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ABSTRACT

Regulatory Competition and Bank Risk Taking*

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. The sensitivity of regulatory standards to bank moral hazard, adverse selection, liquidity risk and the degree of regulatory bias is investigated. A calibration suggests that regulatory reform can halve bank default rates. The paper also shows how a decline in regulators' monitoring capacity gives rise to a gradual rise in bank risk, followed by a sudden interbank crisis.

JEL Classification: G21 and G28
Keywords: arbitrage, bank default, interbank market, moral hazard and supervision

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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. 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. What are the implications of this decision for future regulatory standards and financial stability?

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, and these are often large banks. His results are not merely a facet of mergers and acquisitions, moreover. In fact, in an era in which US banks moved away from state barriers, on aggregate they switched towards state charters, suggesting perverse incentives. Nonetheless, Rosen finds that switches are not followed by large increases in bank risk. He concludes that regulatory competition does not bring about a race to the bottom. Yet, his results are within the current multiple regulator equilibrium. Within such an equilibrium the difference between regulators' standards need not be large. But the gap of importance is that between the standards in a multiple versus a single regulator equilibrium. This determines the social cost of regulatory competition.

We develop a model to analyze this cost. The model contains multiple regulators that 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

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

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. Regulation interacts with both banks' portfolio selection and with their access to funding. On their asset side, banks suffer from moral hazard, as 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, providing the rationale for the presence of regulation.

On their funding side, banks have 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, giving rise to adverse selection. 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.

The model is built up in several steps. We first consider the benchmark of two banks, and a continuum of risk profiles. In this setting regulators fully adjust to banks' wishes, regardless of their weight on welfare. The reason is a Bertrand Nash equilibrium: the gains from cutting standards marginally below those of competing regulators are discrete (more banks under supervision), while the costs are marginal. This benchmark is useful to analyze the trade-offs that banks face. We subsequently extend the model to a continuum of banks, with a random matching technology for interbank participants. Finally, we restrict banks to discrete choice: they can choose from a given number of risky projects. This breaks the Bertrand Nash equilibrium between the regulators and introduces their welfare weight into the comparative statics.

The model is solved numerically. We show that regulatory competition is subject to non-linear dynamics. Parameters are subject to various thresholds, beyond which equilibrium standards vary greatly. Thus, small movements in moral hazard can significantly affect the pressures that regulators face from banks. Small movements in liquidity risk and adverse selection can alter access to wholesale funding, which feeds back in to the regulatory equilibrium. And small changes in regulatory bias can overturn regulators' willingness to adjust to banks' wishes. We also use the model to analyze more general questions, such as the interaction between banks' liquidity risk and their optimal portfolio choice.

Finally, we calibrate the model to obtain a rough estimate of the welfare costs of regulatory competition. We fix liquidity risk on empirical estimates by Cocco et al. (2009), and impute adverse selection premia from CDS spreads in the recent crisis. For moral hazard we compare measures of banks' losses from the crisis - lost market capitalization and expected loan writedowns - to the broader losses from the crisis as measured by (forecasted) output gaps. We then vary the weight that regulators' put on the size of their mandate and compare the outcomes. If regulators weigh welfare by less than about 95% in their objective function, a race on regulatory standards comes about. Under such circumstances, bank default rates can be more than halved by consolidating regulation in a single bank supervisor. Taking welfare in the model to mean the value added to GDP by the financial sector, the welfare gains from this reform are then at least 3% of GDP.

It does not take much regulatory bias, therefore, for regulators to adjust to banks' wishes, and for regulatory consolidation to have social value. Several case studies on regulatory capture document that regulators indeed weigh non-benevolent objectives. Kane (1990, 2001) discusses the importance of regulatory capture in the buildup to the US Savings and Loan Crisis of the late 1980s and early 1990s. Woodward (1998) documents regulatory capture at the Securities and Exchange Commission. For more studies we refer to the literature review in Hardy (2006).

In an extension, 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. This suggests that weakening regulatory capacity may have been one of the causes of the crisis. Decaying monitoring capacity may be especially damaging in an environment of regulatory competition. The reason is that risk taking starts from a higher level, and therefore less decay is needed to reach the breakdown threshold.

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 exist in 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".

Several existing papers model competition between bank regulators. Dell'Ariccia and Marquez (2006) analyze the incentives of heterogeneous, national regulators in the EU 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.

Various 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)).

The next section presents the benchmark model with two banks and continuous risk profiles. Section 3 introduces a continuum of banks, while section 4 brings in discrete choice. Section 5 presents the calibration. And section 6 extends to imperfect monitoring. Finally, section 7 concludes.

2 Benchmark model

We start from a model with 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:

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

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 6 introduces imperfect monitoring.

Finally, note that though $\overline{\rho}_k$ does not figure directly in $\alpha w(\rho_a, \rho_b) + (1-\alpha) m_k$, 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.

In choosing a risk profile, $\rho_i \in [0, 1]$, for their portfolio, banks face a linear-quadratic trade-off. A larger ρ_i means a riskier portfolio with a higher expected return (the linear term), but a higher probability of failure (the quadratic term). This endogenous default probability is realized in stage 4 of the game (the solvency shock). The quadratic default rate is analytically convenient, as it brings about interiority of the optimal risk profile. However, there is also empirical evidence that bank default rates increase convexly in measures of risk taking, such as loan-to-asset ratios (Estrella et al. (2000), Kocagil et al. (2002), Halling and Hayden (2006)).

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 $\overline{\rho}_k$ imposed by their selected regulator. To recap: at stage 1 regulator$_x$ and regulator$_y$ announce $\overline{\rho}_x$ and $\overline{\rho}_y$; 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, $\rho_i \leq \overline{\rho}_k$.

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.

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 $q\left(1-\rho_i^2\right)$. That is: if no solvency shock occurred, $\left(1-\rho_i^2\right)$, 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.[2] As in Freixas et al. an insolvent bank can mimic an illiquid bank in order to receive funding.

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

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 interbank 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 $\left(\varphi_i = n \wedge \varphi_j \neq n\right) \vee \left(\varphi_i \neq n \wedge \varphi_j = n\right)$. 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 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, $\overline{\rho}_k$, 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:

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

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 $(\gamma-r_i)$ to its manager. The probability that he can obtain a loan is $(1-q)\left(1-E_i\left[\rho_j^2\right]\right)$, i.e. the counterparty is liquid and solvent. Finally, with probability $(1-\rho_i^2)\,q$ 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 $\pi(\gamma - r_i)$ 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 $f_i(\rho_i, \rho_j) = 0$.

D Social planner

To close our description of the model, we write down the social planner's problem. The social planner maximizes welfare, $w(\rho_a, \rho_b)$. 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 $w(\rho_a, \rho_b)$.

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

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

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

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

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.

E Comparative statics

Call $\overline{\rho}^*$ banks preferred risk ceiling. Then (proof in appendix I):

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. As discussed in the introduction, this is a useful benchmark case, because it allows us to focus on the comparative statics of bank behavior first. In section 4 we break the Bertrand outcome with discrete choice, and analyze how comparative statics are affected.

Note that Lemma 1 does not necessarily imply zero regulation. Banks do not always want the absence of regulation in our model, because of the interactions on their funding side. Also note that having fully adjusting regulators is not the same as having "self-regulating" banks. The outside regulator has value to banks as a commitment device to risk ceilings. 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 II.

Figure 1: Simulation with $q{=}0.2,\pi{=}0.3,\gamma\in[0,1]$

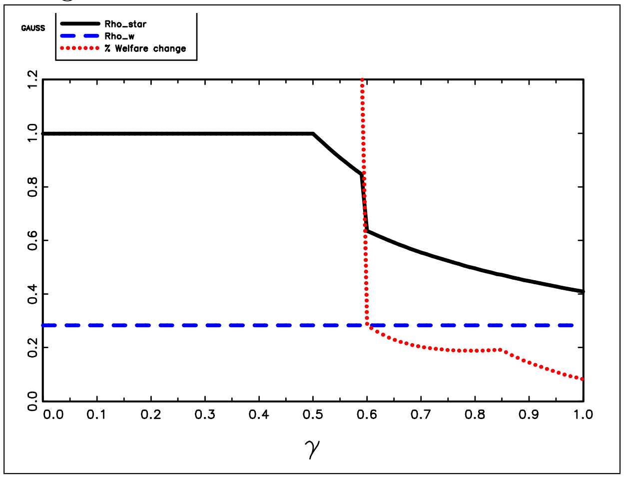


Figure 2: Simulation with $\gamma{=}0.6,q{=}0.05,\pi\in[0,1]$

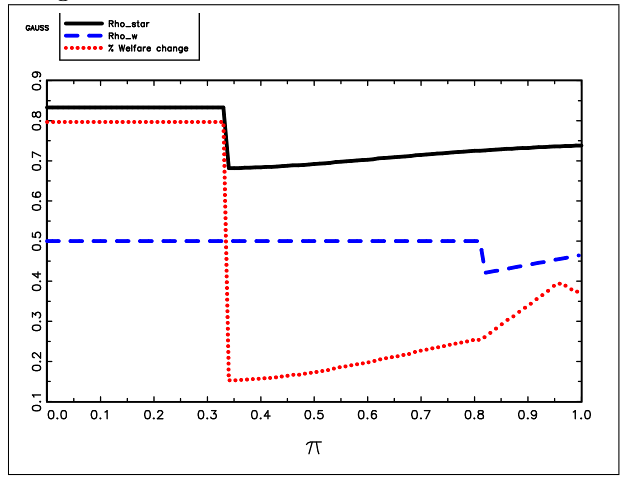


Figure 3: Simulation with $\gamma{=}0.95,\pi{=}0.1,q\in[0,1]$

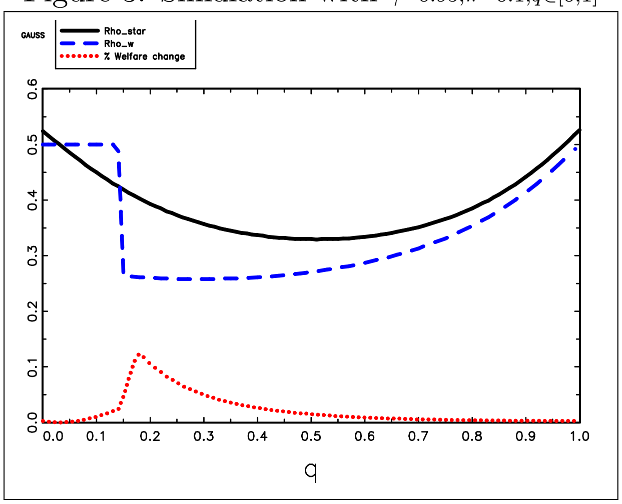
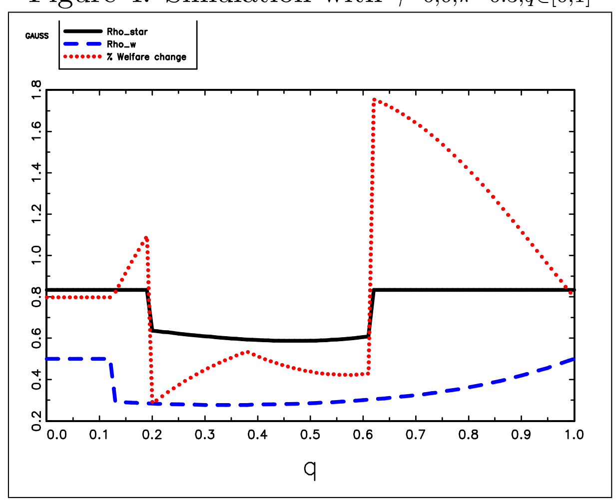


Figure 4: Simulation with $\gamma{=}0{,}6,\pi{=}0.3,q\in[0,1]$



We explain the main comparative statics with the aid 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 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. This is the welfare cost of regulatory competition (recall that a single regulator would implement ρ^w).

A general feature of our simulations is nonlinear dynamics and the presence of thresholds. Overall, the welfare effects of regulatory competition are highly sensitive to the extent of moral hazard, adverse selection and liquidity risk. 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. 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 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 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. When the interbank market is active ($\pi > 0.35$) 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 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 $f_i\left(\rho_i, \rho_j\right)$. Finally, in figure 4 small movements in liquidity risk, from for example $q = 0.60$ to $q = 0.61$, can induce interbank gridlock. With high moral hazard (low γ) credit risk spreads quickly reach the threshold beyond which the market shuts down ($r_i > \gamma$).

3 Continuum of banks

In this section we extend the model to a continuum of banks. 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. This provides a robustness check for the main mechanisms that we found in the benchmark model. Moreover, a continuum of banks may approach reality more closely, especially that of the US banking sector with its large number of banks. This is of use for our calibration.

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:

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

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 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. Figures 5-8 reproduce figures 1-4 with the model of the continuum of banks:

Figure 5: Simulation with q=0.2,π=0.3,$\gamma\in$[0,1]

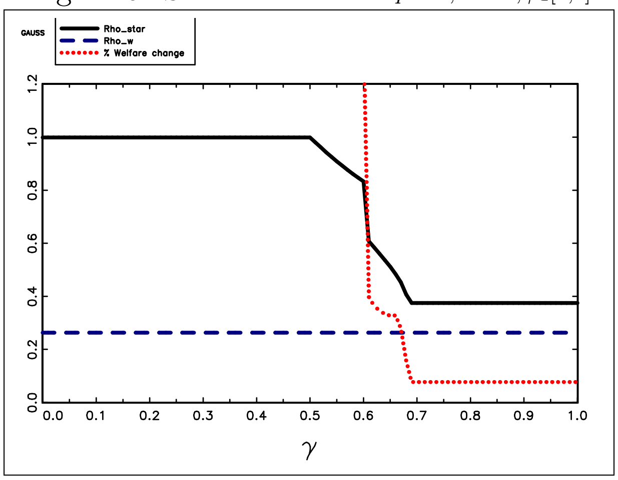
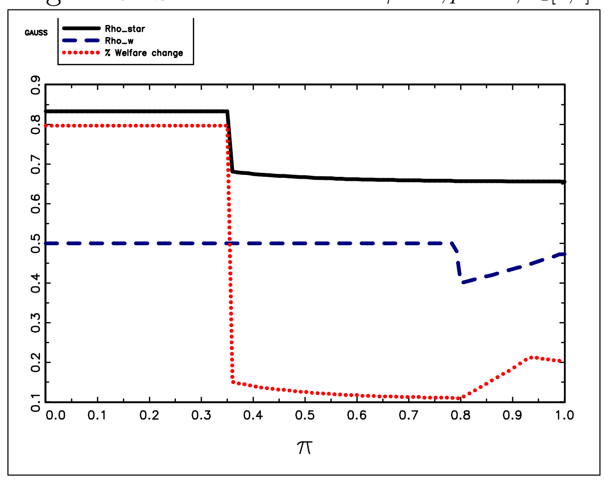


Figure 6: Simulation with γ=0.6,q=0.05,$\pi\in$[0,1]



Figures 5 and 6 - 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 7 and 8 with figures 3 and 4. The reason is the divergent modelling of the interbank market. Nonetheless, the intuitions are similar. For instance, in figure 7 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. In figure 8 the interbank market fails to take off at all, as credit risk spreads remain too high for all q.

Figure 7: Simulation with $\gamma=0.95,\pi=0.1,q\in[0,1]$

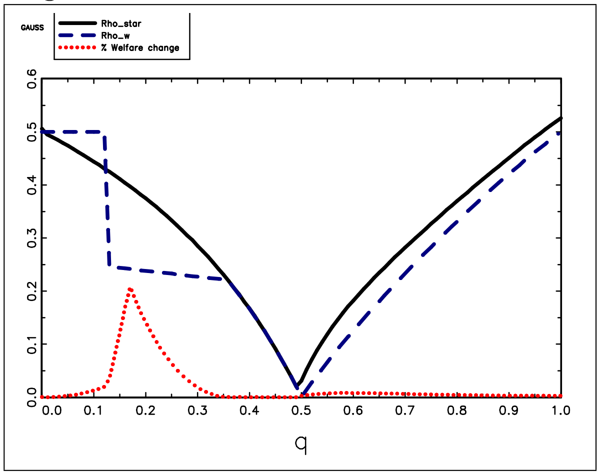
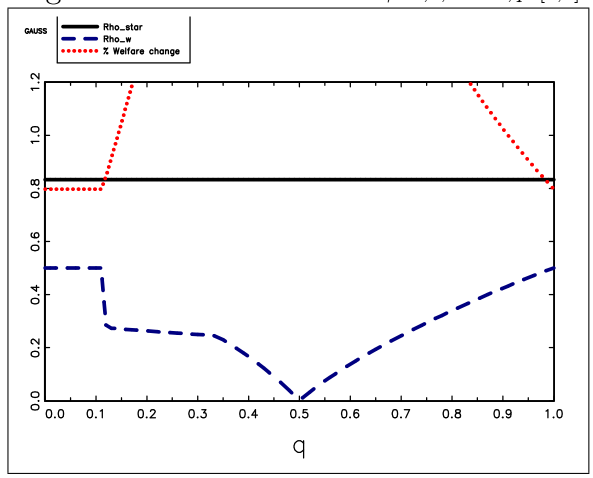


Figure 8: Simulation with $\gamma=0,6,\pi=0.3,q\in[0,1]$



4 Discrete choice

This section introduces discrete choice over bank projects. Instead of choosing a risk profile $\rho_i \in [0,1]$, a bank now chooses one of ten available projects. The first project has profile $\rho_i = 0.1$, the second $\rho_i = 0.2$, ..., and the last $\rho_i = 1$. Because of this discrete choice, Lemma 1 is invalidated. There is no longer necessarily an extreme Bertrand competition outcome among regulators. The reason is that for a regulator to attract banks away from other regulators, it must lower standards by a discrete amount. The cost of attracting banks is thus no longer marginal. Moreover, with bank default probabilities increasing convexly, the cost of lowering standards rises as regulators move away further from the social optimum. As the benefit of lowering standards is constant (a given rise in m_k), there is a point beyond which regulators are no longer willing to adjust to banks' wishes. The location of this threshold depends on α, the weight that regulators put on welfare.[3]

It now also matters how many regulators there are. Preparing for our calibration for the US, we extend the model to three regulators. Numerical solution of the problem with discrete choice proceeds in the following way. For a given parameterization, the Nash equilibrium between the regulators is derived. This is found by checking for the crossing of the cost and

[3]Other ways to break the extreme Bertrand outcome include introducing switching costs, capacity constraints and regulated regulators (the government punishes regulators for deviating from the social optimum).

benefit of deviating from given standards. Standards that are low enough that no regulator wishes to deviate, are called the adjustment ceiling. This is the maximum adjustment to banks' preferences that regulators are willing to make. Of course, the standards that actually emerge need not equal this ceiling. Banks may prefer tougher standards. In equilibrium, standards are the minimum (lowest, therefore most stringent $\overline{\rho}$) of bank preferences and the adjustment ceiling. This is exemplified by figures 9 and 10.

Figure 9: Simulation with $a=0.9,q=0.2,\pi=0.3,\gamma\in[0,1]$

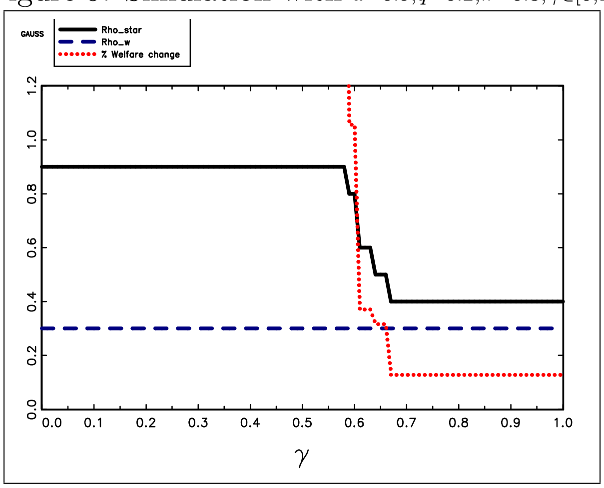


Figure 10: Simulation with $a=0.95,q=0.2,\pi=0.3,\gamma\in[0,1]$

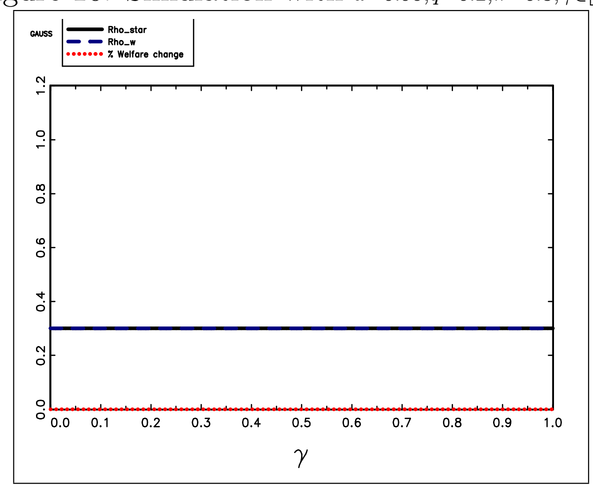
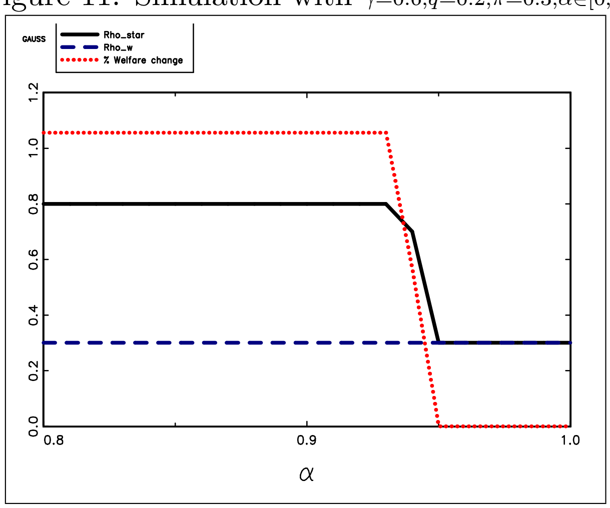


Figure 11: Simulation with $\gamma=0.6,q=0.2,\pi=0.3,\alpha\in[0,1]$



These simulations rely on the same parameter values (q and π) as figures 1 and 5, but with $\alpha = 0.9$, $\alpha = 0.95$, respectively. Comparing figure 9 with figures 1 and 5, the pictures look very similar. The only difference is that the regulators are not willing to lower standards beyond $\overline{\rho} = 0.9$. Thus, when moral hazard is high ($\gamma < 0.58$), regulators' preferences become constraining. However, when regulators put a larger weight on welfare, $\alpha = 0.95$ in figure 10, their adjustment ceiling is immediately constraining. The multiple regulator regime achieves the social optimum now. The sensitivity of standards to the weight that regulators put on welfare is represented by figure 11. Small changes in regulatory bias, from $\alpha = 0.93$ to $\alpha = 0.95$, make all the difference between 110% and 0% welfare costs to regulatory competition.

In figures 9 and 10 regulators' adjustment ceiling is constant over all γ (namely $\overline{\rho} = 0.9$ and $\overline{\rho} = 0.3$). However, this ceiling can also vary over the values of a given parameter. Figures 12 and 13 are for the same values of γ and π as figure 8. In figure 12 $\alpha = 0.9$ and regulators fully adjust to banks' wishes. Instead, in figure 13 $\alpha = 0.95$ and regulators' preferences becoming constraining to banks. However, the adjustment ceiling varies with q. High risk-taking does greatest damage to welfare for intermediate values of q, which is when regulators put the greatest emphasis on constraining risk taking.

Figure 12: Simulation with $a=0.9,\gamma=0.95,\pi=0.1,q\in[0,1]$

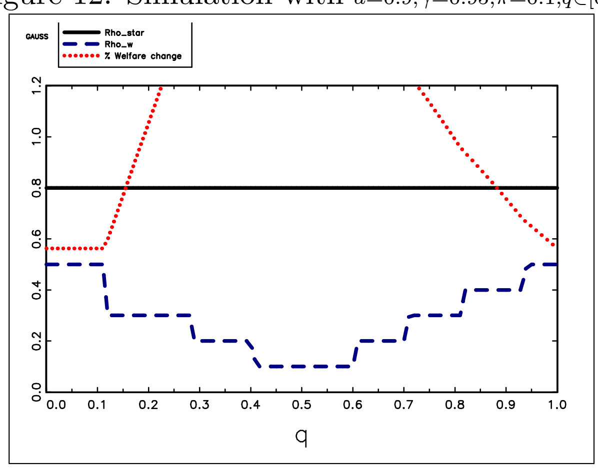
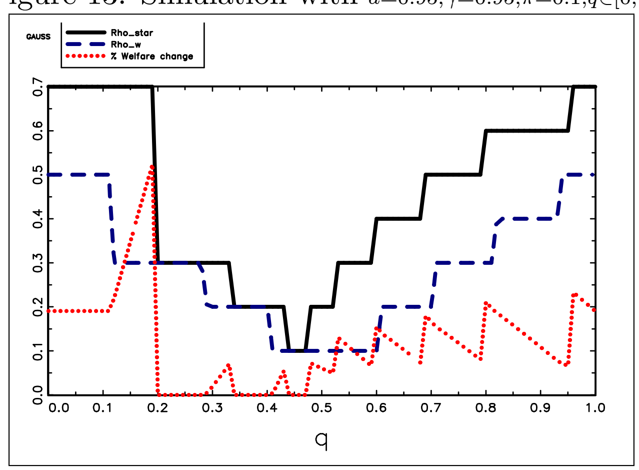


Figure 13: Simulation with $a=0.95,\gamma=0.95,\pi=0.1,q\in[0,1]$



5 Calibration

Our calibration strategy is to impute rough values for the parameters π, q, and γ, and subsequently vary regulators' weight on welfare α. The aim is to get some indication of the size of welfare effects implied by the model. In theory one could use Credit Default Swap (CDS) spreads on insolvent banks to infer the probability of a successful gamble for resurrection, π.

Though the recent crisis would seem to provide ample data, two problems in practice are identifying genuinely insolvent (as opposed to illiquid) banks, and how to disentangle a gamble for resurrection from a gamble for government bailout. We consider the maximum CDS spreads observed in the recent crisis for three banks: Glitnir, Landsbanki and Morgan Stanley (taken from Datastream). What makes the case of the Icelandic banks, Glitnir and Landsbanki, particular is that the government of the country itself was close to bankruptcy. CDS spreads on Icelandic government debt traded at over 1000 basis points prior to the nationalizations of both banks in October 2008. Glitnir's and Landsbanki's CDS spreads reached 5271 and 2758 basis points, respectively. By all accounts, both banks were genuinely insolvent. The depreciation of the Icelandic currency had strongly increased the value of their outstanding foreign liabilities. These banks may come closest to the case of insolvent banks with weak safety nets.

For Morgan Stanley it is impossible to ascertain whether it was insolvent or illiquid at the peak of the crisis. However, US authorities had allowed fellow investment bank Lehman Brothers to fail on September 15$^{\text{th}}$, 2008. Then, till the finalizing of a deal with Mitsubishi UFJ on October 14$^{\text{th}}$, there was significant uncertainty about the fate of the bank.[4] CDS spreads reached 1340 basis points. If we take 1340 (Morgan Stanley) - 5271 (Glitnir) as an indicative range of CDS spreads for banks that gamble for resurrection, and we assume risk neutral investors, then we can impute $\pi \in [0.65, 0.88]$.

For liquidity risk, q, we rely on data from a recent study by Cocco et al. (2009). They investigate the determinants of borrowing and lending behavior on the Portuguese interbank market. They identify liquidity shocks through daily variations in banks' deposits at the central bank, and report that the correlation of such shocks is about 12%. In the context of our model this implies that if a bank has been hit by a liquidity shock, 12% of banks is in the same position: $q = 0.12$.

Finally, we need to parameterize banks' moral hazard, γ. This parameter represents the

[4] On September 21$^{\text{st}}$, 2008, the Federal Reserve allowed Morgan Stanley to change its status from investment bank to bank holding company. But this did not stem the rise in CDS spreads.

cost that banks experience from failure over the cost that society experiences. Let us assume that bank management fully represents its shareholders. A measure of γ could then be market capitalization lost during the recent crisis over society's losses from the crisis. As banks are assumed identical, each bank has the same ratio of equity losses to social damage. Between September 2007 and September 2009, publicly traded US financials lost roughly half of their market capitalization. This amounts to about 1.5 trillion US dollars.[5] Alternatively, we can take direct estimates of banks' losses on loans during the crisis. The IMF's October 2009 Global Financial Stability Report estimates total loan writedowns by US banks over the period 2007-2010 to amount to about 1 trillion US dollars.

Society experiences banks' direct losses too (through bank owners). But in addition it suffers from the externalities on the real economy. One way to approximate these losses is to look at lost output. According to the Congressional Budget Office estimate, US potential GDP growth is 2.3% per year (CBO, 2009). Taking this together with (forecasted) growth 2008-2010 for the US from the IMF World Economic Outlook of July 2009, GDP losses from the crisis amount to roughly 7.6% of GDP. At a nominal GDP of 14.3 trillion US dollars, this loss is 1.1 trillion dollars. Taken together, we obtain $\gamma \approx \frac{1.5}{1.5+1.1} = 0.58$ if we take the market capitalization measure for bank losses, and $\gamma \approx \frac{1}{1+1.1} = 0.48$ if we take the loan writedowns measure. We thus consider $\gamma \in [0.48, 0.58]$

Figures 14 and 15 summarize the results of the calibration. Figure 14 considers $\pi = 0.65$ and $\gamma = 0.48$, while figure 15 considers $\pi = 0.88$ and $\gamma = 0.58$. Thus, figure 14 can be seen as an "upper bound" with adverse selection and moral hazard at the high end of their ranges, while figure 15 is a "lower bound". Both show results by varying regulators' welfare weight, α, which is on the x-axis of the graphs. In figure 14 it takes $\alpha = 1$ for competing regulators to achieve the social optimum. When regulators put between 96% and 99% weight on welfare, bank risk taking increases somewhat above the social optimum. But when that weight decreases below 96%, regulatory competition has strong effects on bank risk taking, and on welfare. In figure 15 it takes a lower α to observe large effects. For $\alpha \in [0.97, 1]$, in

[5] Data from CNN Money (money.cnn.com) and Seeking Alpha.(seekingalpha.com).

fact, the regulators act like social planners. But when their weight on welfare is smaller than 93%, they fully adjust to banks' wishes (which are less extreme than in figure 14, because of the higher γ). Consolidating regulation in a single bank supervisor then more than halves implied default rates (ρ^2). It does not take much regulatory bias for regulatory reform to be socially beneficial, therefore.

Figure 14: Simulation with γ=0.48,q=0.12,π=0.65,$\alpha\in$[0,1]

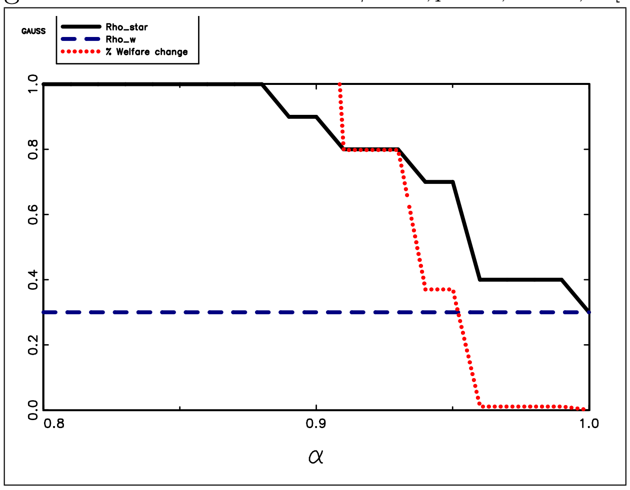
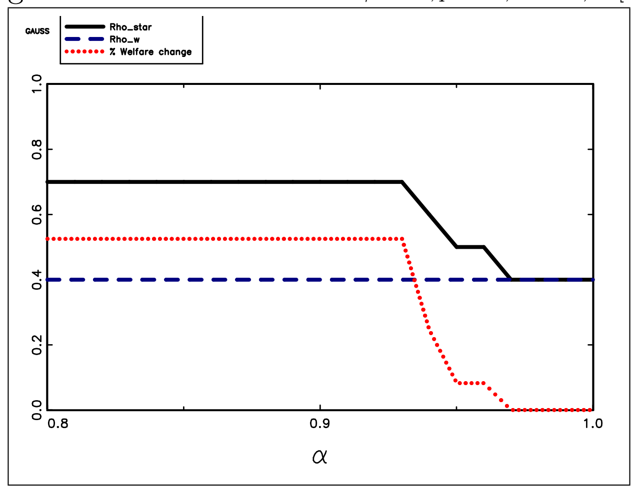


Figure 15: Simulation with γ=0.58,q=0.12,π=0.88,$\alpha\in$[0,1]



One way to conceptualize this social benefit is to equate welfare to GDP and to assume that the welfare captured in the model is only that generated by the financial sector. The value added of the US financial sector accounts for almost 8% of US GDP (Philippon, 2007). Thus, for a sufficiently large regulatory bias ($\alpha \leq 0.93$), our lower bound estimate indicates that regulatory competition implies a cost of at least 3% of GDP.

6 Imperfect monitoring

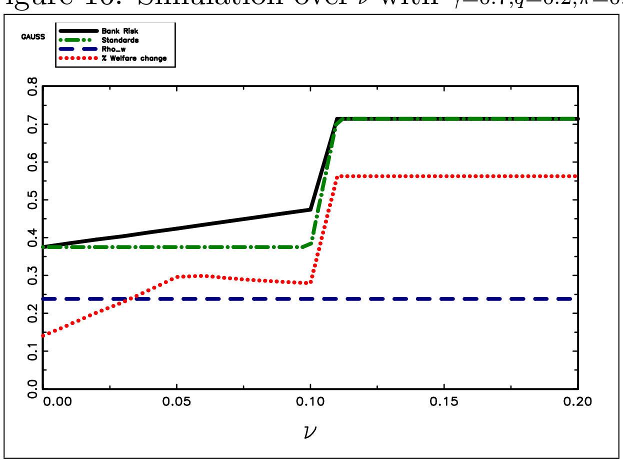
So far we have assumed that bank risk profiles are perfectly observable to regulators. This is a strong assumption, especially given the developments in the buildup to the recent crisis. The growing complexity of banks' assets made the monitoring of bank risk an increasingly difficult task. This extension considers imperfect monitoring by regulators. Relating to the crisis, we apply it to ask what happens when monitoring capacity gradually decreases over time.[6]

In particular, we assume that a regulator can only observe deviations larger than ν from its standards $\overline{\rho}$. The idea is that small deviations are easy to "hide" from a regulator using, for instance, off-balance-sheet items or opaque securitization. But sufficiently large deviations by banks will be observable to the regulator. We proceed from the model with a continuum of banks and a continuum of risk profiles (section 3). We prefer not to use the discrete choice setting here, because gradual effects on bank risk matter, as explained below. 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 $\overline{\rho}_k$.

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

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 16: Simulation over ν with γ=0.7,q=0.2,π=0.1



Here there are four lines, because bank risk taking can now be above the regulatory restriction.

[6] 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 securitisation (Keys et al. (2010 forthcoming)). On the interaction between securitisation and financial stability see also Shin (2009).

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 gradually rises in ν, 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 detriment. 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. It takes a lower ν to reach this threshold when there are multiple regulators, because risk taking starts from a higher level.

7 Conclusions

Did competition between bank regulators play a role in the buildup to the recent financial crisis? To argue that it did not, one needs to believe in nearly benevolent regulators, our calibrated model suggests. With modest regulatory bias, risk taking is significantly higher with competing regulators than under a single regulator. Thus, the sidelining of regulatory consolidation in the planned US regulatory reform, may be a lost opportunity for improving future 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 small rise in bank risk. But asymmetric information problems can suddenly reach a threshold beyond which wholesale financing breaks down completely. In conjunction with regulatory competition, decaying monitoring capacity may be especially damaging.

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 I: 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. ■

Appendix II: Figures

Figure A.1: γ=0.6,π=0,1,q∈[0,1]

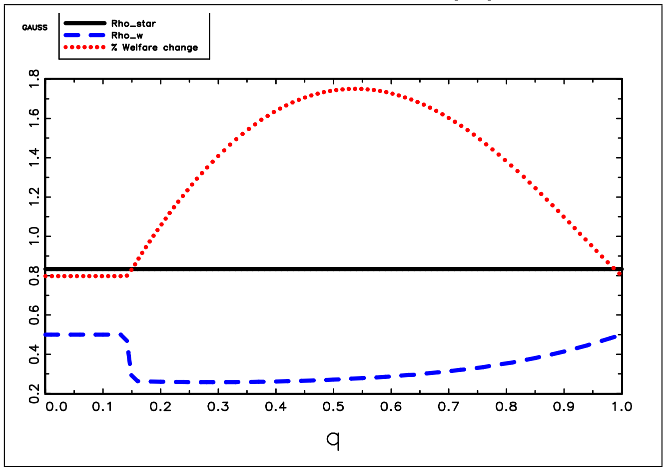


Figure A.2: γ=0,6,π=0.3,q∈[0,1]

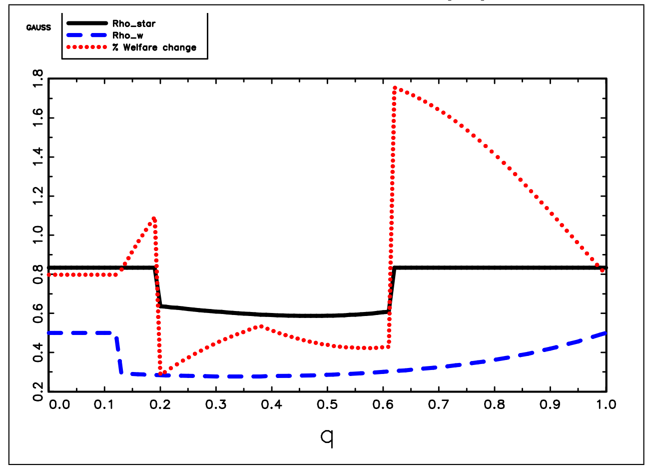


Figure A.3: γ=0.6,π=0.5,q∈[0,1]

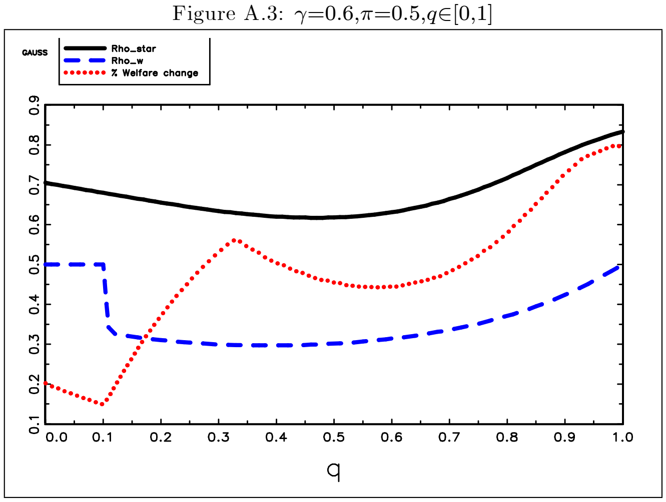


Figure A.4: γ=0.8,π=0,q∈[0,1]

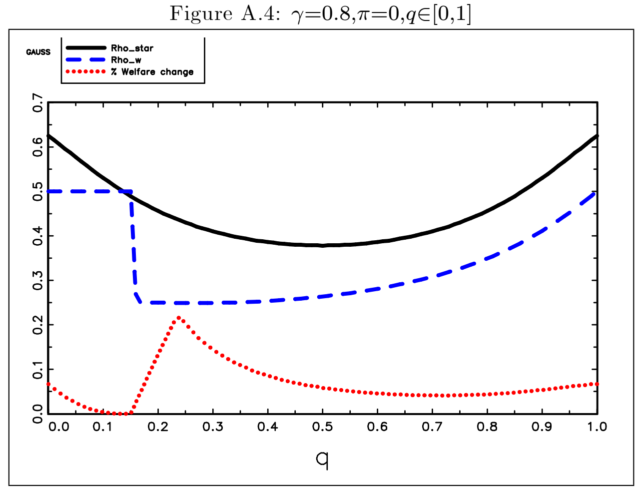


Figure A.5: γ=0.8,π=0.5,q∈[0,1]

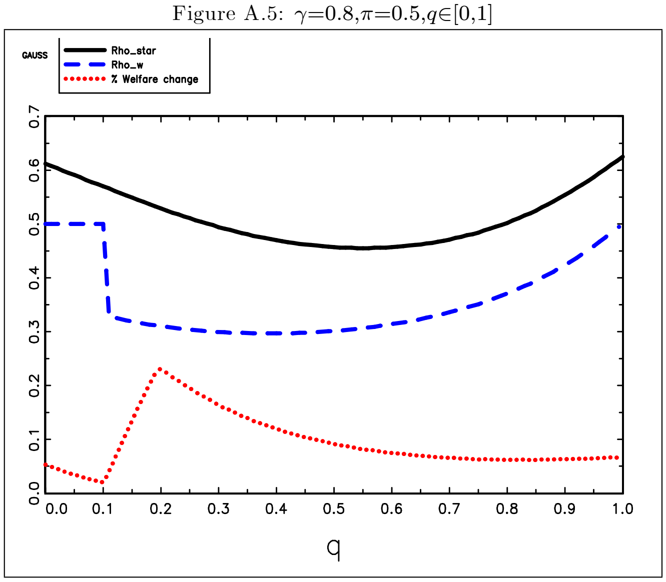


Figure A.6: γ=0.95,π=0.1,q∈[0,1]

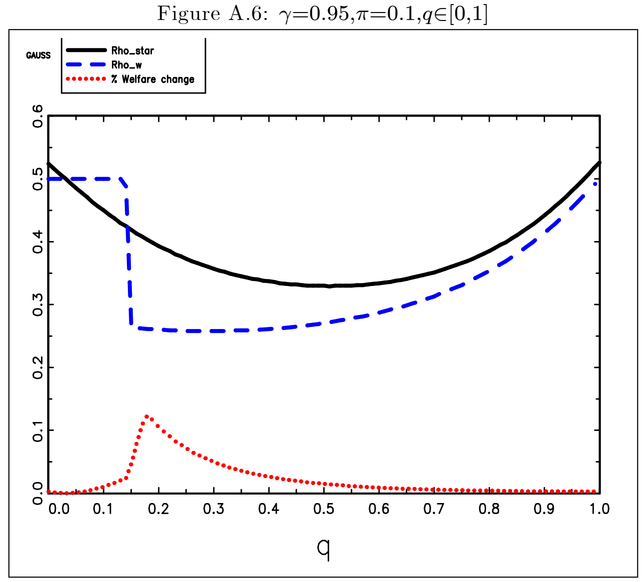


Figure A.7: γ=0.95,π=0.3,$q \in [0,1]$

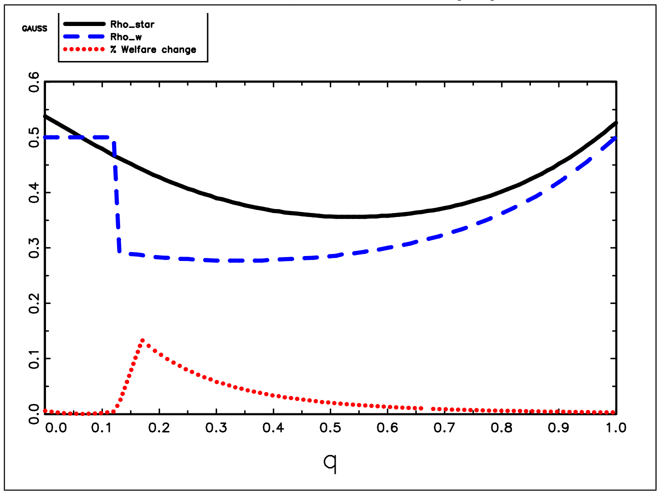


Figure A.8: γ=0.95,π=0.5,$q \in [0,1]$

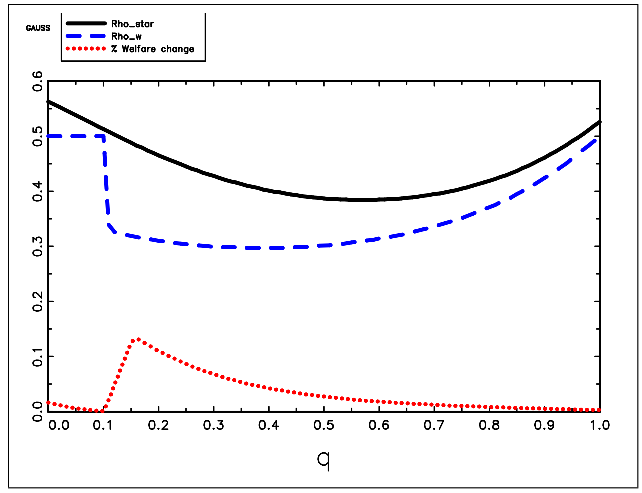


Figure A.9: q=0.1,π=0.1,$\gamma \in [0,1]$

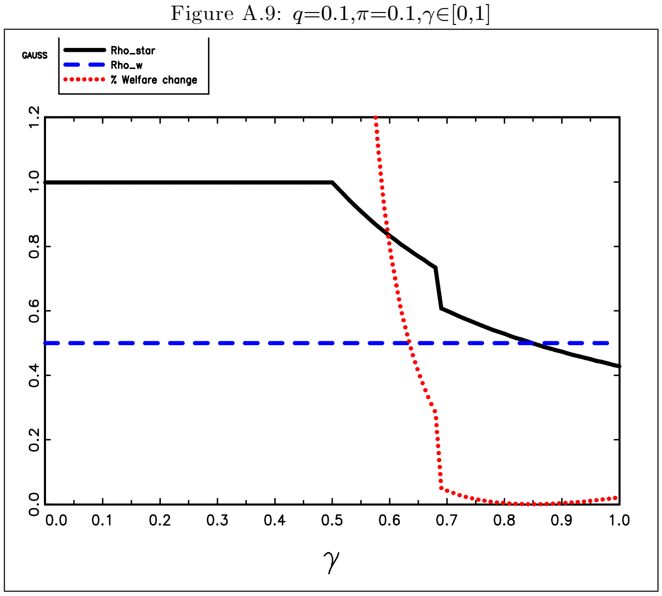


Figure A.10: q=0.2,π=0.3,$\gamma \in [0,1]$

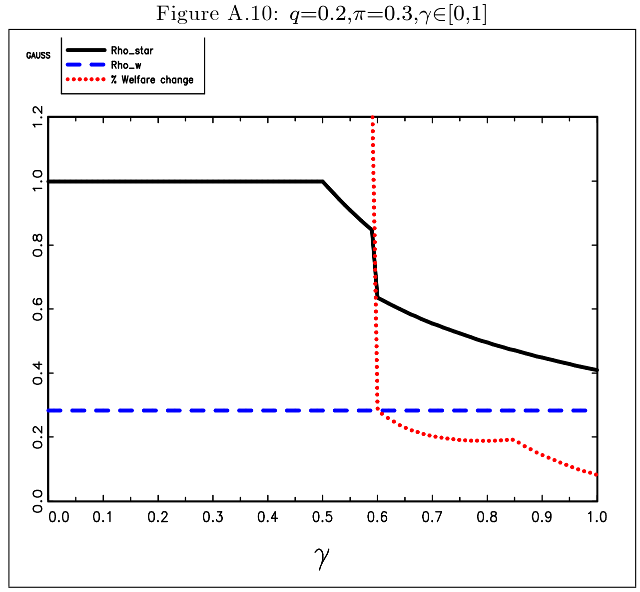


Figure A.11: q=0.2,π=0.8,$\gamma \in [0,1]$

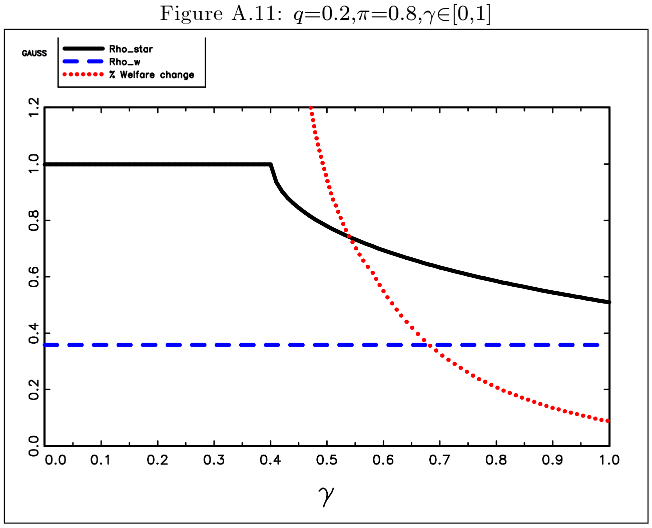


Figure A.12: q=0.5,π=0.3,$\gamma \in [0,1]$

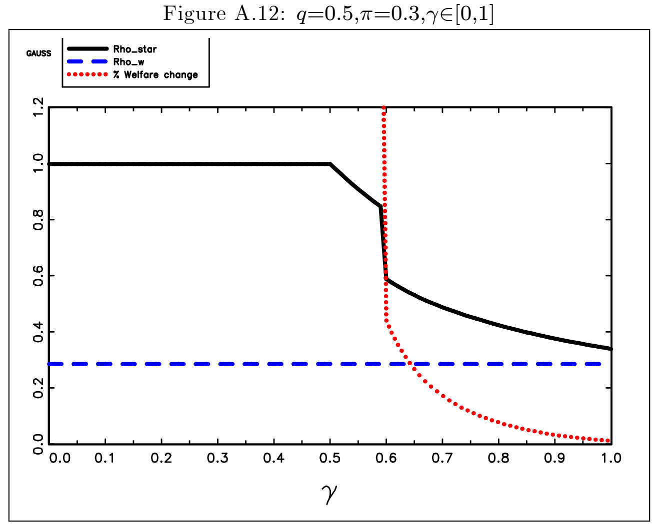


Figure A.13: γ=0.5,q=0.2,$\pi\in$[0,1]

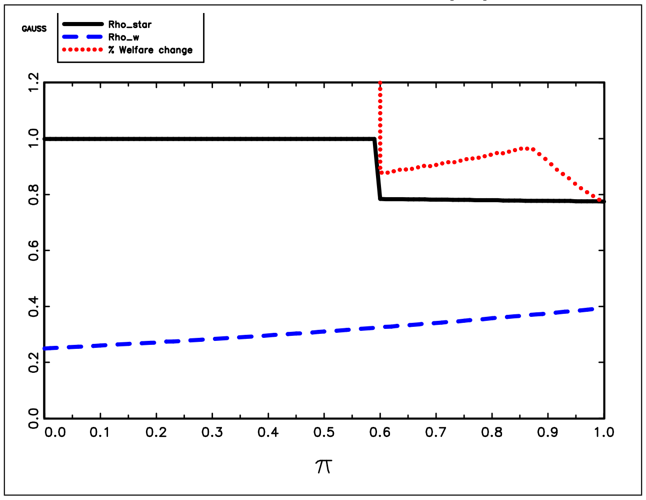


Figure A.14: γ=0.6,q=0.05,$\pi\in$[0,1]

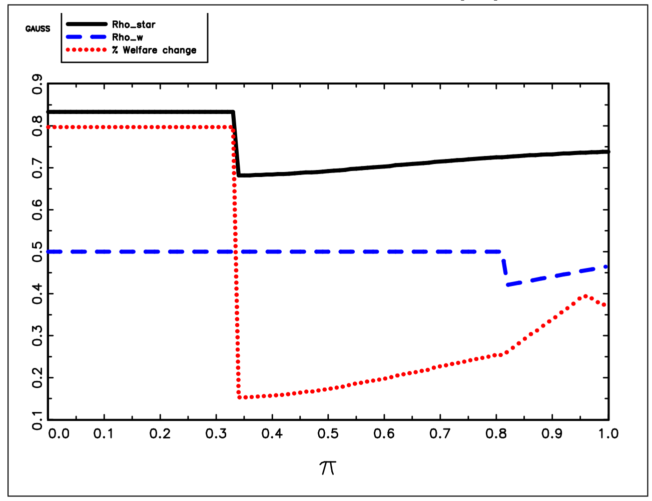


Figure A.15: γ=0.6,q=0.2,$\pi\in$[0,1]

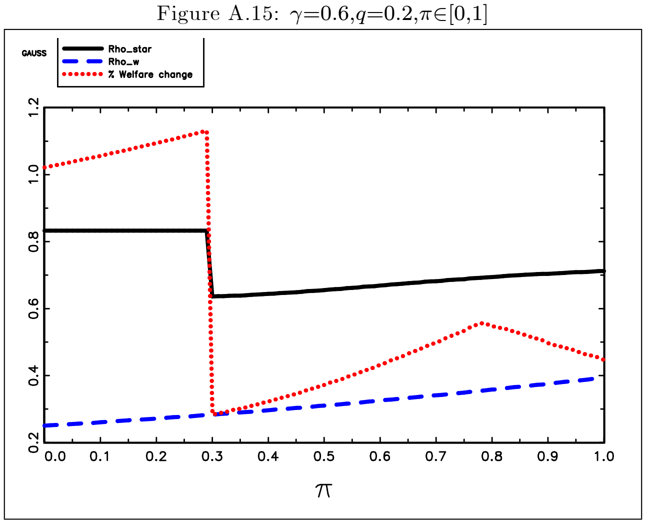


Figure A.16: γ=0.8,q=0.2,$\pi\in$[0,1]

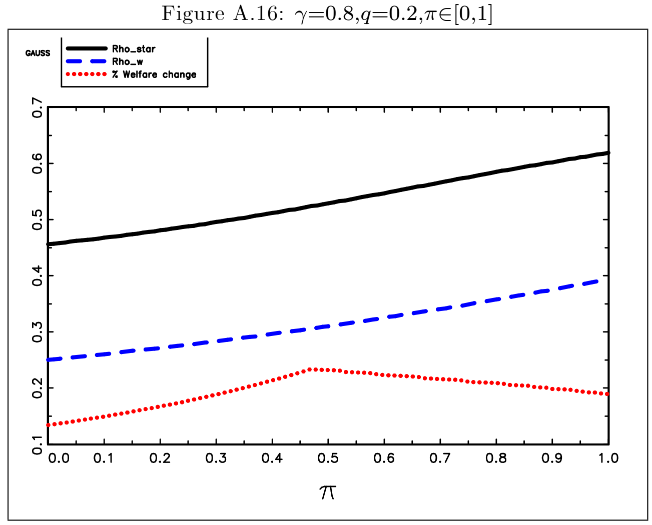


Figure A.17: γ=0.95,q=0.05,$\pi\in$[0,1]

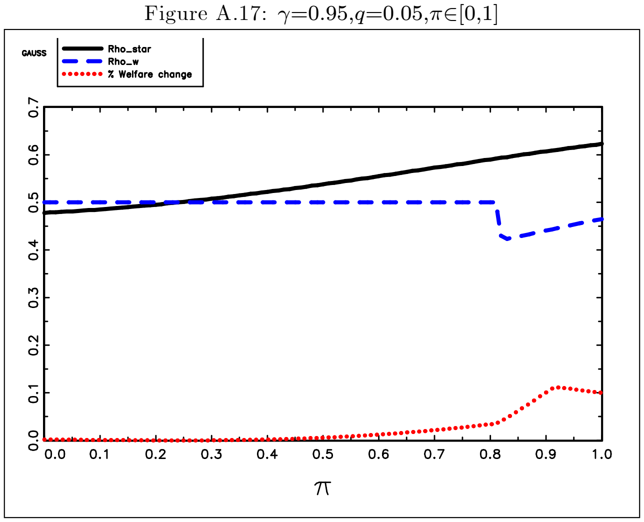
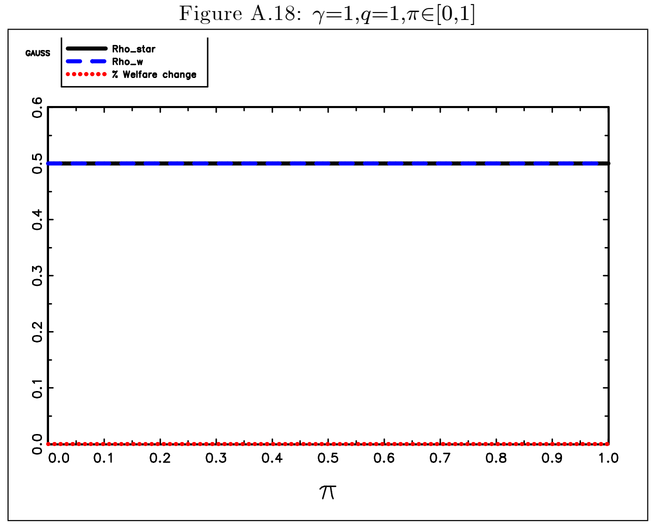


Figure A.18: γ=1,q=1,$\pi\in$[0,1]



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