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

Bong-Geun Choi†, Hyun Lee‡

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Abstract

Household wealth inequality and the level of concentration in the banking sector have both increased in the US recently. This paper develops a novel general equilibrium model to jointly explain these phenomena by embedding heterogeneous banking sector into a standard heterogeneous agent model with incomplete-markets. We show that introducing financial friction in the form of adverse selection under competitive search to the inter-bank market endogenously decouples the savings rate and the borrowing rate. Financial innovation by the big bank may decrease the interest rates for borrowing and saving, which reduces the incentive to accumulate wealth for the poor.

JEL Classification: E13, E21, E44

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

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†Department of Economics and Finance, City University of Hong Kong, 83 Tat Chee Avenue 9-221, Kowloon Tong, Hong Kong; webpage: http://b-choi.com/; email: bgchoi@cityu.edu.hk.

‡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

It has been well documented in the literature that the distribution of wealth among US households is much more concentrated than that of income (Diaz-Gimenez, Quadrini, and Ríos-Rull (1997) and Rodriguez, Díaz-Giménez, Quadrini, and Ríos-Rull (2002)), and that this trend has steadily exacerbated in the past few decades (Alvaredo, Atkinson, Piketty, and Saez (2013) and Saez and Zucman (2016)). Concurrently, we observe that the distribution of asset holdings among US banks have steadily become concentrated toward a few large banks at the top of the distribution. Using the call report data from 1976 to 2011,[1] we document the following stylized facts about the distribution of asset holdings within the US banking sector. First, the average amount of assets held by US banks have been increasing for several decades. Second, the variance of the asset size distribution has also steadily increased. Third, the skewness of the distribution generally decreased over time, while the market discipline continuously pushed smaller banks to drop out or to be merged to bigger banks. In other words, we observe that the growth of the banking sector is led by a few large industry leaders, increasingly dispersing the asset size distribution. This occurs as a few big banks are getting bigger, and smaller banks either exit the market to be replaced by new ones or merge with others to become bigger.

Can an increased concentration of asset holdings among a few industry leaders within the banking sector propagate wealth inequality among households? In this paper, we answer this question by analyzing the impact of financial innovation within a quantitative general equilibrium model, in which a heterogeneous banking sector with information frictions is embedded into a standard Aiyagari (1994) incomplete-markets economy with heterogeneous households. We define financial innovation as a technological progress that improves intermediation efficiency of some banks, ceteris paribus. We use the model to show how various forms of financial innovation would impact the distribution of assets within the banking sector, and how those changes ultimately impact the household wealth distribution.

[1] Due to a drastic change in 2012 of how the call report data is structured, we focus on the 35 year period before this change and drop the data from 2012 and onward.

Through the lens of our model, we are particularly interested in comparing the implications of the financial innovations that increase the friction in the banking sector with the ones that decrease the friction, and deriving empirically testable implications from this comparison.

We model the banking sector as a financial intermediary between the households and the firms, consisting of savings banks and investment banks.[2] The savings banks have direct access to household savings but not to firms, whereas the investment banks can directly invest in firms but do not have direct access to the household savings. Hence, the savings banks and the investment banks have the incentive to meet in an interbank market to split trading surplus so that the aggregate savings from the household can be intermediated to the firms. The key complications in the interbank market are two-fold: (1) under free entry, banks direct their search for a bilateral match with a trading partner, and (2) 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 with competitive search.[3]

For the simplest benchmark allocation results under competitive search with adverse selection, we assume that the interbank market has the same structure à la Guerrieri, Shimer, and Wright (2010) and use their key result that a unique separating equilibrium exists under this setting.[4] In particular, the savings banks in our

[2]The banking sector as a whole grants loans and receives deposits from the public. However, some banks are more specialized in issuing loans, while others are more focused on collecting deposits. In the real world example, savings bank may include not only savings purpose depository institutions (commercial banks, mutual savings banks, credit unions, and savings and loan associations) and contractual savings institutions (insurance companies), but also some investment purpose depository institutions such as mutual funds and money market mutual funds. Investment banks may include commercial banks, finance companies, and securities brokers/dealers. The segregation between loan granting and deposit receiving functions can be extreme. However, some researchers predict that intermediaries offering both loans and deposits might disappear some day, taken over by two types of specialized institutions. See for example, Gorton and Pennacchi (1993).

[3]As a leading example of such a market structure, we can consider the over-the-counter (OTC) market where a large number of potential buyers and sellers direct their search for a trading partner under potential lemons problem, as in Duffie, Gârleanu, and Pedersen (2005) and Lagos and Rocheteau (2009).

[4]There are more general results with less stringent assumptions for similar market micro structures. For example, Guerrieri and Shimer (2014) extended the results of Guerrieri, Shimer, and Wright (2010) to a dynamic setting, while Guerrieri and Shimer (2017) characterized various differ-

model freely enter the interbank market to search 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. Considering the match probabilities and the profitability from each match, investment banks direct their search to a certain type of incentive compatible contract so that all contracts look indifferent in the equilibrium. We show that the inclusion of the heterogeneous banking sector with competitive search and adverse selection frictions into a standard Aiyagari (1994) incomplete-markets economy with heterogeneous households framework 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.

Our model suggests a theoretical measure of the magnitude of the adverse selection problem. 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.[5] The reduction in the rate of return on savings reduces the incentive to engage in precautionary saving for everyone in the household sector. This has a negative effect on accumulated wealth and welfare of all households.[6] Concurrently, the reduction in the net interest spread signifies that the borrowers find it easier to borrow than before. This implies

ent equilibria under private information in multiple dimensions.

[5]The net interest spread is defined as the difference between the rate on household borrowing and the return on household savings.

[6]We measure welfare as the percentage of consumption that the household needs to be compensated for in order to be indifferent about the change.

that the poor households—who tend to be borrowers than savers—accumulate even less wealth compared to their rich counterparts, which signifies that wealth inequality increases. We show that the effect of the reduction in the net interest spread is a second order effect, compared to the first order effect of the reduction in the savings rate. Hence, the key results from our welfare analysis and the subsequent testable implications is that a type of financial innovation that increases the ability gap between banks will reduce welfare for all households—with the caveat that the poor households suffer less relative to the rich, due to the decreased net interest spread—whereas the wealth inequality increases.[7]

The second type of financial innovation we analyze is the diffusion of intermediation technology from "good" banks to "bad" banks, which in our model decreases 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. The increase in the savings rate has positive effect on accumulated wealth and welfare, and the magnitude of this effect is of first order. The reduction in the net interest spread implies that the poor households find it easier to borrow than before, thus decreasing their wealth but increasing their consumption, and subsequently welfare, relative to their richer counterparts. The magnitude of this effect is of second order. Hence, the two effects together imply that if we observe financial innovation in which diffusion takes place, we should expect the welfare of all households to increase, the poor households to gain more welfare than their richer counterparts, and the overall wealth inequality to decrease.

The key insight 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. This is because each of the two margins have opposite effect on the net interest spread. If the financial innovation reduces the overall adverse selection through the intensive margin, then the net interest spread increases. As a result, the welfare of the households with low

[7] If instead, if the financial innovation is undertaken by the industry follower so as to narrow the skill gap, we would obtain the exact opposite: welfare increases and wealth inequality decreases.

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, then the net interest spread decreases. As a result, the welfare of the poor households increase more relative to their richer counterparts.

The key contribution of our paper is that we offer a new quantitative theory that can link the inequality in the banking sector with the inequality in the household sector. The inequality in the banking sector and the inequality in the household sector have independently been well documented in the literature,[8] but the potential link between the two—to our knowledge—has not been discussed much in the literature. This paper fills that gap.

The second 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 macro-prudential 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.

[8] For the increase in household wealth inequality, see De Nardi and Yang (2016) and Kennickell (2003). For the changes in bank asset size distribution over time, see Janicki and Prescott (2006).

The third contribution of this paper is that our model—to our knowledge—is the first framework that extends standard heterogeneous agent model to endogenously generate three different interest rates—the rate of return on household savings, the rate of return on household lending (the interest on household borrowing), and the rate of return on equity—within the incomplete market heterogeneous agent framework. 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, we quantitatively show that decoupling the rate of return on household savings and the rate of return on household lending is the main reason why our model is able to generate a Gini coefficient on wealth distribution that is much higher than the standard Aiyagari (1994) model. As a result, our paper adds heterogeneous banking sector as 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 as surveyed by De Nardi (2015)) that helps the heterogeneous agent models to better match the magnitude of wealth inequality observed in the data.

This paper is related to several different strands of literature. First, our 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 in light of the Great Recession. 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 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.[9] 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

[9] 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.

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 (2017); Chang (2017)).

The rest of the paper is as follows. In Section 2, we document how the size distribution of assets held by US banks has changed in the past several decades. In Section 3, we describe the model and its recursive stationary equilibrium. We also discuss how we compute the solution of the model. In Section 4, 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 5, we calibrate a benchmark specification using moment matching and then do a series of welfare analysis. The last section concludes.

2 Motivating Facts

US banks are required to file a quarterly Consolidated Report of Condition and Income—commonly referred to as the call report—that contains statements on a bank's income, assets, liabilities, and write-offs. This report is the main means through which the bank regulatory agencies monitor bank's activities and this data is made publicly available by the Federal Deposit Insurance Corporation. We use this call report from 1976 to 2011 to document how the asset size distribution of the US banks have evolved over time. We restrict our data sample to this 35 year period, because a fundamental change in how call report data is collected took place in the first quarter of 2012.[10]

Table A1 in Section A of the Appendix shows summary statistics of US bank assets from 1976 to 2011.[11] Until the late 1980's, the total number of US banks have been quite steady at about 15,000. However, in the next two decades, the number of US banks have dramatically dropped; by 2011, the number of US banks is less than half it had been thirty years prior. Despite the reduction in the number of banks, we document that both the average and median bank size have steadily increased. By 2011, US banks on average held 26 times more asset than they did in 1976. This increase in average over this time period is much faster compared to how the median increased, which implies that the big banks have consistently gotten bigger over time. This is corroborated by the fact that the variance has steadily increased during this time period. All of this paints a picture in which the growth in the banking sector has largely been driven by the dynamics of big banks getting even bigger. At the same time, we observe that the skewness has always been a positive number but decreases over time, which indicates that the right tail has always been longer than the left, but the tail has been getting somewhat shorter. This indicates that the US banking sector has many small banks that either consistently try to keep up with the industry leading big banks by increasing its own asset size or exit the market completely thereby shifting the distribution toward the right tail.

Figure (1) in Section A of the Appendix graphs how the distribution of US bank assets has evolved every 10 years and corroborates what we observed in Table A1. In this figure, the bars show the empirical distributions, whereas the curve shows the lognormal distribution that best approximates the empirical distribution. Starting from 1976, we observe that the distribution consistently shifts to the right while the peak of the distribution is diminishing over time.

[10] Before 2012, savings and loans associations filed a report known as the Thrift Financial Report that was separate from the call report. That changed in the first quarter of 2012, as all savings and loan associations were now required to file a call report instead of the Thrift Financial Report, thereby drastically changing the sample size and composition.

[11] As previously stated, we dropped the observations from 2012 to 2017. However, the overall trend of the assets held by US banks described in this section still remains consistent even with the addition of 2012 to 2017 data.

3 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.

3.1 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:

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

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

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

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

3.2 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:

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

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

3.3 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.[12] 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 gen-

[12] 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.

erality 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.[13] 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 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 $g(i) R p_s A$ 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:

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

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

[13] 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.

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:

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

3.4 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: $\forall\xi_s\in\Xi$

$$\left[\frac{\mu\left(\Theta\left(\xi_s\right)\right)}{\Theta\left(\xi_s\right)}\cdot\left(\sum_{i=0,1}\gamma_i\left(\xi_s\right)\cdot\left\{q_s g\left(i\right)Rp_sA+R^B\left(1-p_s\right)A\right\}\right)+\left(1-\frac{\mu\left(\Theta\left(\xi_s\right)\right)}{\Theta\left(\xi_s\right)}\right)R^BA\right]\leq\tau$$

with equality if $\xi_s\in\Xi^P$. The first term of the left hand side of the condition above

$$\frac{\mu\left(\Theta\left(\xi_s\right)\right)}{\Theta\left(\xi_s\right)}\cdot\left(\sum_{i=0,1}\gamma_i\left(\xi_s\right)\cdot\left\{q_s g\left(i\right)Rp_sA+R^B\left(1-p_s\right)A\right\}\right)$$

represents profit from successfully matching with an investment bank, and the second term

$$\left(1-\frac{\mu\left(\Theta\left(\xi_s\right)\right)}{\Theta\left(\xi_s\right)}\right)R^BA$$

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 $\forall s \in \{0,1\}$

$$\mu\left(\Theta\left(\xi_s\right)\right) u_s\left(p_s, q_s; R, A\right) \leq \bar{U}_s\left(R, A\right)$$

with equality if $\Theta\left(\xi_s\right) < \infty$ and $\gamma_s\left(\xi_s\right) > 0$, where

$$\bar{U}_s\left(R, A\right) = \max_{\xi_s \in \Xi} \mu\left(\Theta\left(\xi_s\right)\right) \cdot u_s\left(p_s, q_s; R, A\right)$$

3. Market Clearing

$$\begin{aligned} \int_{\Xi^P} \frac{\gamma_1\left(\xi_s\right)}{\Theta\left(\xi_s\right)} d\lambda\left(\{\xi_s\}\right) &\leq \eta \\ \int_{\Xi^P} \frac{\gamma_0\left(\xi_s\right)}{\Theta\left(\xi_s\right)} d\lambda\left(\{\xi_s\}\right) &\leq 1-\eta \end{aligned}$$

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:

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

The optimization problem (3) chooses market tightness $\theta_0 \equiv \Theta\left(\xi_0\right)$ and contract $\xi_0 = \left(p_0, q_0\right)$ 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:

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

The optimization problem (4) chooses market tightness $\theta_1 \equiv \Theta\left(\xi_1\right)$ and contract $\xi_1 = \left(p_1, q_1\right)$ 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).

3.5 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 Secto**r : 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.

3.6 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 B.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. The details are in Section B.2 of the Appendix.

4 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 $s = 1$ 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.

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

4.1 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 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

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	

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.

4.2 Results from Comparative Statics Exercises

Section A 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 (2) 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 (2). 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 (2) 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 (3) 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 (3) and Figure (2) 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 (3). 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 (3), 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 (2), 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.[14] The key difference between the two is that their impact on the net

[14]Figures (5) and (7) 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

interest spread $R^B - R^A$ is different.[15] This is the key insight that will allow us to do moment matching and then the subsequent welfare analysis.

Figure (4) 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.

5 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.

5.1 Moment Matching

As mentioned in Section 4, 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.

through the intensive margin when we only focus on R^A and R.

[15]This can also be seen in Figure (6), which is a three-dimensional figure that show how the net interest spread is affected simultaneously by the two margins.

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	

5.2 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

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

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

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

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

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 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 (8), 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 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 (8) suffer relatively less compared to others.

5.3 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 (9) 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 (8), x-axis denotes the percentile of asset holding and y-axis denotes the percentile of

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

labor earnings among all households at the steady state. Comparing this figure against Figure (8), 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 (9). 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.

6 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.

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Appendix

A Figures and Tables

Figure 1: Distribution of US Bank Assets

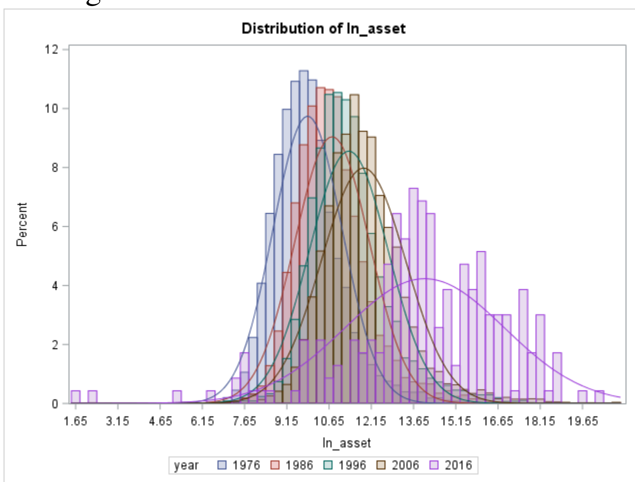

Figure 2: Comparative Statics: Changing $g(0)$

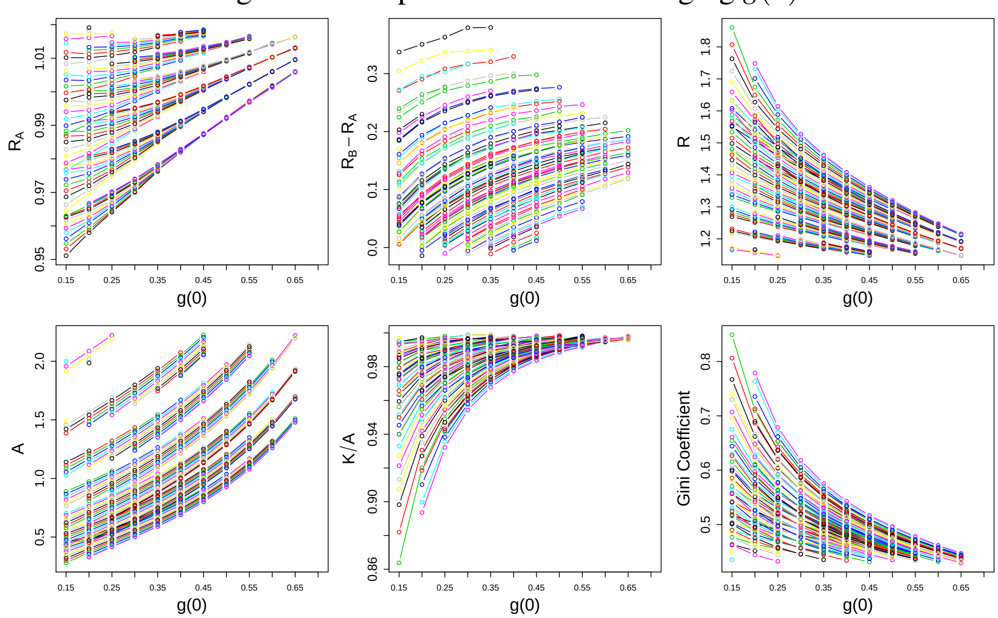

Figure 3: Comparative Statics: Changing η

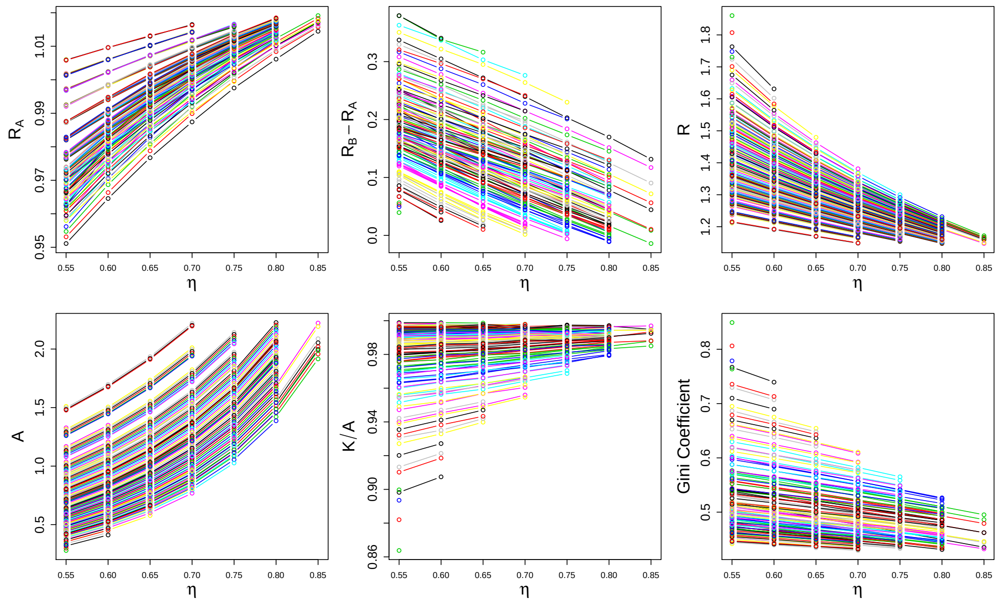

Figure 4: Comparative Statics: Changing τ

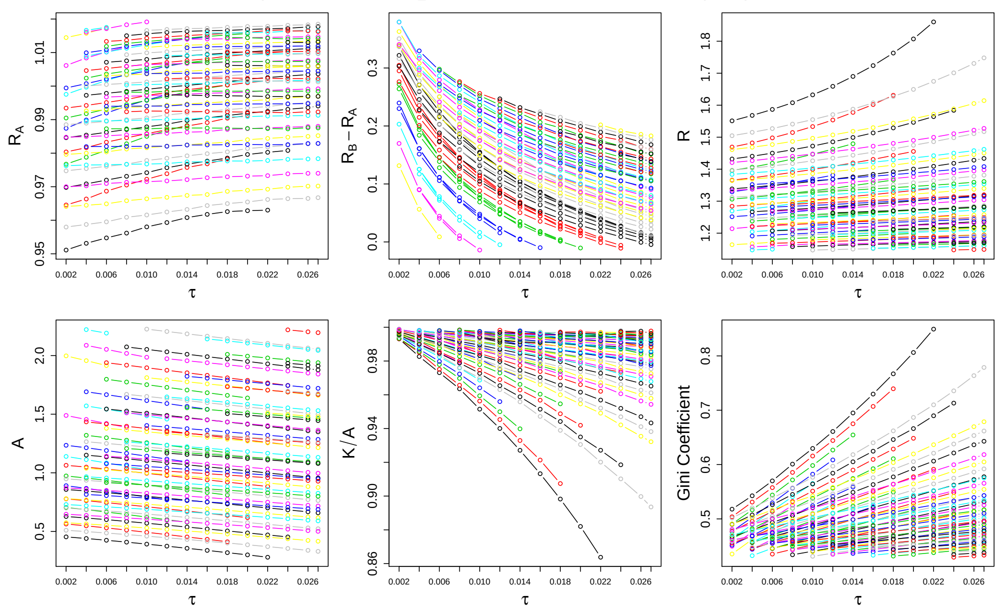

Figure 5: Impact of the Two Margins of Adverse Selection on R^A

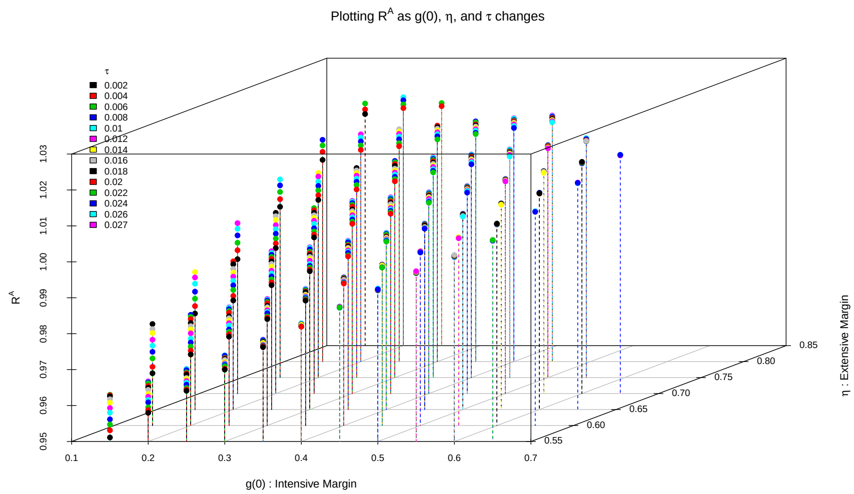

Figure 6: Impact of the Two Margins of Adverse Selection on Net Interest Spread

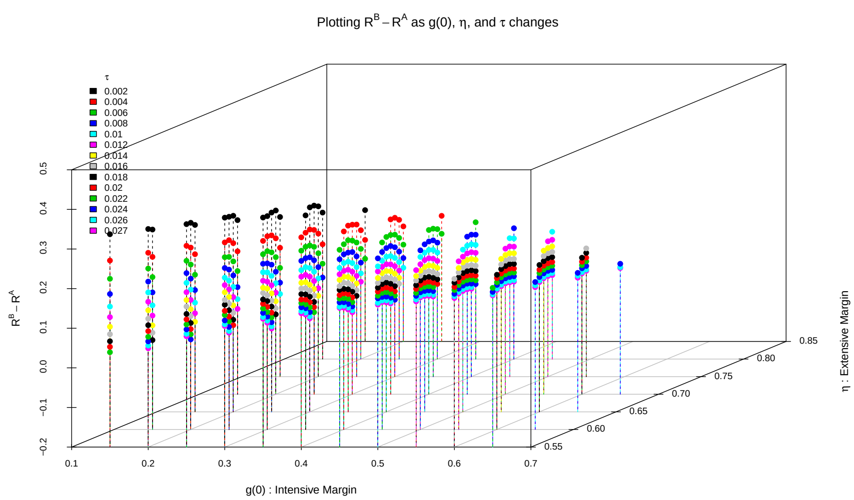

Figure 7: Impact of the Two Margins of Adverse Selection on R

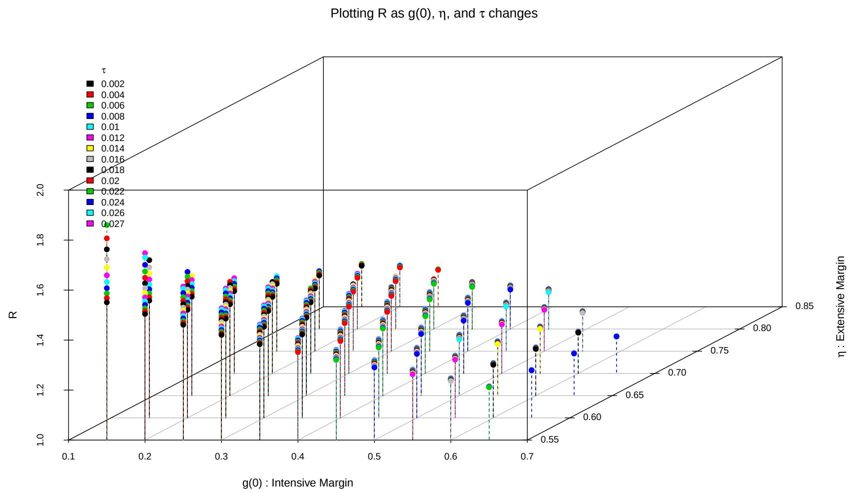

Figure 8: Welfare Analysis: Financial Innovation Magnifies the Adverse Selection Problem Through the Intensive Margin

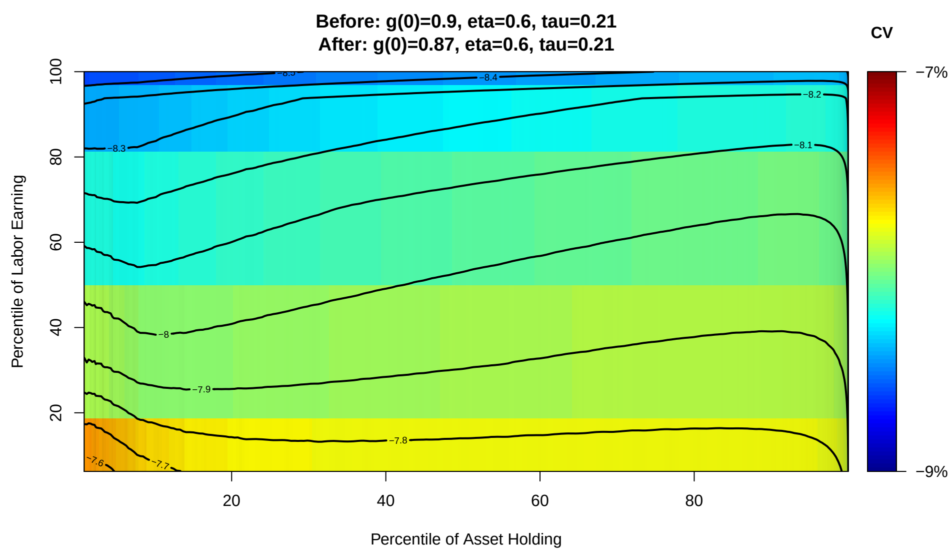

Figure 9: Welfare Analysis: Financial Innovation Lessens the Adverse Selection Problem Through the Extensive Margin

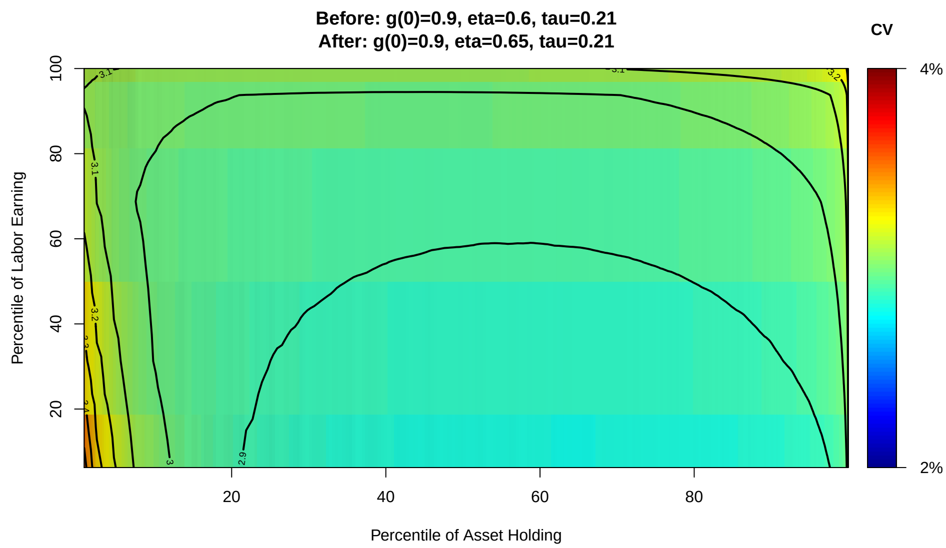

Table A1: Summary Statistics of US Bank Assets

Year	Observation	Mean (million \$)	Median (million \$)	Variance	Skewness
1976	14740	884.19	174.14	1.13×10^{12}	46.3274693
1977	15251	1003.05	195.74	1.43×10^{12}	47.1248488
1978	15040	1149.81	221.39	1.87×10^{12}	46.6266725
1979	14917	1268.95	238.81	2.47×10^{12}	46.7877916
1980	15300	1429.28	265.12	2.84×10^{12}	45.1456884
1981	15364	1551.64	290.84	3.21×10^{12}	44.4112183
1982	15433	1677.31	314.40	3.48×10^{12}	43.0483532
1983	15426	1795.02	340.61	3.46×10^{12}	41.0630224
1984	15396	1908.95	356.29	3.65×10^{12}	40.1583111
1985	15392	2090.76	379.46	4.20×10^{12}	41.1261741
1986	15278	2318.83	408.22	4.66×10^{12}	40.370786
1987	14791	2500.94	420.41	4.80×10^{12}	38.5911205
1988	14225	2747.64	439.93	5.03×10^{12}	35.4476899
1989	13820	2998.84	471.01	5.79×10^{12}	35.2646925
1990	13442	3175.43	502.32	6.08×10^{12}	33.4523638
1991	13022	3356.79	530.53	6.58×10^{12}	33.2939283
1992	12619	3530.57	570.22	7.92×10^{12}	34.3338499
1993	12170	3816.53	602.60	9.64×10^{12}	33.2591039
1994	11632	4300.18	628.99	1.33×10^{12}	33.8749726
1995	11089	4820.65	678.24	1.67×10^{12}	32.0496938
1996	10632	5334.66	712.29	2.58×10^{13}	35.0956669
1997	10197	6089.25	732.35	3.99×10^{13}	31.1760767
1998	9763	6797.24	781.49	5.46×10^{13}	31.4525417
1999	9491	7315.38	811.79	7.88×10^{13}	42.3629744
2000	9180	8196.42	849.06	9.66×10^{13}	38.9201701
2001	8971	9268.08	920.41	1.26×10^{14}	36.186822
2002	8730	10126.36	990.33	1.58×10^{14}	35.5782373
2003	8590	11029.82	1054.37	1.92×10^{14}	34.343353
2004	8409	12568.54	1117.23	3.21×10^{14}	38.5918825
2005	8284	13974.89	1189.25	4.27×10^{14}	39.6427009
2006	8224	15893.18	1240.77	5.97×10^{14}	39.3269657
2007	8082	18249.36	1312.26	8.11×10^{14}	38.0803535
2008	7855	20130.37	1405.17	1.06×10^{15}	40.203764
2009	7597	19929.66	1512.27	1.01×10^{15}	39.3682548
2010	7267	21351.09	1543.97	1.16×10^{15}	37.2653391
2011	7056	23133.17	1608.66	1.36×10^{15}	36.9190071

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B Mathematical Detail

B.1 Proof of Proposition 2

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

$$\bar{U}_0(R,A) = \max_{p_0,q_0,\theta_0} \left[\min\{\theta_0, 1\}(1-q_0)\, g(0)\, R p_0 A\right] \tag{7}$$

$$\text{subject to} \quad \left[\min\left\{\frac{1}{\theta_0}, 1\right\}\left\{q_0 g(0) R p_0 + R^B (1-p_0)\right\} + \left(1 - \min\left\{\frac{1}{\theta_0}, 1\right\}\right) R^B\right] A \geq \tau$$

and

$$\bar{U}_1(R,A) = \max_{p_1,q_1,\theta_1} \left[\min\{\theta_1, 1\}(1-q_1)\, g(1)\, R p_1 A\right] \tag{8}$$

$$\text{subject to} \quad \left[\min\left\{\frac{1}{\theta_1}, 1\right\}\left\{q_1 g(1) R p_1 + R^B (1-p_1)\right\} + \left(1 - \min\left\{\frac{1}{\theta_1}, 1\right\}\right) R^B\right] A \geq \tau$$

$$\min\{\theta_1, 1\}(1-q_1)\, g(0)\, R p_1 A \leq \bar{U}_0(R,A)$$

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

$$\tau = \left[\min\left\{\frac{1}{\theta_s}, 1\right\}\left\{q_s g(s) R p_s + R^B (1-p_s)\right\} + \left(1 - \min\left\{\frac{1}{\theta_s}, 1\right\}\right) R^B\right] A$$

$$\Longrightarrow \quad \tau = \left[\min\left\{\frac{1}{\theta_s}, 1\right\}\left\{q_s g(s) R p_s - R^B p_s\right\} + R^B\right] A$$

$$\Longrightarrow \quad q_s = \frac{1}{g(s) R p_s A}\left[R^B p_s A + \frac{\tau - R^B A}{\min\left\{\frac{1}{\theta_s}, 1\right\}}\right] \tag{9}$$

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

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

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

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

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

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

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

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

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 $p_1 = 1$.[16] 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

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

B.2 Algorithm for Computing the Steady State

The algorithm for computing the steady state is the following:

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 B.3.

[16] 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.

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 B.4.

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.[17] We use a step function to approximate the CDF of the stationary distribution.

B.3 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, $K \neq A$. 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

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

[17] 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.

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.

B.4 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 B.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

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

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

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

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