Regulatory Competition and Bank Risk Taking

Itai Agur (Dutch Central Bank)[*]

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Abstract

How damaging is competition between bank regulators? This paper models regulators that compete because they want to supervise more banks. Both banks' risk profiles and their access to wholesale funding are endogenous, leading to rich interactions. Regulatory competition does not generally lead to a "race to the bottom". But with multiple regulators banks are both more profitable and more fragile. Welfare gains from regulatory consolidation are highly sensitive to liquidity risk, moral hazard and adverse selection. The paper also shows how complex balance sheet items give rise to a gradual rise in bank risk, followed by a sudden interbank crisis.

Keywords: Supervision, Arbitrage, Bank risk, Liquidity risk, Interbank market

JEL Classification: G21, G28

1   Introduction

"Retaining multiple regulatory agencies preserves the regulatory arbitrage that allows institutions to pick the oversight scheme that benefits them most, often at the expense of consumers and the health of the system overall" Letter by Senator Schumer to Treasury Secretary Geithner.[1]

The potential for competition between bank regulators to harm regulatory standards is high on the political agenda. In the US banks can in effect select their primary regulator by choosing their charter and deciding on Fed membership. The OCC regulates nationally chartered banks, the Fed state-chartered member banks and the FDIC state-chartered non Fed-members. In Europe, instead, financial conglomerates and the fracturing of regulation along national lines are possible sources for regulatory arbitrage.

How damaging is it that banks can play out one regulator against the other? To what extent does regulatory competition have the potential to induce laxity in regulatory standards? On June 17th, 2009, President Obama revealed plans for a new system of US financial regulation. His administration backed away from consolidating all banking regulation in one agency, however. Is this decision detrimental to future financial stability? This paper develops a model to rigorously analyze these questions. It considers the role of regulatory competition in an environment in which both the riskiness of banks' asset portfolios and their access to funding are endogenous.

The model contains two regulators. The regulators weigh not only social welfare, but also have agency considerations. They gain utility from supervising more banks. It is this non-benevolent aspect of their preferences that gives rise to the competition amongst them. Optimizing over both welfare and their ability to draw in banks, regulators announce their standards for bank risk taking. Subsequently, banks choose the regulator that they prefer to supervise them.

Subject to the constraints of the chosen regulator, banks then determine their optimal risk

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[1]MSNBC, June 17th, 2009: http://www.msnbc.msn.com/id/31354523/ns/business-stocks_and_economy

profile. Risk taking increases expected return while raising the probability of bank failure. However, bank managers do not fully internalize the social costs of bank failure (due to safety nets). Thus, banks take too much risk from a social perspective. This moral hazard provides the rationale for the presence of regulation.

The final stages of the game model banks' access to liquidity through an unsecured interbank market. This interbank market is modelled similarly to Freixas et al. (2004). Banks are subject to both liquidity and solvency shocks. The latter are endogenous to bank risk. However, interbank participants are unable to disentangle the type of shock that a bank is subject to. This matters because insolvent banks have an incentive to borrow and use the acquired funds to gamble for resurrection. This gives rise to adverse selection problems. The higher a bank's risk is thought to be, the larger the credit risk spreads it needs to pay. Access to wholesale funding can even freeze altogether. The importance of such mechanisms in the recent crisis is discussed by Morris and Shin (2009), Brunnermeier (2009) and Heider et al. (2009). Under these conditions, regulation has value to banks. It allows them to credibly convey limits on their risk taking. This reduces borrowing costs and facilitates access to interbank funding. A similar signalling effect is found in Allen et al. (2009), where banks hold extra capital to signal good loan monitoring incentives, thereby facilitating wholesale funding.

We solve the model numerically. A robust finding is that regulatory competition rarely leads to extreme outcomes ("race to the bottom"). We compare welfare under regulatory competition to that under a single regulator. Welfare effects are highly sensitive to liquidity risk, adverse selection and, above all, banks' moral hazard. Aggregating over thousands of simulations, we find that on average the model predicts only modest welfare gains to regulatory consolidation. However, behind the average welfare gain hide two forces: bank profit and default risk. Regulatory consolidation cuts bank risk taking by about 15-25%. This reduces bank profitability by 7-8%. The Obama administration's decision not to consolidate regulation is thus a choice for retaining a profitable but fragile financial system.

The basic model contains only two banks. We extend the model to a continuum of banks and analyze the implications for the model's results, which are shown to be quite robust.

Subsequently, we relax the assumption that regulators are able to perfectly observe banks' chosen risk profiles. Relating to the buildup to the current crisis, we analyze the consequences of a gradual decrease in monitoring capacity. This can happen due to a rise in the complexity of items on banks' balance sheets (and off-balance-sheet products). We show that weakening monitoring leads to a gradual rise in bank risk until a threshold is reached. Beyond it, the interbank market freezes.

We also find several more general results, not particular to regulatory competition. Firstly, interbank market activity can sometimes be socially detrimental. Society bearing part of the cost of bank failure brings about an implicit, and sometimes unwarranted, subsidy on interbank activity. More often, however, adverse selection causes the interbank market to freeze when it would be socially optimal for it to remain open. Moreover, small movements in liquidity risk are capable of inducing such an interbank gridlock. Finally, we show that banks' optimal risk taking is v-shaped in liquidity risk. Banks take least portfolio risk for medium liquidity risk, when access to funding matters and there is enough credit available.

Rosen (2003) empirically investigates the effects of regulatory competition in the US. Over his 1983-1999 sample period 10% of banks switched regulators at least once. Big banks are more likely to change regulator. Rosen finds that switches are not followed by significant increases in bank risk.[2] This finding is not at odds with our theory. On the path to equilibrium regulators only marginally undercut each other. At each given point, the difference between regulators' standards is small, therefore. But the difference between the single and multiple regulator steady states might still be large, depending on parameter values.

Our theory does not capture some potentially beneficial effects of regulatory competition. For instance, regulators can differentiate horizontally (Tiebout (1956)). Competition can also enhance the efficiency of regulatory services (Kane (1984), Dermine (1991)), and it can help prevent collusion between the regulator and the regulated firms (Laffont and Martimort (1999)). Abstracting from these issues raises the question why separate regulators exists in

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[2]Gart (1993) instead discusses several cases of US regulators luring in new members with the incentive of reducing the burden of regulation.

our model. However, it is often claimed that the US system of bank regulation evolved for historical reasons, and is sustained as a political equilibrium (Scott, 1977). Thus, a recent Financial Times article argues that "the administration has decided not to consolidate more regulators due to the political difficulties involved" (Guha and Braithwaite, 2009). In his article "America Needs a Single Bank Regulator" Senator Warner (2009) explicitly states that "as past administrations have learnt, the status quo has many stakeholders who will bitterly oppose even the most objectively meritorious change".

Three existing papers model competition between bank regulators. Dell'Ariccia and Marquez (2006) analyze the incentives of heterogeneous, national regulators to form a regulatory union. Banks are multinational. A trade-off arises between internalizing the externalities imposed by international banking and losing flexibility in a union. In Dalen and Olsen (2003) bank risk is not lowered by a union. Though externalities imply sub-optimal capital requirements, national regulators' concern for the cost of deposit insurance induces them to raise loan quality standards in response. Finally, Freixas et al. (2007) study regulatory arbitrage by financial conglomerates. They show that a conglomerate's shifting of assets to the less regulated division can help improve market discipline. Assets are shifted away from sectors where safety nets create moral hazard incentives. In contrast to the above papers we focus on the US setting: one country, one industry (banking), and several regulators. Moreover, we add an endogenous bank funding side.

Several papers model the potential for interbank failures. These include Allen and Gale (2000), Allen et al. (forthcoming), Rochet and Tirole (1996), Rochet and Vives (2004), Freixas et al. (2000, 2004) and Freixas and Holthausen (2005). As mentioned, our interbank market modelling follows Freixas et al. (2004). For general reviews of the literature on bank regulation we refer to Battacharya et al. (1998), Santos (2001) and Carletti (2008). Competition among regulators is also investigated in the literatures on tax competition (Fuest et al. (2005)) and environmental regulation (Oates (1996)).

2 Model

Our model consists of two banks, bank$_a$ and bank$_b$, and two regulators, regulator$_x$ and regulator$_y$. The game between banks and regulators takes the form depicted in table 1.

Table 1: Timing of the Game

1. Regulators announce policy
2. Banks choose regulator
3. Banks choose risk profile
4. Solvency shock realized
5. Liquidity shock realized
6. Interbank borrowing and lending

We first describe the objectives of regulators, then those of banks, and finally the role of shocks and the interbank market.

A Regulators

Regulators are assumed to suffer from agency problems. Aside from society's welfare, they put a weight on the size of their regulatory mandate. In particular, they care about the number of banks under their supervision. Regulatory competition arises from non-benevolent objectives. Regulators that are purely concerned with social welfare would not compete against each other, after all. Regulators' objective function is:

$$\max_{\bar{\rho}_k} \left\{ \alpha w \left(\rho_a, \rho_b \right) + \left(1 - \alpha \right) m_k \right\} \tag{1}$$

Here $k = x, y$ indexes the regulator, m is the number of banks supervised by regulator$_k$ and $\alpha \in (0, 1)$ is regulators' weight on social welfare. Moreover, ρ_a and ρ_b are the risk profiles chosen by the two banks. Social welfare, $w \left(\rho_a, \rho_b \right)$ is a function of these risk profiles. The way in which welfare depends on risk profiles is discussed later.

Finally, $\overline{\rho}_k$ is the risk ceiling that the regulator$_k$ sets on banks under its regulation. One can think of this risk-ceiling as the corollary of a capital requirement. A regulator that has a risk-weighted capital requirement essentially imposes a risk ceiling for a given amount of bank capital. Thus, assuming that banks enter the game with a given amount of capital, regulators fix the maximum risk profile that banks are allowed to choose.

Two assumptions underlie the optimization in equation (1):

Assumption 1 Regulators can perfectly monitor banks. They observe the risk profiles ρ of the banks under their supervision.

Assumption 2 Regulators can enforce their risk ceiling $\overline{\rho}_k$ on the banks they supervise.

Especially in light of recent events, the ability of regulators to effectively monitor banks has been questioned. Section 4 introduces imperfect monitoring.

Finally, note that though $\overline{\rho}_k$ does not figure directly in $\alpha w\left(\rho_a, \rho_b\right) + (1 - \alpha) m_k$, in equilibrium the risk ceiling will affect both bank risk profiles, (ρ_a, ρ_b), and the number of banks under a regulator's supervision, m_k.

B   Banks

Banks' role in the model is threefold. Firstly, banks choose their regulator. Banks are assumed not to have been assigned to any regulator before the start of the game. Or, equivalently, there is a zero switching cost from the previous regulator. Secondly, banks choose their risk profile, subject to the policy of the regulator they have chosen. And, thirdly, banks interact on the interbank market.

In particular, the objective function of bank i (with $i = a, b$) is as follows:

$$\max_{\rho_i \leq \overline{\rho}_k} \left\{ \rho_i - \gamma \rho_i^2 + f_i\left(\rho_i, \rho_j\right) \right\} \tag{2}$$

with $j \neq i$. This formulation is described in several steps. Underlying it are the following assumptions:

Assumption 3 Banks are risk neutral.

Assumption 4 Banks do not fully internalize the social cost of their own failure.

Banks choose a risk profile, $\rho_i \in [0, 1]$, for their portfolio (including loans and other assets). A larger ρ_i means a riskier portfolio. The advantage of taking more risk is a higher expected return. The first term in the maximization problem, ρ_i, implies that the expected return increases linearly in the chosen risk profile. The disadvantage of a riskier portfolio is a higher probability of bank failure. At stage 4 of the game banks are faced with a solvency shock. If a bank is hit by the shock, it fails. The probability of being hit by the shock is ρ_i^2. That is, the probability of bank failure increases quadratically in the risk profile. In combination with the linear benefit, this will ensure interiority of the optimal risk profile.

If a bank fails, society experiences a loss worth 1. This loss represents all the costs that the bankruptcy imposes on welfare, such as lost bank-depositor and borrower-bank relationships, and direct losses to stakeholders. As stated by assumption 4, banks internalize only a part of this cost. This is represented by $\gamma \in [0, 1]$. In reality there can be various reasons that bank management does not fully internalize the cost of bank failure. Safety nets, such as deposit insurance, and principal-agent problems figure prominently. Essentially, γ is a reduced form of the standard moral hazard problems associated with banking, which drive banks to take on too much risk from a social perspective. In turn, the fact that banks take on too much risk motivates the presence of regulatory agencies in the model.

Banks optimize subject to the risk constraint $\bar{\rho}_k$ imposed by their selected regulator. To recap: at stage 1 regulator$_x$ and regulator$_y$ announce $\bar{\rho}_x$ and $\bar{\rho}_y$; at stage 2 banks select their regulator; and at stage 3 banks then optimize their risk profile subject to the risk ceiling of their regulator, $\rho_i \leq \bar{\rho}_k$.

The last term in the bank's problem, $f_i\left(\rho_i, \rho_j\right)$, represents the value of the interbank market and its relation to bank risk taking. It is explained below. The reason that this term figures in banks' stage 3 optimization is that banks realize how their decisions influence the interbank market, and take this into account when setting their risk profile.

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C   Interbank market

The setup of the interbank market is similar to Freixas et al. (2004), in which banks are subject to both solvency and liquidity shocks. In contrast to Freixas et al., however, the solvency shocks are endogenous in our model, and occur with probability ρ_i^2, as discussed above. The liquidity shock then occurs with probability $q(1 - \rho_i^2)$. That is: if no solvency shock occurred, $(1 - \rho_i^2)$, then there is an exogenous chance, q, that a bank will be subject to a high liquidity withdrawal. The solvency and liquidity shocks are stages 4 and 5 of the game.

The fundamental problem of the interbank market is the opacity of banks' balance sheets. A bank cannot discern whether another bank has been hit by a liquidity or a solvency shock.[3] As in Freixas et al. an insolvent bank can mimic an illiquid bank in order to receive funding. This funding is of value to it, because it allows the bank to gamble for resurrection. However, gambling for resurrection is a negative NPV activity, destroying part of the value of the loan. Thus, the interbank market is plagued by adverse selection problems.

Gambling for resurrection is assumed to succeed - the borrowing bank is saved - with an exogenously given probability $\pi \in [0,1]$. The lending bank is assumed to lose the entire value of the loan if the borrowing bank defaults. If, instead, the gamble succeeds, it receives back the loan and the interest on it.

Assumption 5 Banks are unable to distinguish solvency from liquidity shocks in their inter-
bank partners.

Assumption 6 Insolvent banks attach positive value to receiving a loan.

Call φ_i the state of bank i with $\varphi_i = s, l, n$ meaning that the bank faces a solvency shock (s), a liquidity shock (l), and no shock (n), respectively. The liquidity shock is always of a given size. That is, the size of the required loan is fixed. We normalize it to 1. As the basic model contains two banks, interbank lending can only take place when one of the banks has not been hit by any shock. That is, lending can take place for $(\varphi_i = n \wedge \varphi_j \neq n) \vee (\varphi_i \neq n \wedge \varphi_j = n)$.

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[3]The role of banks' information about each other on the interbank market is empirically investigated by Cocco et al. (2009).

The possibility of an aggregate liquidity shock is particular to the setup with a finite number of banks. In section 3 we extend to a continuum of banks in which there is always a fraction of banks capable to lend (though credit rationing or interbank gridlock can still occur in equilibrium).

The interest rate

In an interbank market with a finite number of banks, the issue of bank market power could play a role (Acharya et al. 2007). We abstract from such considerations, and focus on interest rates as they would prevail in perfectly competitive markets. We set the risk free interest rate to zero, and assume that a lending bank receives a spread over the risk-free rate if the borrowing bank is solvent. We do not specifically model the period of repayment as it is not essential to the model. Then, the interest spread, r_i, on an interbank loan from bank j to bank i can be computed from:

$$E_j \left[\left(1 - \rho_i^2 \right) \right] (1 + r_i) + E_j \left[\rho_i^2 \right] \pi (1 + r_i) = 1$$

as with expected probability $E_j \left[(1 - \rho_i^2) \right]$ the borrowing bank is solvent and the lending bank receives return r_i. With expected probability $E_j \left[\rho_i^2 \right]$ the borrowing bank is insolvent, and the lending bank receives a positive return only if the gamble for resurrection succeeds (and zero otherwise). This yields:

$$r_i = \frac{1}{1 - E_j \left[\rho_i^2 \right] (1 - \pi)} - 1 \tag{3}$$

Intuitively, therefore, greater risk taking raises the spread, as do larger expected losses on lending to an insolvent bank (lower π).

Note that despite the fact that banks are identical, the expectations operator cannot be deleted. It can be foreseen that in equilibrium banks will have the same risk profile. But this is not the same as banks knowing each other's risk profile. In principle, off equilibrium each bank optimizes given its expectations of the other's behavior. However, regulatory standards, $\bar{\rho}_k$, will provide a credible way to fix mutual expectations of risk taking.

The value of the interbank market

The expression for the value of access to the interbank market, $f_i\left(\rho_i, \rho_j\right)$, is given by:

$$f_i\left(\rho_i, \rho_j\right) = \max\left\{0, \left(\gamma - r_i\right)\left(1 - q\right)\left(1 - E_i\left[\rho_j^2\right]\right)\left[\left(1 - \rho_i^2\right)q + \rho_i^2\pi\right]\right\} \tag{4}$$

First, by equation (3) the expected value of lending on the interbank market is zero. Hence, the expected value of borrowing determines $f\left(\rho_i, \rho_j\right)$. Default costs a bank γ, while the cost of borrowing is r_i. Thus, successfully saving a bank is worth $\left(\gamma - r_i\right)$ to its manager. The probability that he can obtain a loan is $\left(1 - q\right)\left(1 - E_i\left[\rho_j^2\right]\right)$, i.e. the counterparty is liquid and solvent. Finally, with probability $\left(1 - \rho_i^2\right)q$ the bank is borrowing because it is illiquid, while with probability ρ_i^2 it is actually insolvent. In the latter case, receiving the loan is worth only $\pi\left(\gamma - r_i\right)$ to it. However, when credit risk spreads are so high that $r_i > \gamma$, no bank would be willing to borrow. In this case the interbank market freezes and $f_i\left(\rho_i, \rho_j\right) = 0$.

D   Social planner

To close our description of the model, we write down the social planner's problem. The social planner maximizes welfare, $w\left(\rho_a, \rho_b\right)$. Note that the problem of a benevolent social planner is equivalent to that of a non-benevolent, single regulator. In the latter's objective function, given by equation (1), the number of banks supervised, m, is fixed (the single regulator supervises all banks). Hence, he only maximizes over $w\left(\rho_a, \rho_b\right)$.

As banks are identical a social planner sets $\rho_a = \rho_b = \rho$. This simplifies notation to

$$w\left(\rho\right) = 2\left(\rho - \rho^2\right) + g\left(\rho\right) \tag{5}$$

where $\left(\rho - \rho^2\right)$ is the social value of bank risk taking (with cost of failure 1 instead of γ). Furthermore, $g\left(\rho\right)$ is the social value of interbank lending:

$$g\left(\rho\right) = \max\left\{0, 2\left(1 - \rho^2\right)^2 q\left(1 - q\right) - 2\rho^2\left(1 - \rho^2\right)\left(1 - q\right)\left(1 - \pi\right)\right\} \tag{6}$$

Note that g, like f_i, has a max operator. As we will show, for some parameter values it can be optimal for the social planner to close down the interbank market. In the absence of this option, welfare could perversely be higher in the competitive equilibrium than under the social planner.

The social planner thus has two tools to maximize $w(\rho)$: he can set bank risk taking, ρ, and he can decide whether to leave the interbank market open or not. However, there exists no analytical solution for the social planner's problem. This is shown in a proof available upon request. Instead, we resort to numerical methods to solve the planner's problem. We do the same for the competitive equilibrium, because the FOC from banks' optimization problem is a fifth-order equation. By Abel's Impossibility Theorem, polynomials above the fourth-order are incapable of general algebraic solution (Abel, 1826).

E   Results

We first derive one useful property that will facilitate the numerical programming. Call $\overline{\rho}^*$ banks preferred risk ceiling. Then (proof in appendix B):

Lemma 1 $\overline{\rho}_x = \overline{\rho}_y = \overline{\rho}^*$.

What this Lemma says is that in equilibrium regulators fully adjust to banks' preferences. Both regulators, x and y, set their standards according banks' preferred regulation, $\overline{\rho}^*$. This happens regardless of the weight α that regulators place on social welfare in their objective function. The reason is that marginally reducing standards below those of the competing regulator, reduces welfare only marginally, but leads to a discrete gain for the regulator: both banks choose it as a supervisor. As formally shown in the proof, this leads to Bertrand competition between the regulators, continuing until banks' preferred standards are reached.

This property need not imply extreme outcomes. Regulation may fully adjust to banks' wishes, but banks do not necessarily want the absence of regulation in our model. Thanks to Lemma 1 the equilibrium of the game can be derived from an optimization problem by banks only. They set both their preferred regulation and their preferred risk taking subject

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to that regulation. Note that this is not the same as investigating "self-regulation" by banks. As previously discussed, the presence of the outside regulator has value to banks as a signal of solvency.

For given parameterizations, we numerically solve for $\overline{\rho}^*$. The same is true for socially optimal risk taking, ρ^w. The GAUSS program that we have written to solve these problems is available upon request. The output of the numerical simulations for a wide variety of parameterizations is given in figures in appendix A. In this section we first list the main robust findings that emerge from our simulations. Subsequently, we discuss four figures as examples of those findings. Four key findings on regulatory competition are:

Finding 1: Regulatory competition often does not lead to extreme outcomes ("race to the bottom").

Finding 2: Welfare effects are highly sensitive to the extent of liquidity risk, adverse selection and, above all, moral hazard.

Finding 3: Averaging over simulations, the welfare gains of reforming regulation are modest.

Finding 4: Both bank profitability and financial fragility are higher with multiple regulators.

Three findings that are not particular to regulatory competition are:

Finding 5: Both interbank market activity and gridlock can be socially detrimental.

Finding 6: Small movements in liquidity risk can induce an interbank gridlock.

Finding 7: Bank optimal risk taking is non-monotonic in liquidity risk.

We explain these findings with the help of examples of simulations depicted in figures 1-4. The robustness of the figures' features can be checked with the figures in the appendix. In these figures the solid line represents $\overline{\rho}^*$: the standards that emerge under regulatory competition. As is simple to show, furthermore, in equilibrium a bank always sets its risk taking equal to the risk constraint, $\rho_i^* = \overline{\rho}^*$. Thus, the solid line represents both regulatory standards and

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banks' optimal risk taking. The dashed line is socially optimal risk taking, ρ^w. Finally, the dotted line represents the welfare gain achieved by implementing socially optimal risk taking (ρ^w) as opposed to banks' preferred risk taking ($\overline{\rho}^*$). The value of the dotted line should be multiplied by one hundred to get the percentage welfare gain. For instance, if the value of the dotted line is 0.1 this implies a 10% welfare gain to moving from $\overline{\rho}^*$ to ρ^w. We call this the welfare gain of regulatory reform. Equivalently, this can be termed the welfare cost of regulatory competition (recall that a single regulator would implement ρ^w).

Figure 1: Simulation with $q=0.2, \pi=0.3, \gamma \in [0,1]$
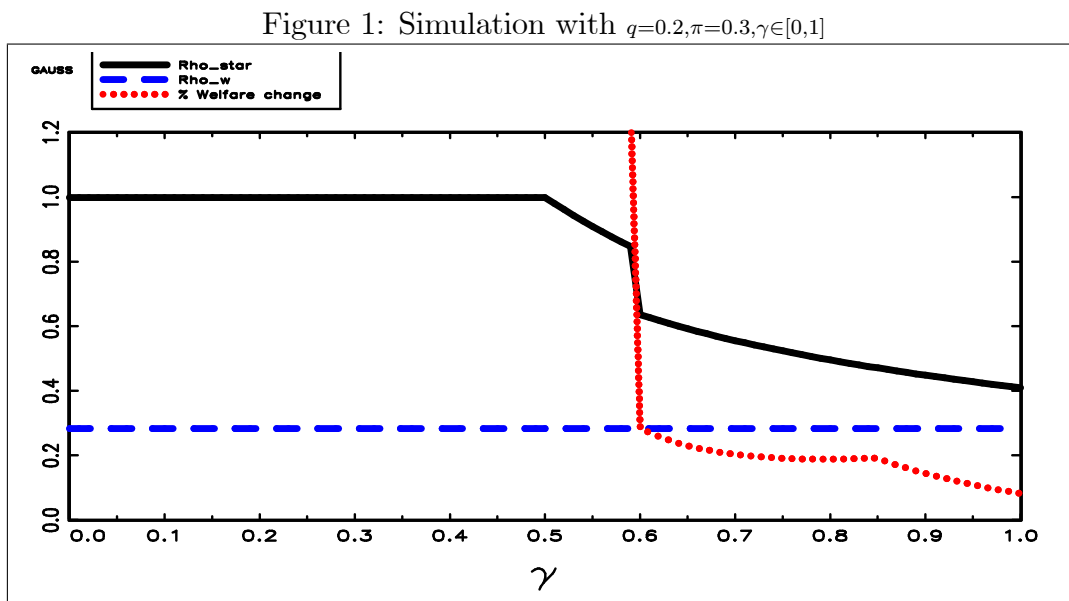
Figure 1 plots the outcome of a simulation in which $q = 0.2$, $\pi = 0.3$ and γ is varied between 0 and 1. That is, the values of γ are on the x-axis. This figure shows how sensitive welfare effects are to banks' moral hazard. As moral hazard problems worsen - γ decreases - the welfare costs of regulatory competition grow explosively. This can be seen from the pattern of the dotted line. When bank managers internalize less than half the costs of their bank's failure, $\gamma < 0.5$, they prefer zero regulation and the highest possible risk taking. Between $\gamma = 0.5$ and $\gamma = 0.6$ banks choose to set risk below $\rho = 1$. However, the interbank market remains frozen as credit risk spreads are too high. At about $\gamma = 0.6$ a functioning interbank market becomes a sustainable equilibrium. Here, regulation becomes of value to banks, and regulatory standards jump up (bank risk falls). As a consequence, the welfare

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costs of regulatory competition decrease strongly.

Note that $\overline{\rho}^* \nrightarrow \rho^w$ for $\gamma \to 1$. That is, banks that fully internalize are not equivalent to social planners. The reason is that even for $\gamma = 1$ a bank internalizes only the social cost of its own failure. But it does not internalize the costs that it imposes on the other bank. By taking more risks banks lower the value of the interbank market to each other. This is essentially an additional (endogenous) source of moral hazard in the model, not captured by γ.

Figure 2: Simulation with $\gamma=0.6, q=0.05, \pi\in[0,1]$
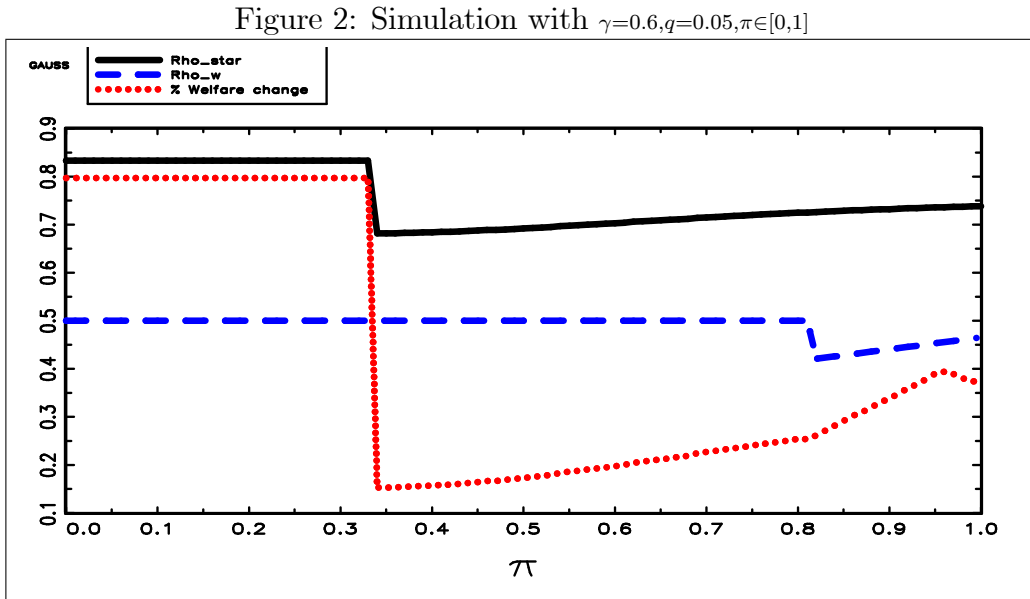
Figure 2 shows the sensitivity of the outcomes to adverse selection problems. A lower π means more severe adverse selection on the interbank market (costlier gambling for resurrection). In this simulation it takes $\pi > 0.35$ for the interbank market to work. At this point bank risk taking decreases, as do the welfare costs of regulatory competition. The sensitivity of welfare to π is less extreme than to γ, however. Interestingly, moreover, the social planner (dashed line) keeps the interbank market shut till $\pi = 0.8$. That is, the interbank market functions commercially, but its activity is socially detrimental. The reason is that society bears some of the value lost from gambling for resurrection by insolvent banks. Banks do not fully internalize the social cost of their activities, after all. Essentially, the fact that society pays for part of the cost of bank failure brings about an implicit subsidy on interbank activity.

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There is one final point of interest to notice about figure 2. When the interbank market is active (for $\pi > 0.35$) bank risk taking *rises* in π. Less severe adverse selection problems lead to more risk taking. The reason is that credit risk spreads fall when π increases. This means that the cost of accessing the interbank market becomes less prohibitive. As banks face less stringent conditions, they are willing to take more risk.

Figure 3: Simulation with $\gamma=0.95, \pi=0.1, q\in[0,1]$
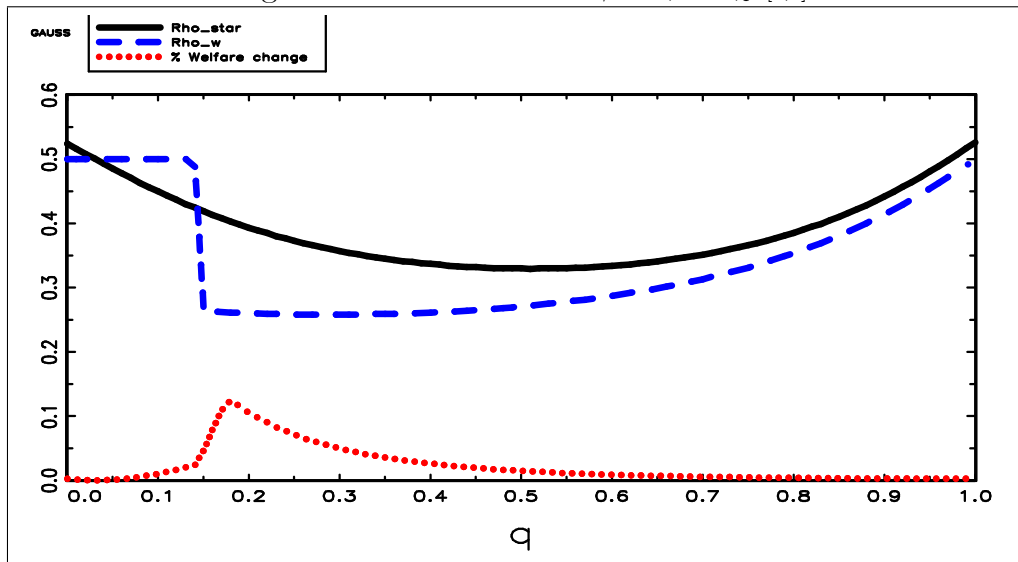
Figure 3 depicts sensitivity to liquidity risk. Bank risk taking first decreases and then increases in liquidity risk. The explanation for this convex shape is as follows. When liquidity problems are rare ($q \to 0$), access to the interbank market is relatively unimportant. Thus, a bank primarily optimizes over $\rho_i - \gamma\rho_i^2$. When liquidity risk becomes more prevalent, however (higher q), a bank puts greater emphasis on access to external funding. To obtain this access at reasonable credit spreads a bank requires sufficiently strict regulatory standards to signal its strength. Thus, $\overline{\rho}^*$ decreases pronouncedly in q, up to $q = 0.5$. But as q increases further, it becomes increasingly unlikely that the interbank market will function well. Aggregate shocks occur more often. Thus, the value of access to the interbank market decreases. And, once again, banks take their decisions primarily based on their direct risk-return trade-off, rather

than considering the implications on $f_i\left(\rho_i, \rho_j\right)$.

Figure 4: Simulation with $\gamma=0,6, \pi=0.3, q\in[0,1]$
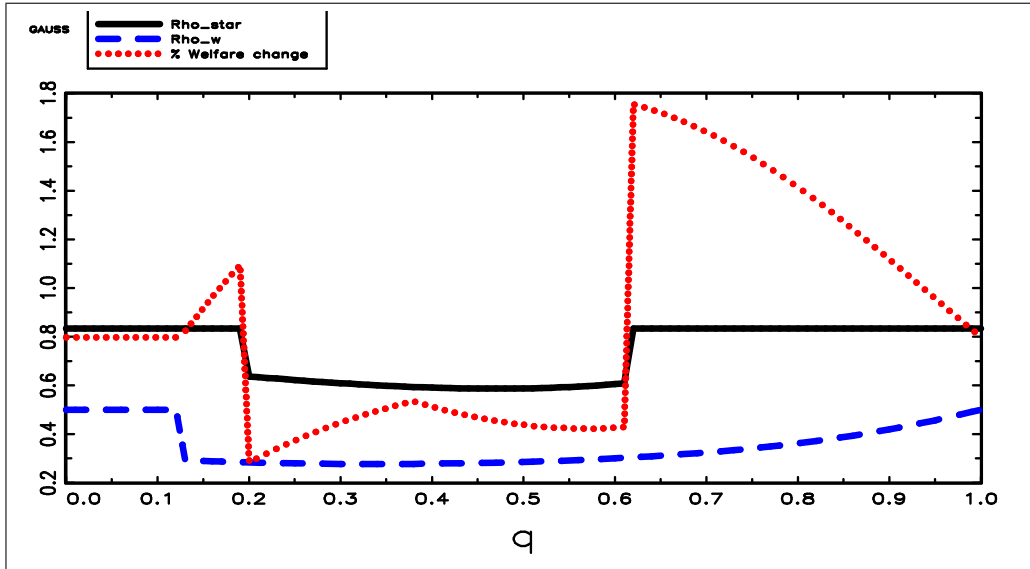
In figure 4 the interbank market freezes even though it is socially optimal for it to stay open. The social planner would open the interbank market beyond $q > 0.12$. But the solid line $(\overline{\rho}^*)$ is constant over q for both low liquidity risk $(q < 0.2)$ and high liquidity risk $(q > 0.6)$. This happens because $f_i\left(\rho_i, \rho_j\right) = 0$: the interbank market is closed. With high moral hazard (low γ) credit risk spreads quickly reach the threshold beyond which the market shuts down $(r_i > \gamma)$. As can be seen a small movement in liquidity risk, from for example $q = 0.60$ to $q = 0.61$, can induce interbank gridlock.

The simulations discussed so far have been examples of specific parameterizations. However, we would like to get some measure of the average size of the welfare gains from regulatory reform in our model. Figure 5 depicts a histogram of welfare effects that aggregates 45,000 simulations. Here, we have chosen to look at all parameterizations for $\gamma > 0.7$, $q < 0.3$, and $\pi < 0.5$ at steps of 0.01 (i.e., $\gamma = 0.7$, $\gamma = 0.71$ up to $\gamma = 1$, and for each of value of γ: $q = 0$, $q = 0.01$,..., $q = 0.3$, and for each value pair of γ and q: $\pi = 0$, $\pi = 0.01$, up to $\pi = 0.5$ - which gives $30 \times 30 \times 50 = 45,000$ different parameterizations). In figure 5 the average welfare effect is 8.3%, the median is 6.1%, while the standard deviation is 7.9 percentage points.

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Figure 5: Welfare effects for $\gamma>0.7, q<0.3, \pi<0.5$
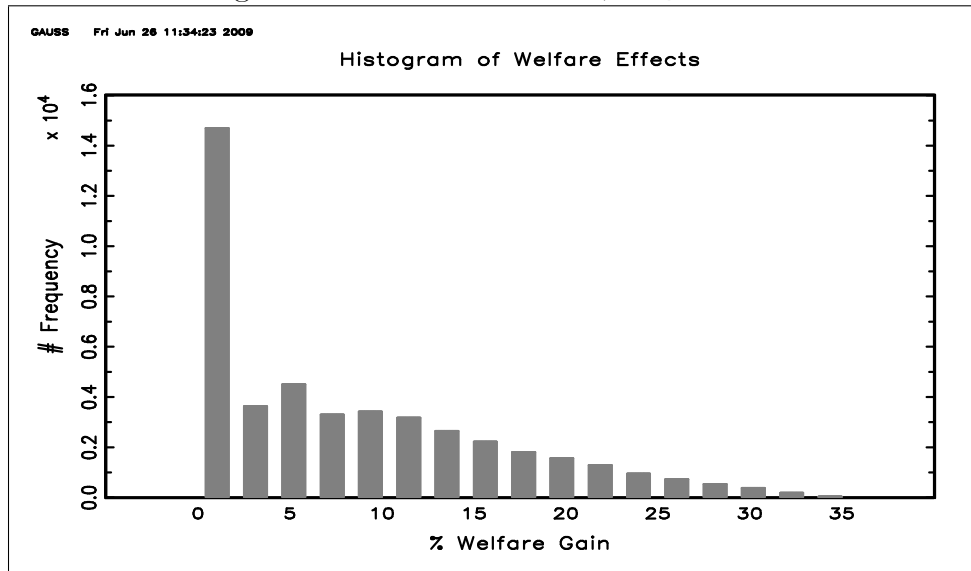
The value added of the US financial sector accounts for almost 8% of US GDP (Philippon, 2007). If we equate welfare to GDP, and assume that the welfare captured in the model is only that generated by the financial sector, then the 8.3% rise in the welfare translates into a 0.7% GDP gain. This seems quite a modest figure. However, the key problem is identifying what constitutes a relevant range of parameter values. The most important parameter in this respect is the degree to which banks internalize the costs of their failure, γ, as can be intuited from figure 1. Anecdotal evidence from the recent financial crisis certainly suggests that a significant fraction of the costs of bank failure is borne by society as opposed to bank equity holders. Lowering the cutoff for the range over γ to, say, $\gamma > 0.5$ has sizeable consequences for the average welfare effect. Aggregating over 75,000 simulations for $\gamma > 0.5$, $q < 0.3$, and $\pi < 0.5$ we obtain an average welfare effect of 133.5%. This is largely due to extreme observations for low γ, however. The median welfare gain is only 13.1%.

Even so, the regulatory setup matters for the type of financial system that evolves. Consider the simulations over $\gamma > 0.7$, $q < 0.3$, and $\pi < 0.5$. On average, bank risk taking is about 25% higher in a multiple regulator system. Moreover, bank profitability is 7% higher with multiple regulators. Consolidating bank supervision in a single regulator is a choice for a more stable, but less profitable financial system, therefore.

3 Continuum of banks

In this section we extend the model to a continuum of banks. There are several reasons for doing this. Firstly, with a continuum of banks the model yields smoother interbank dynamics. As long as $q < 1$ there are always some banks capable of lending. In the two-bank world once both banks are hit by a liquidity shock, no interbank trade can take place. Secondly, this provides a robustness check for the main mechanisms that we found in the basic model. And, finally, a continuum of banks may approach reality more closely, especially that of the US banking sector with its large number of banks.

We do not extend to a larger number of regulators. As is quite obvious from Lemma 1, this will make no difference in equilibrium. In addition, we retain the assumption of identical banks.[4]

In continuum notation, regulators' objective becomes:

$$\max_{\overline{\rho}_k} \left\{ \alpha w\left(\rho\right) + \left(1 - \alpha\right) m_k \right\} \tag{7}$$

where m_k is the mass of banks supervised by regulator k and where $\sum_k m_k = 1$: the total mass of banks is normalized to 1. Moreover, ρ is the risk taking of the representative atomistic bank.

An individual bank's objective function is:

$$\max_{\rho_i \leq \overline{\rho}_k} \left\{ \rho_i - \gamma \rho_i^2 + f_i\left(\rho_i, \rho\right) \right\} \tag{8}$$

An important issue is how to model the functioning of the interbank market when there is a continuum of banks. In particular, how borrowers match to lenders. In the basic model with two banks there was only one possible match. Instead, with a continuum we assume a random

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[4]Considering bank heterogeneity, it is known from the empirical literature that larger banks take on more risk (Demsetz and Strahan, 1997). If so, then regulatory standards first become binding for large banks. Therefore, it would be the behavior of large banks that drives the outcomes of regulatory competition. This, in fact, is consistent with Rosen's (2003) findings that it is mainly large banks that switch regulators. Our setup with identical banks could then be interpreted as a model of "large" banks only.

matching technology. Given the two pools of banks - those who want to borrow and those willing to lend - borrowers randomly match to lenders. Now f_i can be written as:

$$f_i(\rho_i, \rho) = A\left(\max\left\{0, (\gamma - r_i)\left[\left(1 - \rho_i^2\right)q + \rho_i^2\pi\right]\right\}\right) \tag{9}$$

where

$$A = \min\left\{1, \frac{(1 - \rho)(1 - q)}{1 - (1 - \rho)(1 - q)}\right\} \tag{10}$$

The reason is as follows. Among the mass of banks, the fraction of lenders is $(1 - \rho)(1 - q)$: banks that are both solvent and liquid. When this fraction is greater than 0.5, there are more lenders than borrowers. Therefore, every borrower can find a lender to match to. In this case, $A = 1$. Notice that if there are more lenders than borrowers, there is no expected loss to the lenders that do not match to a borrower: given the fair credit risk spread, lenders' expected return from lending is zero.

When, instead, $(1 - \rho)(1 - q) < 0.5$, then there are more banks that want to borrow than those willing to lend. Rationing takes place. The random matching technology then implies that each borrower has a probability of $\frac{\text{number of lenders}}{\text{number of borrowers}}$ to match to a lender. This probability is represented by the right part of the operator in equation (10).

Finally, the term for the credit risk spread, r_i, is as before (equation(3)). Welfare can now be written as:

$$w = \rho - \rho^2 + g(\rho) \tag{11}$$

where

$$g(\rho) = A\left(\max\left\{0, \left(1 - \rho^2\right)q - \rho^2(1 - \pi)\right\}\right) \tag{12}$$

Like for the basic model, we solve the model with a continuum of banks with numerical techniques (note that the proof of Lemma 1 is still valid with a continuum of banks). We can compare the models along two dimensions: the graphs for comparative statics and the welfare effects. To get an idea of the comparative statics figures 6-9 reproduce figures 1-4 with the

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model of the continuum of banks:

Figure 6: Simulation with $q=0.2, \pi=0.3, \gamma \in [0,1]$
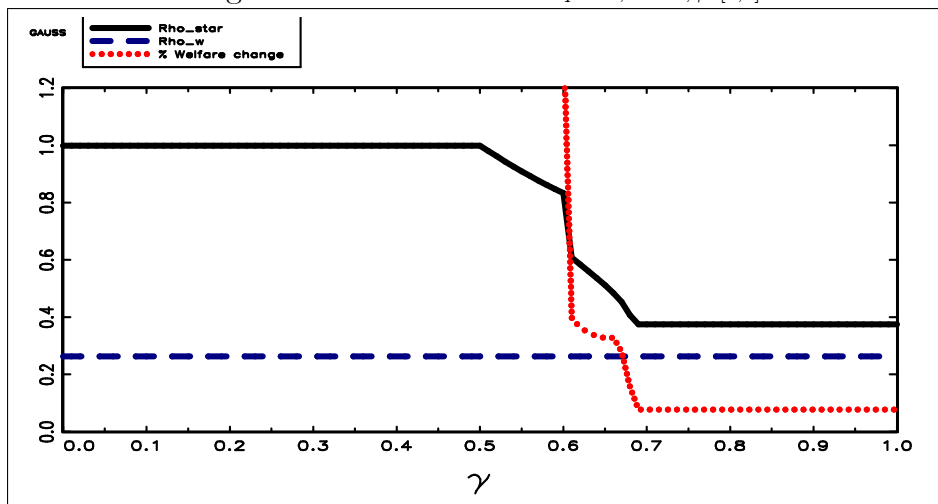
Figure 7: Simulation with $\gamma=0.6, q=0.05, \pi \in [0,1]$
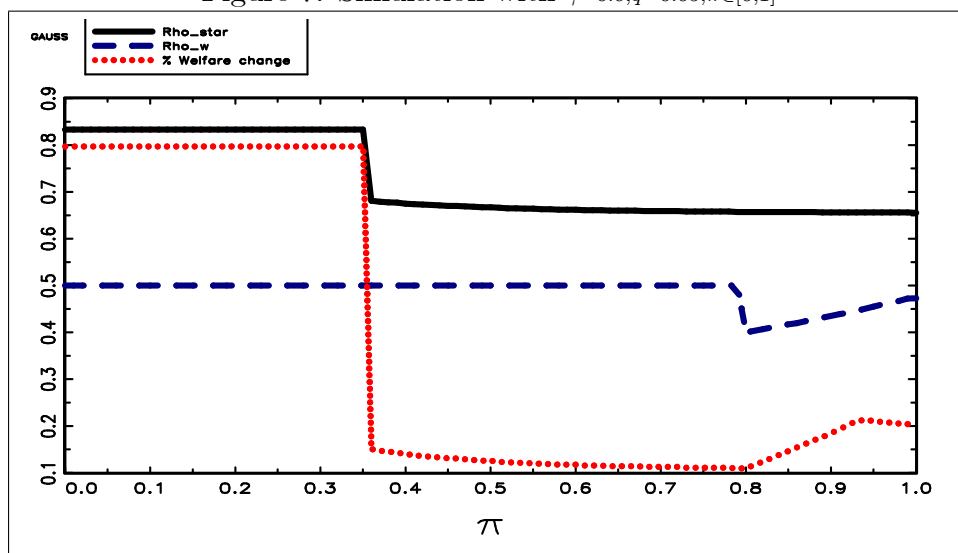
Figures 6 and 7 - the comparative statics over γ and π - are very similar to those of the basic model in figures 1 and 2. For liquidity risk, q, the comparative statics look somewhat different, however, as can be seen from comparing figures 8 and 9 with figures 3 and 4. The reason is the divergent modelling of the interbank market. Nonetheless, the intuitions are similar. For instance, in figure 8 bank risk is v-shaped in liquidity risk, as opposed to the convexity in figure 3. But the reason that bank risk first decreases and then increases in q is the same. For low liquidity risk access to funding is relatively unimportant, and for high risk

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the probability of finding financing drops. It is for medium values of q that banks care most about signalling their strength on the interbank market, and are willing to accept tougher regulatory standards. Finally, in figure 9 the interbank market fails to take off at all, as credit risk spreads remain too high for all q.

Figure 8: Simulation with $\gamma=0.95, \pi=0.1, q\in[0,1]$
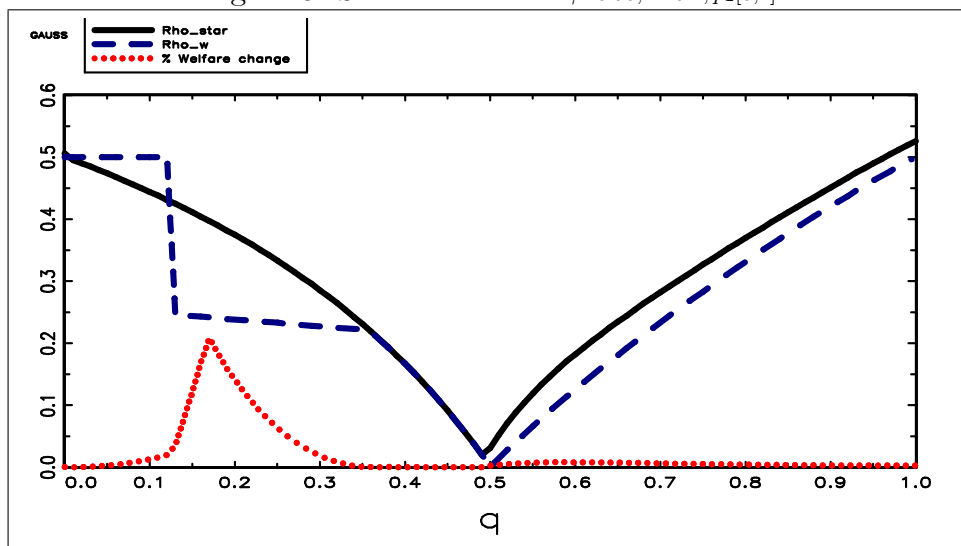
Figure 9: Simulation with $\gamma=0,6, \pi=0.3, q\in[0,1]$
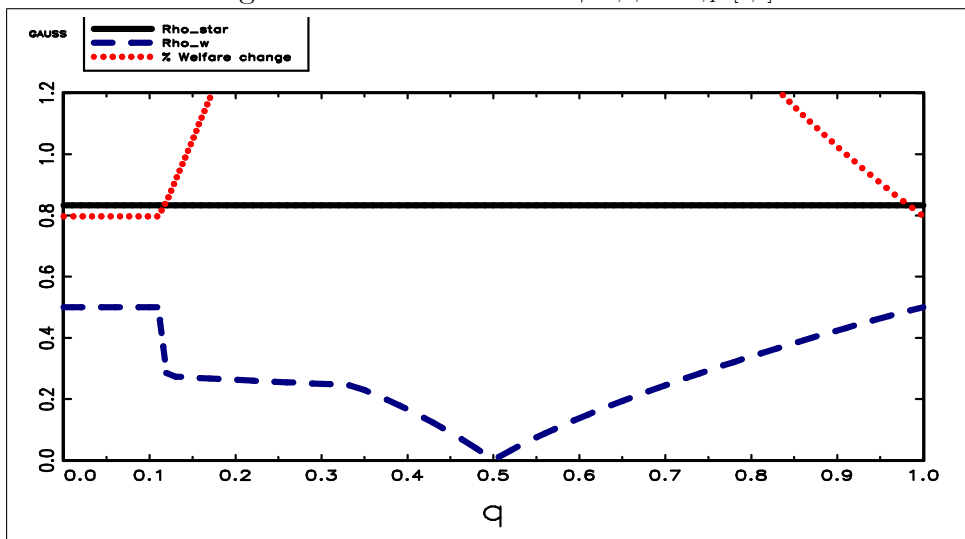
Overall, the welfare effects are smaller in the model with a continuum of banks. For $\gamma > 0.7$, $q < 0.3$ and $\pi < 0.5$, the average welfare gain from regulatory reform is 5.2%, while the median is 3.2%, both about 3 percentage points lower than in the basic model. Figure 10 depicts the distribution. Regulatory consolidation now reduces bank risk taking by 17.5% on

average. This increase in financial stability comes at a cost of 7.5% lower bank profitability. The reason that welfare effects are more modest in the model with a continuum of banks is that the interbank market functions more smoothly. A given decrease in bank risk taking improves wholesale financing less strongly. The same is true for an aggregation over higher moral hazard - $\gamma > 0.5$ - where the median welfare gain is 8.5%, 4.5 percentage points less than in the basic model.

Figure 10: Welfare effects for $\gamma > 0.7, q < 0.3, \pi < 0.5$
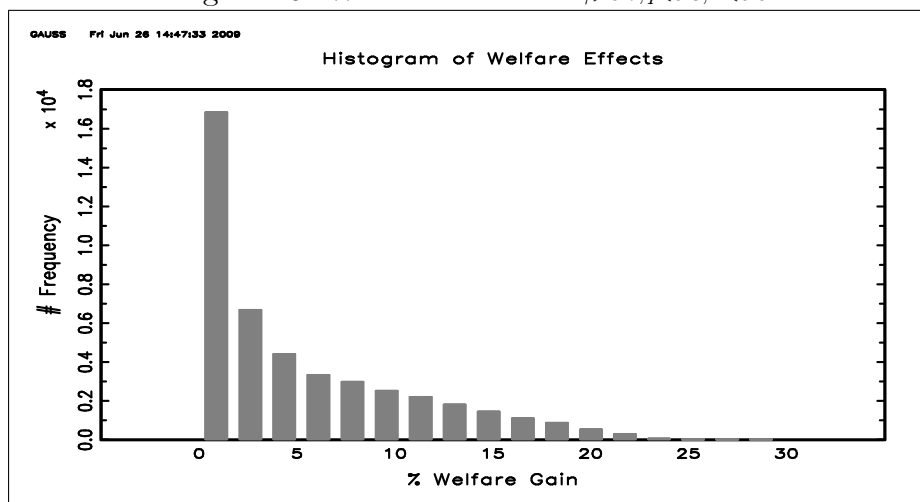
4 Imperfect monitoring

So far we have assumed that bank risk profiles are perfectly observable to regulators. This is a strong assumption, especially given the developments in the buildup to the recent crisis. The growing complexity of banks' assets made the monitoring of bank risk an increasingly difficult task. This extension considers imperfect monitoring by regulators. Relating to the crisis, we apply it to ask what happens when monitoring capacity gradually decreases over time.[5]

In particular, we assume that a regulator can only observe deviations larger than ν from its standards $\bar{\rho}$. The idea is that small deviations are easy to "hide" from a regulator, using off-balance items or opaque securitization, for instance. But sufficiently large deviations by

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[5]We focus purely on a decrease in the monitoring capacity of regulators, not of banks. The latter has also been of relevance in the buildup to the crisis, primarily because of securitization (Keys et al. (2010 forthcoming)).

banks will be observable to the regulator. We proceed from the model with a continuum of banks. Formally the only thing that changes is banks' optimization problem, which is now maximized subject to $\rho_i \leq \overline{\rho}_k + \nu$. That is: at most a bank can set its risk at ν above the regulatory standards $\overline{\rho}_k$.

$$\max_{\rho_i \leq \overline{\rho}_k + \nu} \left\{ \rho_i - \gamma \rho_i^2 + f_i \left(\rho_i, \rho \right) \right\} \tag{13}$$

We solve the problem numerically. The general feature that arises from the numerical simulations is that of a threshold monitoring capacity. When regulators' ability to monitor falls below this threshold, the interbank market breaks down. The reason is that adverse selection problems become too severe. Below is an example of a simulation result:

Figure 11: Simulation over ν with $\gamma=0.7, q=0.2, \pi=0.1$
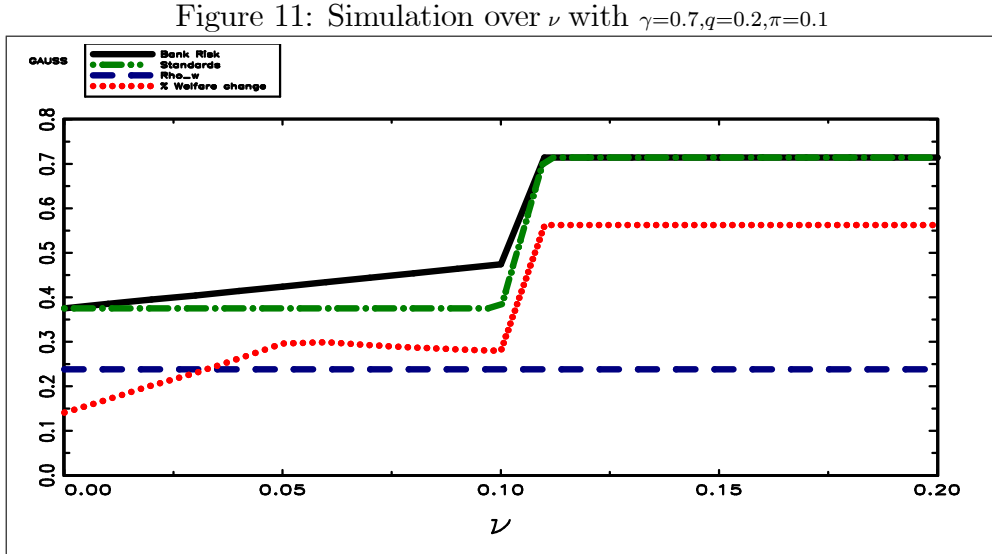
Here there are four lines, because bank risk taking can now be above the regulatory restriction. In the above figure the solid line represents bank risk taking (ρ_i^*) while the dashed-dotted line is regulatory standards $(\overline{\rho}^*)$. The other two lines are as before. As ν rises, regulators are less capable of monitoring banks. Bank risk taking rises, because banks will optimally deviate from standards. Since this deviation is unobservable, there is no cost to it for an individual bank. However, because all banks deviate, aggregate risk taking rises as do insolvency probabilities. Adverse selection problems on the interbank market thus become more severe. Beyond a threshold, here at $\nu = 0.10$, the interbank market breaks down, to society's detri-

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ment. Therefore, a gradual rise of opaque devices on banks' balance sheets can lead to a slow increase in bank risk and, at some point, a sudden financial crisis.

5   Conclusions

Did competition between bank regulators play a role in the buildup to the recent financial crisis? Our research indicates that a system with multiple regulators is both more profitable and more fragile. The years before the crisis witnessed high financial sector profits, while the crisis revealed the system's fragility. Perhaps if one aggregates over the years, the high profits partly compensate for the subsequent losses. Our simulations indicate that the overall welfare cost of regulatory competition may be modest. But even so, the choice between a multiple and a single regulator system is one between two different paths for financial stability.

Our research also points towards another mechanism behind the buildup to the crisis. Namely, the gradual decay of regulators' monitoring capacity due to the rising complexity of bank activities. This may show up only as a modest rise in bank risk. But asymmetric information problems can suddenly reach a threshold beyond which wholesale financing breaks down completely.

There are several avenues to build on the model and further enrich our understanding of regulatory competition. One could introduce heterogeneous regulators, through for instance horizontal differentiation. More generally, introducing benefits to regulatory competition could lead to richer trade-offs. One could also consider heterogeneity among banks, or a microfounded modelling of their model hazard. One could make banks compete for retail depositors. Thus, regulatory competition would indirectly affect depositors' savings conditions. Finally, this paper has abstracted from policy tools such as bank closure and Lender of Last Resort intervention, which could interact with prudential regulation in interesting ways.

Appendix A: Figures

Figure A.1: $\gamma=0.6, \pi=0.1, q \in [0,1]$
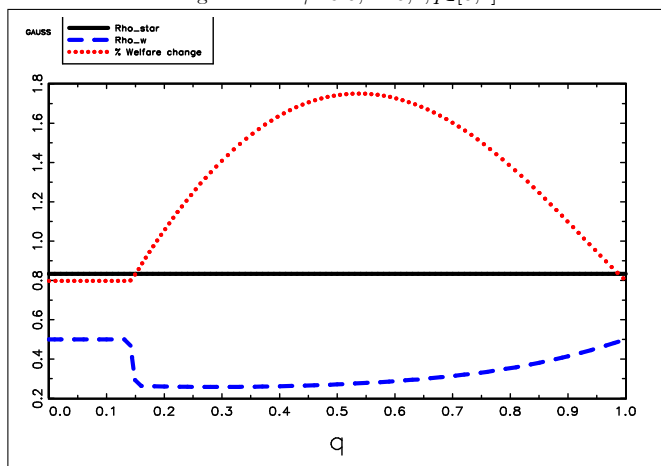
Figure A.2: $\gamma=0.6, \pi=0.3, q \in [0,1]$
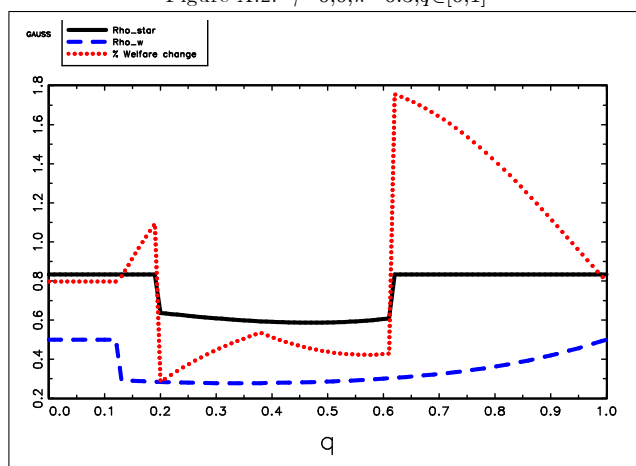
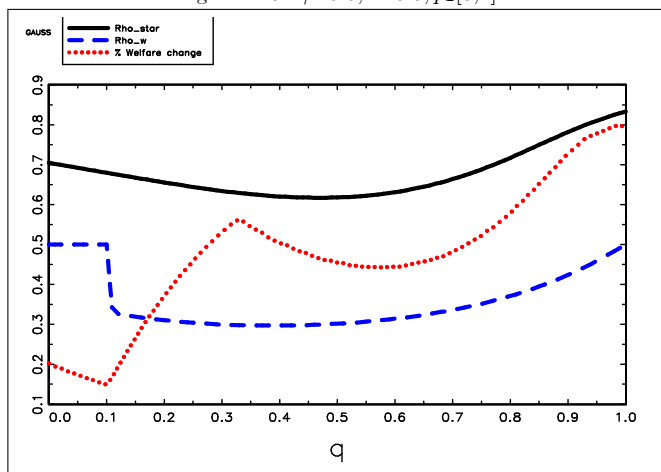
Figure A.3: $\gamma=0.6, \pi=0.5, q \in [0,1]$
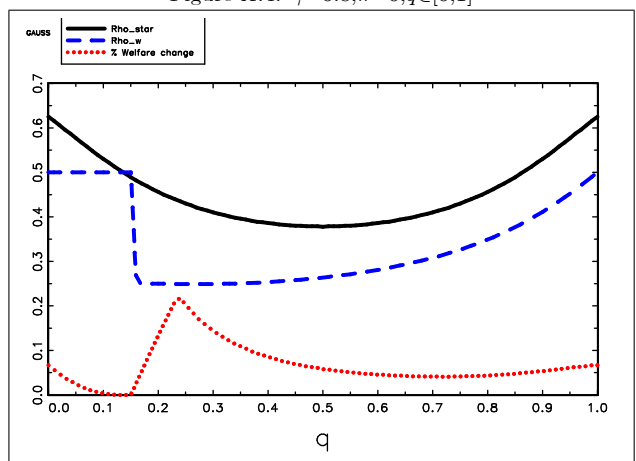

Figure A.4: $\gamma=0.8, \pi=0, q \in [0,1]$
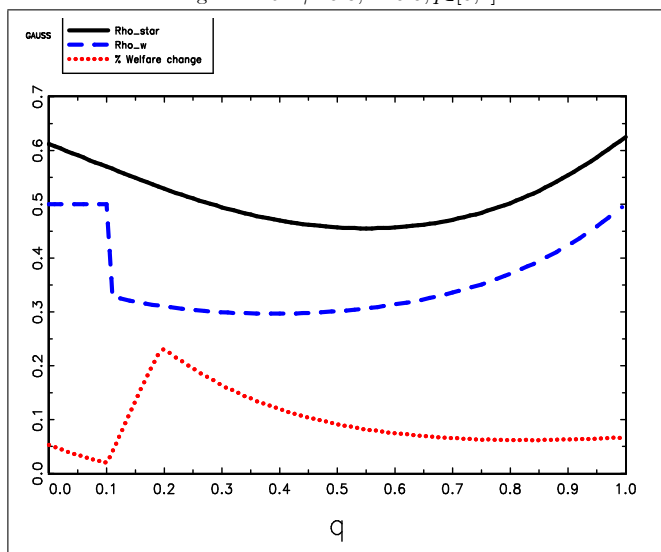

Figure A.5: $\gamma=0.8, \pi=0.5, q \in [0,1]$
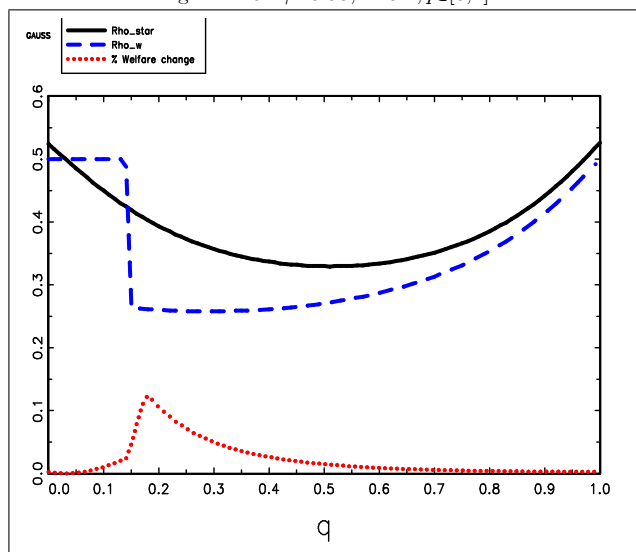

Figure A.6: $\gamma=0.95, \pi=0.1, q \in [0,1]$
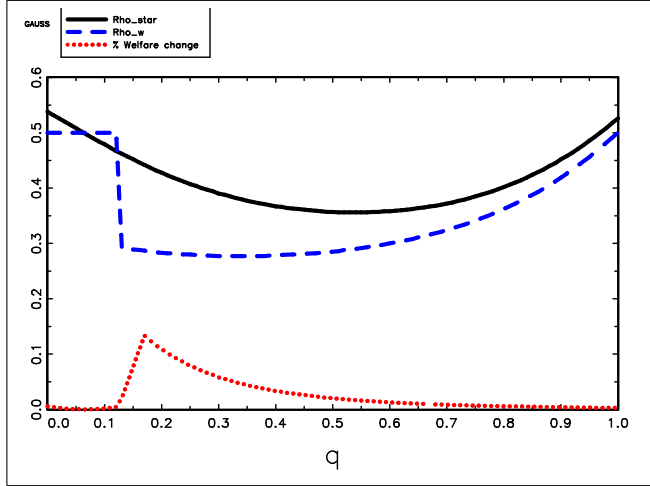
Figure A.7: $\gamma=0.95, \pi=0.3, q\in[0,1]$
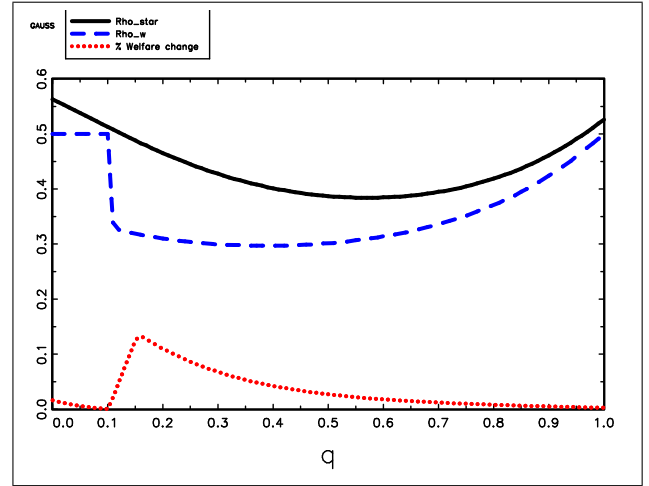
Figure A.8: $\gamma=0.95, \pi=0.5, q\in[0,1]$
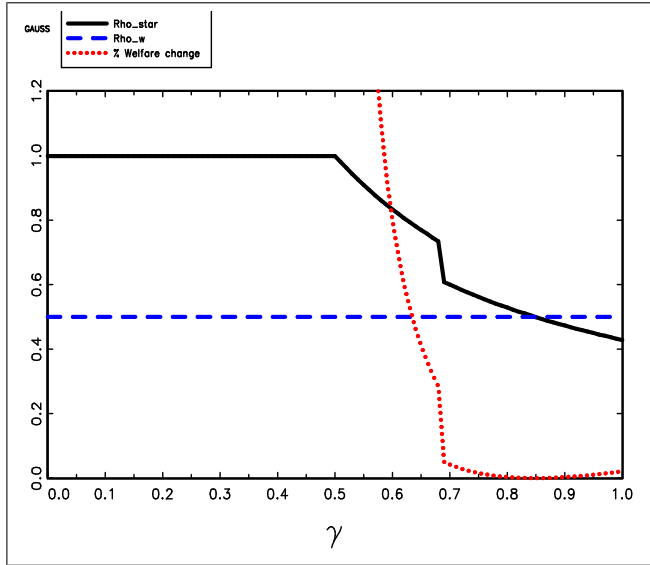
Figure A.9: $q=0.1, \pi=0.1, \gamma\in[0,1]$

Figure A.10: $q=0.2, \pi=0.3, \gamma\in[0,1]$
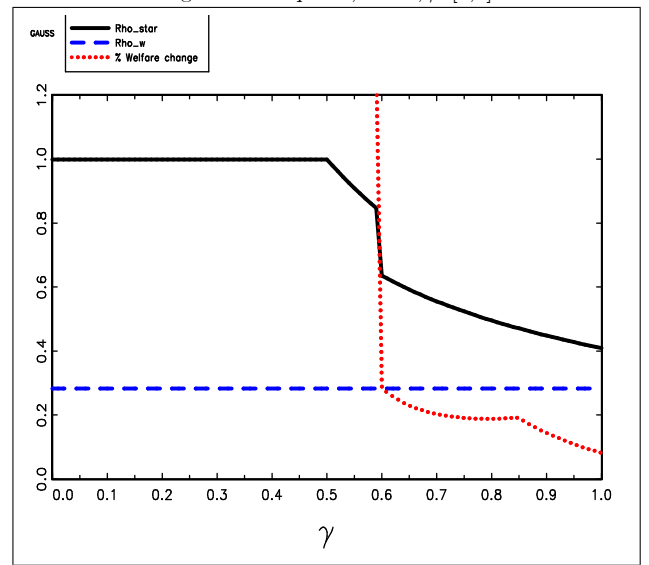
Figure A.11: $q=0.2, \pi=0.8, \gamma\in[0,1]$
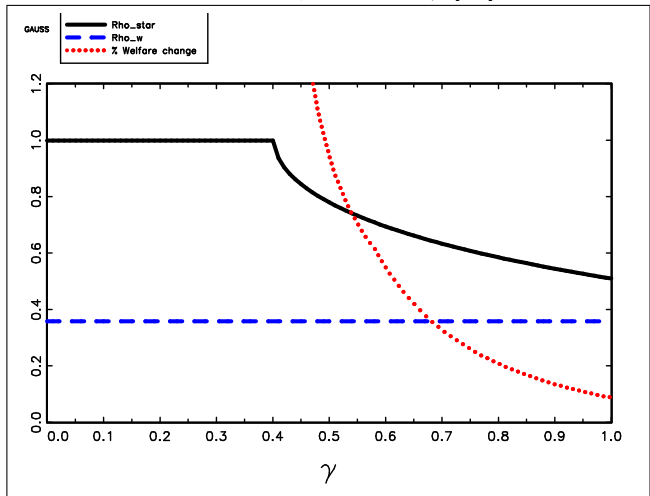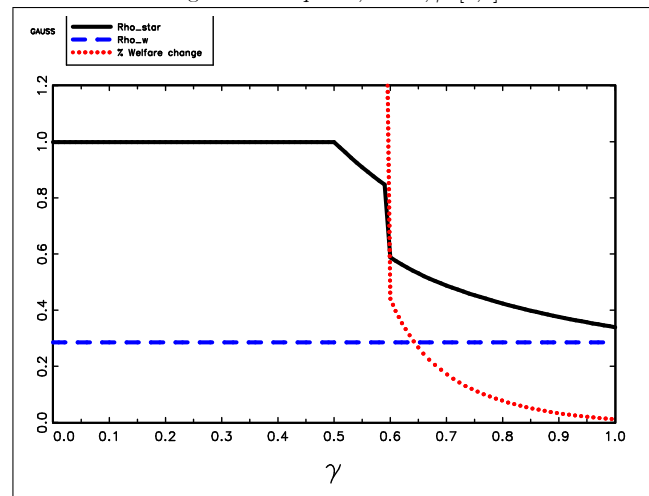
Figure A.12: $q=0.5, \pi=0.3, \gamma\in[0,1]$
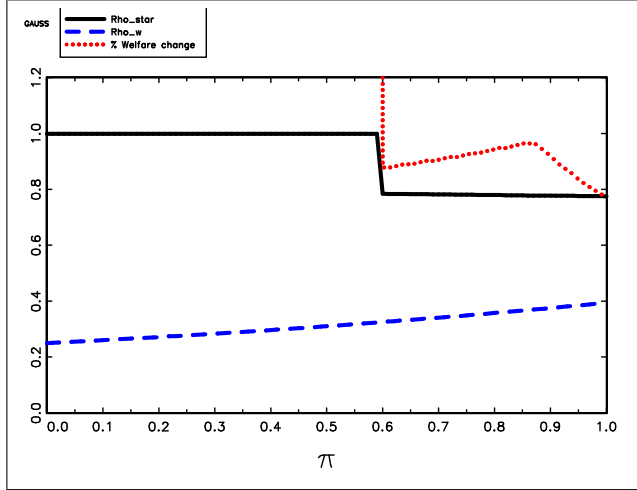
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Figure A.13: $\gamma=0.5, q=0.2, \pi\in[0,1]$

Figure A.14: $\gamma=0.6, q=0.05, \pi\in[0,1]$

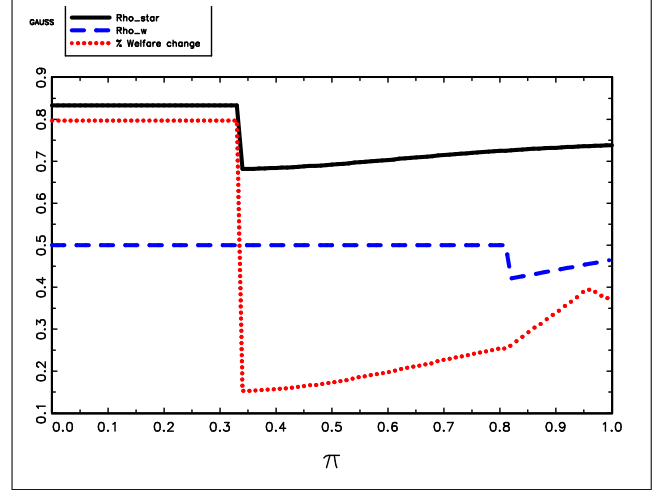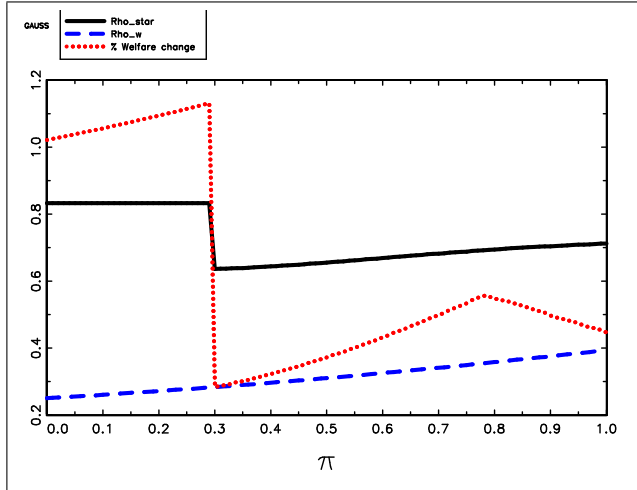Figure A.15: $\gamma=0.6, q=0.2, \pi\in[0,1]$
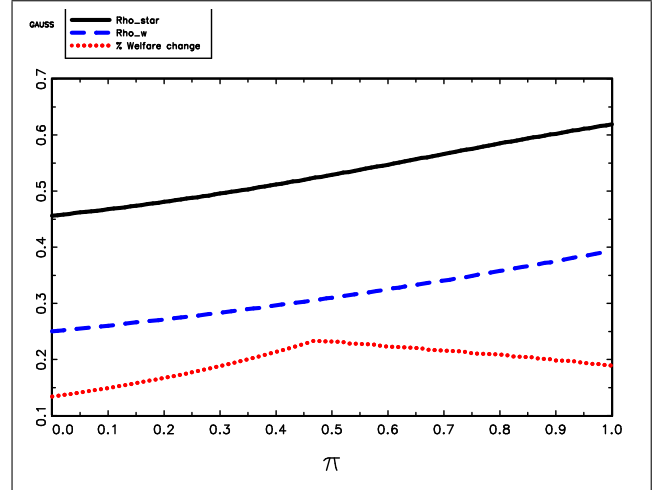
Figure A.16: $\gamma=0.8, q=0.2, \pi\in[0,1]$
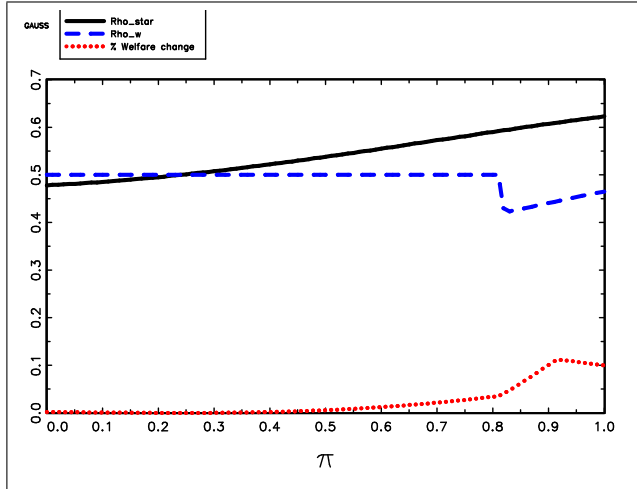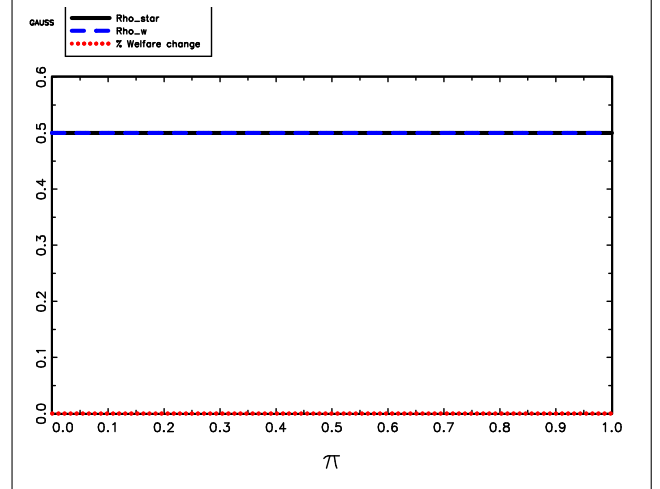
Figure A.17: $\gamma=0.95, q=0.05, \pi\in[0,1]$

Figure A.18: $\gamma=1, q=1, \pi\in[0,1]$

Appendix B: Proof of Lemma 1

Proof. Consider regulators' objective function, given by equation (1). Assume that initially $\rho^w < \overline{\rho}_x < \overline{\rho}_y < \overline{\rho}^*$. That is: regulator$_x$ has more stringent standards than regulator$_y$, while banks prefer even laxer standards. Moreover, socially optimal standards are tougher than current ones. Under current standards, banks would choose regulator$_y$, therefore. Then for any $\alpha \in (0,1)$ and $\varepsilon \to 0^+$ it holds that for regulator$_x$ setting standards at $\overline{\rho}_x = \overline{\rho}_y + \varepsilon$ implies a gain:

$$\frac{\partial m_x}{\partial \overline{\rho}_x} + \frac{\partial w}{\partial \overline{\rho}_x} > 0$$

After all, $\frac{\partial w}{\partial \overline{\rho}_x} \to 0^-$ because the loss in welfare brought about by banks' move from standards $\overline{\rho}_y$ to $\overline{\rho}_y + \varepsilon$ is marginal. Instead, $\frac{\partial m_x}{\partial \overline{\rho}_x} = 2$: a discrete gain. With discrete gains and marginal losses from adjusting to banks' preferences the only equilibrium is $\overline{\rho}_x = \overline{\rho}_y = \overline{\rho}^*$. Obviously, the same also holds for a reverse initial order: $\overline{\rho}_y < \overline{\rho}_x$. Regulator adjustment also occurs for initial standards that are more lax than $\overline{\rho}^*$: in that case both $\frac{\partial m_k}{\partial \overline{\rho}k}$ and $\frac{\partial w}{\partial \overline{\rho}_x}$ are positive. Similarly, both $\frac{\partial m_k}{\partial \overline{\rho}k}$ and $\frac{\partial w}{\partial \overline{\rho}_x}$ are positive when initial standards are below the social optimum: $\overline{\rho}_x < \overline{\rho}_y < \rho^w < \overline{\rho}^*$. Thus, convergence to $\overline{\rho}_x = \overline{\rho}_y = \overline{\rho}^*$ always occurs. ∎

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