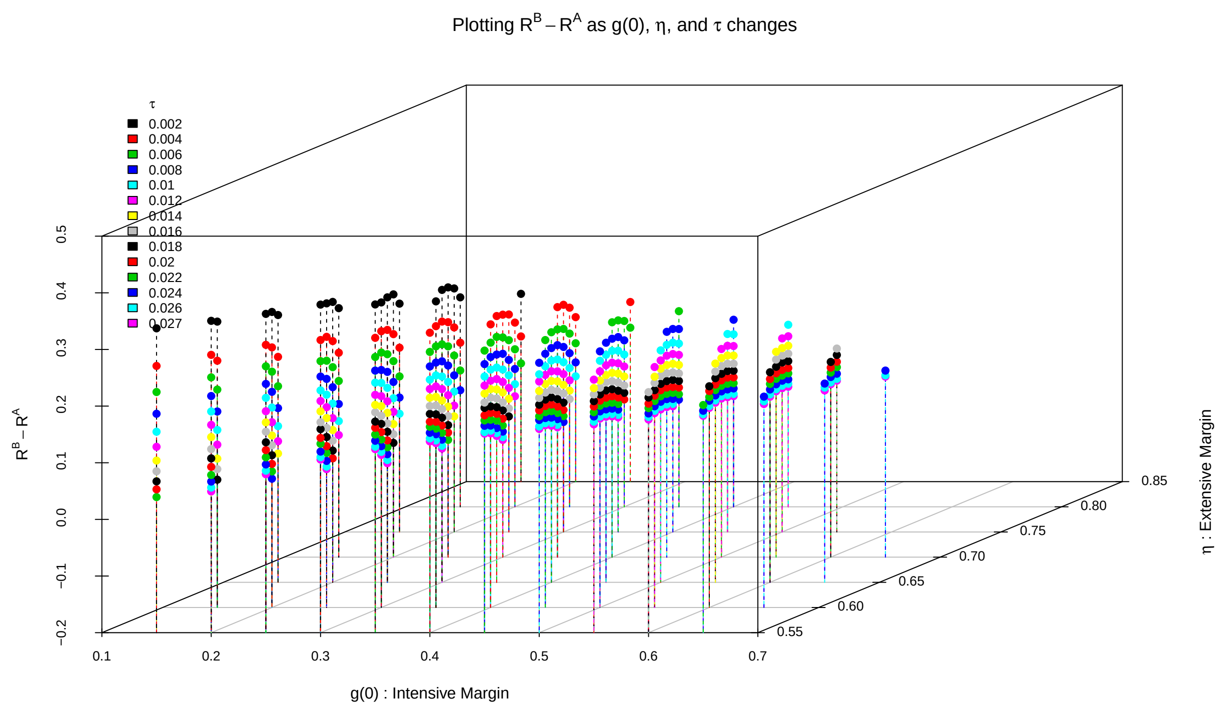

Figure 6: Impact of the Two Margins of Adverse Selection on R

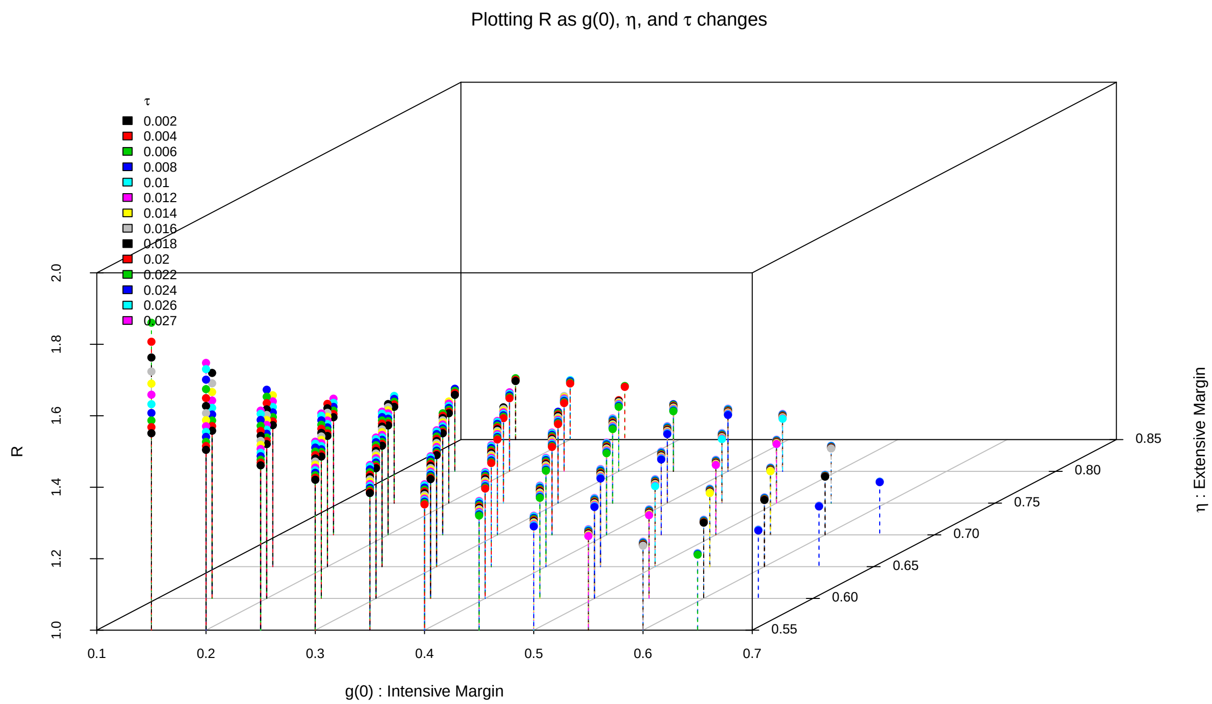

Figure 7: Welfare Analysis: Financial Innovation Magnifies the Adverse Selection Problem Through the Intensive Margin

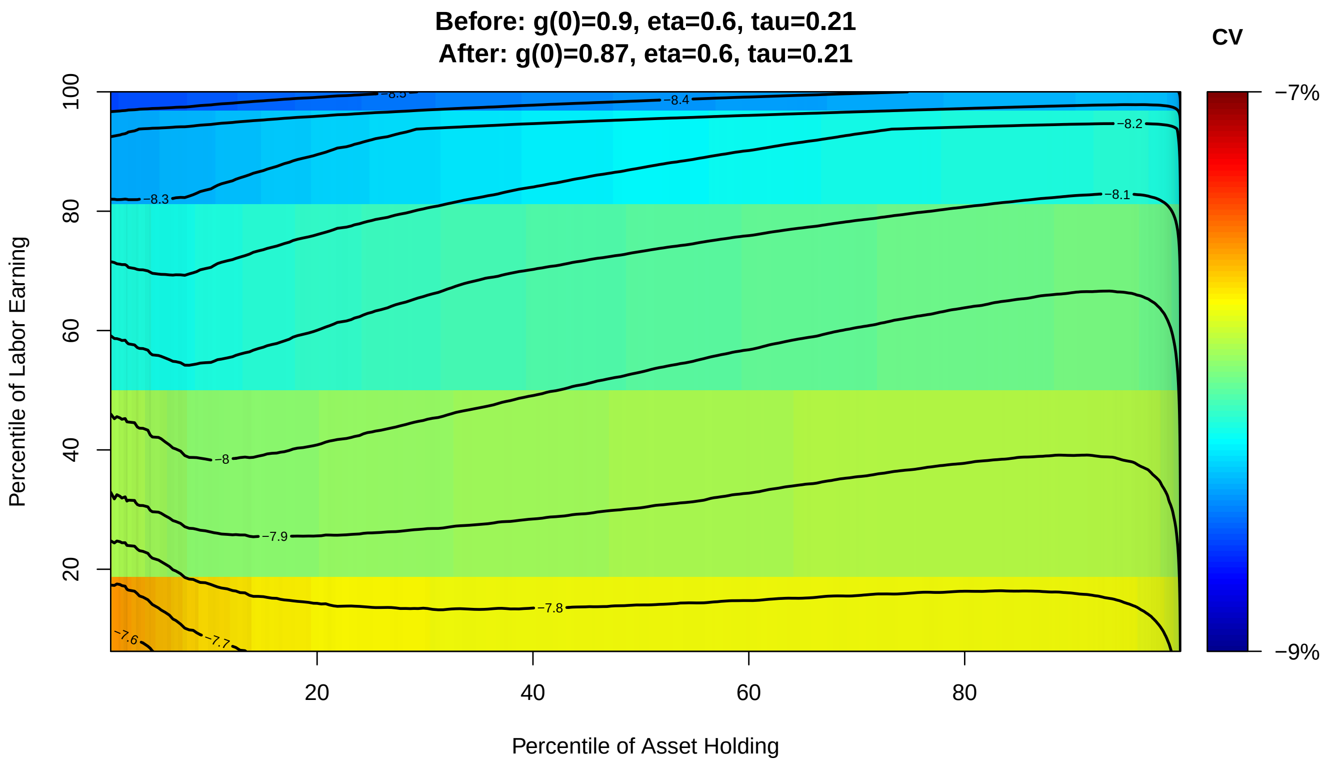

Figure 8: Welfare Analysis: Financial Innovation Lessens the Adverse Selection Problem Through the Extensive Margin