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Government intervention, linkages and financial fragility

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HIGHLIGHTS

- We analyze what government intervention maximizes stability and welfare.
- We show that financial integration is never optimal in the absence of additional policies.
- The lender of last resort, recapitalization through taxes and capital requirements are evaluated.
- There is a trade-off between solving banking crises and providing public goods.
- Key role of the opportunity cost of capital and the importance assigned to consuming public goods.

Abstract

We examine how financial integration affects financial stability and what government intervention maximizes stability and well-being, in a set up where depositors can obtain information on the quality of investments in their own bank but there is a friction that prevents them from determining the quality of the investments of the other banks in the system. In this way, depositors will try to withdraw their deposits when they observe that the expected profitability in their bank is low. This will lead to a contagion problem as troubled banks may be forced to liquidate their investments in other banks. To prevent this contagion risk and reduce the costs of crises, we look at various policies governments can use, such as recapitalizing troubled banks, increasing capital requirements, or a lender-of-last-resort policy.

Keywords: Capital Requirements, Contagion, Interbank Market, Lender of Last Resort, Recapitalization, Technology Risk.

JEL classification: G21; G28

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1 Introduction

The financial crisis has reintroduced the debate on the effectiveness of interbank linkages. They allow banks to save in terms of liquidity and improve the quality of investments, but in the event of a crisis they increase the risk of contagion and can transform problems affecting a financial institution into systemic risk (see, for example, Rodrik and Subramanian , 2009, Pineda et al., 2022, Baumohl et al. 2022 or Addi and Bouoiyour 2023). The harmful effects of financial integration on global leverage and the risk of contagion among countries have been recently demonstrated. For example, the paper by Mishkin (2011) shows that what started in 2007 as a crisis in one small part of the financial system led to a worldwide economic conflagration by late 2008 and early 2009. The paper mentions that there are two key lessons from what has happened. First, the global financial system is far more interconnected than was previously recognized and excessive risk-taking that threatened the collapse of the world financial system was far more pervasive than almost anyone realized.[1] On the other side, Devereux and Yu (2020), use a large cross-country database of financial crises in developing and developed economies over a forty-year period, and find evidence in support of their model, that is, financial integration helps to diversify risk but may also spread crises among countries.

Likewise, banking crises increase the need of a safety net in the form of bailout packages to reduce their impact on the level of credit. Although there are various mechanisms available to the regulator, they are all very costly. Laeven and Valencia (2008) present a study of 42 banking crises and show that in most of them there was some type of government intervention to rescue the troubled banks. In most cases, they took the form of cash injections into banks, access to credit lines or the government's acquisition of bad assets. For example, the purchase of toxic assets was observed in both the Mexican and Japanese crises, while in the cases of Norway, Sweden and Finland the recapitalization of banks with public funds was preferred.

[1] For example, before the financial crisis, there was an increase investment in mortgage backed securities, where banks were buying securities issued by other banks. More recently, there has been an increase investment in different types of securities, as reported in Abbassi et al. (2016).

The importance that government intervention has taken in all these events and the implied trade-off affecting the provision of other public goods and services cannot be minimized.

Based on the previous facts, the aim of this paper is to see how interbank linkages affect financial stability and which government intervention maximizes stability and welfare, in the face of increased financial integration. In this work banks establish financial linkages in order to diversify their investments and consequently offer more attractive contracts to their depositors. Although depositors can obtain information about the quality of the investments in their own bank, there is a friction that prevents them from determining the quality of the investments of the other banks in the system. In this way, depositors will try to withdraw their deposits when they observe that the expected return in their bank is low. This will lead to a problem of contagion since the banks in trouble may be forced to liquidate their investments in other banks. This risk of contagion engenders that banks may prefer to remain isolated instead of seeing their activities harmed. To prevent this risk of contagion while reducing the costs of crises, we discuss various policies that governments can use, such as the recapitalization of distressed banks, an increase in capital requirements or a lender-of-last-resort policy. We contribute to the existing literature in several ways: first, we show that financial integration is never optimal, in the absence of additional policies. Second, our model provides a thorough comparison of the most important policy interventions that have been used by governments, not only in terms of costs of funds but also welfare.[2]

In particular, we consider an economy composed of two regions with a representative bank in each of them. Each of these regions is populated by a continuum of depositors who invest their money in banks. Likewise, we introduce the idea that the government can collect taxes to provide public goods such as education, health, social security, national security, recreational activities, etc. The provision of these public goods is non-discriminable, so it can be consumed by all consumers/depositors in a region at the same time. The funds that

[2]There is an extensive literature on these policies, but most papers analyze them in isolation. For example, papers on capital regulation include Hellman et al. (2000), Gale (2010) and Plantin (2015), among others. Studies on the lender of last resort include Freixas et al. (2004) and finally, some papers that focus on recapitalization are Acharya and Yorulmazer (2007, 2008) and Diamond and Rajan (2009).

remain after paying taxes are deposited in banks. Banks can maintain those funds in the form of liquidity or invest them in more illiquid and risky investments. The performance of those projects is discovered at the time of maturity; however, depositors can acquire information on the evolution of those investments in their own bank. In case of observing a weak financial situation they can run on their bank. Likewise, banks can maintain financial linkages with other banks to diversify the risk of their investment's projects (in this sense, Ahrend and Goujard, 2015, empirically analyze the effect of disturbances in bank balance sheets on the probability of occurrence of bank systemic crises). In this system, various equilibria are possible: a verification equilibrium with partial runs, a verification equilibrium with full runs and an equilibrium without verification and runs (pure run equilibrium). In the first of these equilibria, runs only take place on bad banks (partial bank runs), even though other banks may be affected by contagion. A second equilibrium with runs on all banks arising through widespread contagion and a global withdrawal from the banking system is also possible. Finally, a panic equilibrium where depositors withdraw from all banks without acquiring information can also occur. We compare the case where banks establish financial linkages with other institutions to the case of islands (where banks operate independently). In our model, we show that the island case always outperforms that of interbank ties in the absence of intervention policies. We then analyze the welfare impact of a lender-of-last-resort policy, where the central bank can inject liquidity to avoid contagion in the interbank market. However, we show that this policy never improves over the island case. Finally, we analyze the cases of bank recapitalization through taxes or an increase in capital requirements. In this sense, we find that the optimal policy will depend on the value of different parameters such as the opportunity cost of capital or the importance that agents assign to the consumption of public goods. These results have novel policy implications, since in those countries where agents are used to a centralized provision of public services and where the opportunity cost of investing is high (like in Mexico and Argentina), then our model recommends to have more disintegrated financial systems. While in other regions where the opportunity cost of capital is still high but agents are less accustomed to obtain central services (like in Chile and Peru), the optimal policy should be bank recapitalization and a more integrated financial system. Finally, in more developed countries where agents value the provision of central services but the opportunity cost of capital is not that high (like in France or Finland), then capital requirements should be applied to restore the benefits of financial linkages in case of possible crises.

Our paper is inspired by various articles in the banking literature. We follow one trend of the literature that considers the idea that the interbank market is the main driver of contagion. One of the main explanations for the existence of the interbank market lies in the provision of liquidity (see Allen and Gale, 2000, Brusco and Castiglionesi, 2007, Hasman and Samartín, 2008 or Castiglionesi et at. 2019). In Allen and Gale (2000) interbank linkages are the main drivers for the existence of contagion, generating the possibility of a chain reaction for bank liquidations. Our article also models contagion as an equilibrium problem but without the need to resort to an unexpected shock. Following the line opened by Hasman and Samartín (2008), in this model banks establish links that allow them to reduce the volatility of their investments through diversification. In this way we are able to model the relationship between shocks to bank fundamentals and financial contagion.[3] Nevertheless, crises do not appear as a result of incomplete markets but due to the presence of incomplete information for depositors.[4]

We also contribute to the literature on financial integration (see Brusco and Castiglionesi 2007, Castiglionesi et al. 2019 or Freixas and Holthausen 2005). In the case of Brusco and Castiglionesi (2007), banks establish interbank ties to protect themselves from negatively correlated liquidity shocks. However, in a context of limited liability, banks may take ex-

[3]In a recent contribution, Sydow et al. (2021) build a model of contagion propagation using a very large and granular data set for the euro area. Similarly to our model, their contagion mechanism operates through a dual channel of liquidity and solvency risk.

[4]Other articles have emphasized different sources of inefficiencies capable of generating a considerable drop in the liquidity of the system during a financial crisis (see, for example, Wagner 2008, Allen et al. 2009 or Acharya et al. 2011). Our paper is closer to those articles that study information problems in the interbank market, whether due to asymmetric information problems (Rochet and Tirole, 1996) or moral hazard (Brusco and Castiglionesi, 2007).

cessive risks. Recapitalization can solve moral hazard problems in autarky, however this is not possible in a financially interconnected world. In this context, crises occur with positive probability and they can move across borders via these financial linkages. Unlike our paper, in their article financial integration generates a Pareto improvement situation since depositors/consumers benefit from liquidity co-insurance in exchange for accepting greater exposure to systemic risk. In Castiglionesi et al. (2019) financial integration induces banks to reduce their liquidity holdings and to modify their portfolios towards more profitable but also more illiquid investments. However, when a systemic shock occurs, the total value obtained by liquidating all assets is significantly less than in autarky. Therefore, financial integration produces higher interbank rates of return during normal times but generates interest peaks in times of crisis. They find, however, that financial integration improves well-being.

Another article that studies the effects of financial integration is that of Freixas and Holthausen (2005). In it, banks face the need to liquidate their assets or substantially raise their debt levels. In this sense, they study the effects of greater international banking integration through unsecured loans in the presence of incomplete information. They show that greater international integration is not always optimal and that a system with disintegrated markets is also plausible and can be an optimal equilibrium of the system. They introduce a repo market that reduces interest rate spreads and achieves a better solution than the one obtained with segmented markets. Differently from their case, in our article interbank problems arise as a consequence of bad returns and not liquidity shocks. Consequently, in our context bank runs may be optimal. This is in line with one of the reasons for the financial crisis in 2008, where after a price shock to real assets, many debtors returned their houses to banks and many depositors withdrew their deposits fearing a possible future failure of their bank.

Empirical literature on financial integration includes Berger et al. (2021). They use a matching method that constructs synthetic counterfactual states to identify the channels that link bank deregulation to financial integration, and thereby to economic growth. They document a positive, but conditional, effect of financial integration on economic growth.

Finally, we contribute to the literature on capital regulation (Santos, 2001, provides an excellent survey of this literature[5]) and bailouts (see Allen et al. 2011 or Cooper and Nicolov, 2018). Overall, these papers analyze the effects that these policies have on moral hazard on the side of managers. In our paper, we abstract from moral hazard issues (as in Hasman and Samartín, 2017) and explicitly evaluate the cost of the different policies. For that purpose, we introduce a government that can recapitalize banks by raising taxes. Additionally, we focus on fundamental runs and the role that depositors play in enhancing market discipline.

The rest of the paper is structured as follows. Section 2 provides the basic model. Section 3 presents the social optimal allocation, while section 4 contains the main analysis when banks remain isolated. Section 5 describes the model with linkages and the exposure to contagion. A comparison between islands and linkages is presented in section 6. Section 7 introduces the-lender-of-last-resort policy, while capital requirements are developed in section 8. Section 9 analyzes recapitalization by the government using public goods. Finally, section 10 contains a numerical example and the concluding remarks are summarized in section 11.

2 The model

We consider a three period economy ($t = 0, 1, 2$) with two regions ($i = A, B$), and a representative bank in each of them. In each region, there is a continuum of agents of measure one. These agents have one unit of endowment at $t = 0$, that they can deposit in the bank or store it on their own. Storage provides one unit of the good at each date.

At date 0, the government may raise an exogenous level of taxes T, with $0 < T < 1$, so as to invest in a public asset.[6] The taxpayers are the depositors. The public asset transforms the T units of the good into public services that are consumed by everybody at date 1. We

[5]Recent empirical literature that analyzes capital regulation includes Irani et al. (2021).

[6]We assume that the size of the public expenditure, T, is exogenous. For instance, T could be the result of a political program or the rate of taxation at which maximal revenue is generated (the point at which the Laffer curve achieves its maximum).

assume that the utility of consuming public services is a linear function of its cost: θT, where $\theta > 0$. The government's objective is to maximize the agents' expected utility.

As in Diamond and Dybvig (1983) consumers are ex-ante identical, but are subject to a liquidity shock at $t = 1$. Given this shock, individuals can be of type-1 (or impatient) with probability γ and derive utility from consumption only in that period, or they can be of type-2 (or patient) with probability 1-γ and derive utility from consumption at $t = 1$ and $t = 2$. The probability γ is also the fraction of impatient consumers in the population of region i.

We assume that if impatient agents consume less than $r > 1$ of the good at $t = 1$, then their utility is lower by $\pi > 0$.[7] The utility function of a type-1 agent is

$$U_1(c_1, \pi) = \begin{cases} c_1 - \pi + \theta T & \text{if} \quad c_1 < r \\ c_1 + \theta T & \text{if} \quad c_1 \geq r \end{cases} \tag{1}$$

and the utility function of a type-2 agent is

$$U_2(c_1, c_2) = c_1 + c_2 + \theta T. \tag{2}$$

There are two types of assets available to the bank in this economy. The first is the storage technology, described above. Second, there is an illiquid asset that takes one unit of the good at date 0 and transforms it into R^H or R^L units of the good at date 2 depending on the state of nature, and both states being equally probable. If the illiquid technology is liquidated prematurely at $t = 1$, we obtain $\tau < 1$. It is assumed that that the expected return ($R^* = \frac{1}{2}R^L + \frac{1}{2}R^H$) is greater than r and $0 < \tau < R^L \leq 1 < r < R^* < R^H$.

In each region the bank may obtain the high return on the investment project (expansion bank, from now on good bank), with probability one half and a low one (recession bank,

[7] We use the same utility function as in Chen and Hasan (2006, 2008) and Hasman et al. (2011). Agents normally face fixed payments but sometimes they require extra funds to deal with special contingencies (so as to cover r). If they do not have enough cash, they face some costs. Then, the variable π is a liquidity loss in utility.

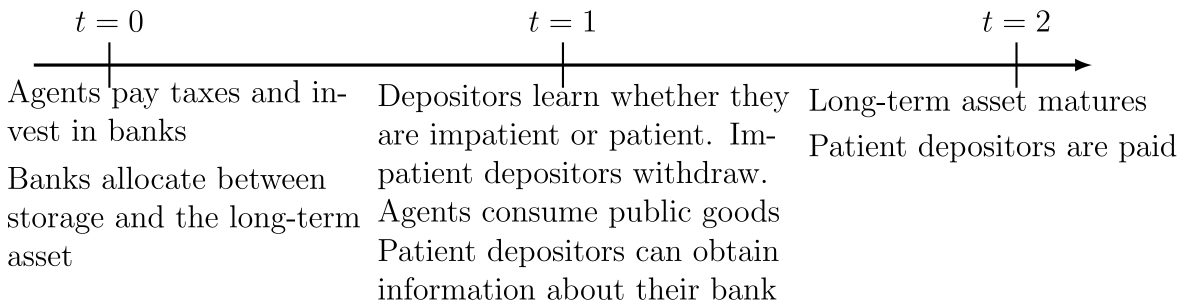

Figure 1: Sequence of events

from now on bad bank), with probability one half. Neither bankers nor depositors know the *type* of their own bank nor that of the other one. Nevertheless, they know the distribution of shocks in the whole economy. The information is revealed to consumers-depositors at $t = 2$, although they can obtain information at $t = 1$ at a cost of ε. This information cost can be understood as a monitoring cost. Although information might be perfect and free, depositors need time and other resources to process it.[8]

The sequence of events is as follows. At $t = 0$, agents pay taxes and invest the rest in banks. The bank then invests the receipts between storage and the long-term asset. At $t = 1$, agents discover whether they are impatient or patient, and consume public services. Patient depositors can obtain information about their bank. At $t = 2$, the long-term asset matures and patient depositors are paid. Figure 1 illustrates the timing of the model.

3 The social planner and the first best allocation

As a useful benchmark, we will first analyze the first-best allocation. Since the consumers in one region are ex ante identical to consumers in another region, all consumers will be treated alike.

Notice that if we consider both banks as a single one there are three possible states, concerning the technology shocks. With probability 1/2 the return is $R^* = \frac{1}{2}R^L + \frac{1}{2}R^H$, with probability 1/4 the return is R^L and with probability 1/4 the return is R^H.

[8] See Nikitin and Smith (2007) for a discussion of this assumption.

Let $c_t = \{c_1, c_2^s\}$ be the optimal contract. The social planner can invest $y = \gamma c_1$ in storage and $1 - T - y$ in the technology which provides a higher expected return at $t = 2$ than the storage technology.

In order to avoid the utility loss for early depositors, the social planner will offer the following contract:

$$c_1 = r \tag{3}$$

$$c_2^s = \frac{(1 - T - y)}{1 - \gamma} R^s \tag{4}$$

where $R^s = R^H, R^L, R^*$.[9]

The increase in utility due to consumption at or above the threshold r is sufficiently large that it compensates for investing less than one in the technology at $t = 0$. This requires a sufficiently high π so that it is optimal to provide consumption smoothing.[10]

The expected utility achieved with a social planner, when verification does not take place is:

$$\mathrm{E}\, U^{FB} = \gamma r + (1 - \gamma) \left[\frac{1}{4} \left(c_2^H + c_2^L \right) + \frac{1}{2} c_2^* \right] + \theta T \tag{5}$$

On the other hand, if there is verification, the social planner will liquidate the project in the bad state, and impatient individuals will suffer the utility loss.

The expected utility would be:

$$\frac{1}{4} \left[\gamma r + (1 - \gamma) c_2^H + y + (1 - T - y)\tau - \gamma\pi \right] + \frac{1}{2} \left[\gamma r + (1 - \gamma) c_2^* \right] + \theta T - \varepsilon \tag{6}$$

And so we can obtain a threshold value of ε above which verification will not take place with the social optimum, and viceversa. This value that ensures that verification is not optimal is obtained by equalizing the expected utility without verification, given in equation

[9] Note that this optimal contract guarantees the expected return of the asset, while minimizing its volatility.

[10] See Dwyer et al. (2022) for a detailed derivation of this result.

(5) and the expected utility with verification given in (6), that is:

$$\frac{1}{4}\left[\gamma r + (1-\gamma)c_2^H + y + (1-T-y)\tau - \gamma\pi\right] + \frac{1}{2}\left[\gamma r + (1-\gamma)c_2^*\right] + \theta T - \varepsilon \leq$$
$$\gamma r + (1-\gamma)\left[\frac{1}{4}\left(c_2^H + c_2^L\right) + \frac{1}{2}c_2^*\right] + \theta T \tag{7}$$

or

$$\frac{1}{4}[(1-T-y)\tau - \gamma\pi] - \varepsilon \leq \frac{1}{4}(1-T-\gamma r)R^L \tag{8}$$

which states that the value of acquiring and withdrawing in the bad state is worse than not acquiring information, waiting and finally being in the bad state of nature.

The above condition simplifies to

$$\varepsilon \geq \overline{\varepsilon} = \frac{1}{4}\left[(1-T-y)\tau - \gamma\pi - (1-T-y)R^L\right] \tag{9}$$

Therefore, the social planner will not acquire information whenever $\varepsilon \geq \overline{\varepsilon}$, and will acquire it otherwise.

4 Banks in isolated islands

In this section we analyze a decentralized economy where banks are isolated in each region and there are two possible states of nature.

As mentioned in the previous section, if π is sufficiently high, banks will offer $c_1 = r$ to impatient agents. In the second year, depositors receive the remaining funds.[11]

Therefore, banks will invest $y = \gamma c_1$ in storage and $1-T-y$ in the long-term technology.

[11] Allen and Gale (2007) provide a discussion of the optimal contract in this line.

If the high return realizes, the payment in the second year will be:

$$c_2^H = \frac{(1-T-y)}{1-\gamma} R^H \tag{10}$$

On the contrary, if the low return realizes, consumption in the second period will then be:

$$c_2^L = \frac{(1-T-y)}{1-\gamma} R^L \tag{11}$$

If $c_1 > 1$ and $R^L \leq 1$, then $c_2^L < c_1$. If depositors verify the type of banks and find out that the return is the low one they will withdraw their deposits.[12]

The following propositions describe conditions for the existence of the different equilibria.

Proposition 1 *In the island case, there is a verification equilibrium where depositors will withdraw their deposits in the first period when they receive a negative signal and will maintain them otherwise if the following conditions are satisfied:*

$$c_1 \geq c_2^L \tag{12}$$

$$[y + (1-T-y)\tau] \geq \varepsilon \tag{13}$$

Equation (12) guarantees that it is optimal for depositors to withdraw their deposits in the first period, if the return is low. Equation (13) ensures that if all agents play the verification equilibrium, it is not optimal for any agent to deviate.[13]

The expected utility achieved is:

$$\mathrm{E}\, U^I = \frac{1}{2}\left\{\left[\gamma r + (1-\gamma)c_2^H\right] + \left[y + (1-T-y)\tau - \gamma\pi\right]\right\} + \theta T - \varepsilon \tag{14}$$

We have the traditional equilibria which are summarized in the proposition below:

[12] The utility when there is a run is $\gamma[y+(1-T-y)\tau-\pi]+(1-\gamma)[y+(1-T-y)\tau] = y+(1-T-y)\tau-\gamma\pi$.

[13] This is in line with the banking panic in Northern Rock, where once the insolvency of the bank was recognized all depositors decided to withdraw their deposits, instead of waiting and receiving an uncertain return.

Proposition 2 *In the island case, the no-run and the full run are Nash Equilibria, if the following conditions are satisfied:*

$$\frac{1}{2}[c_2^H + c_2^L] \geq c_1 \tag{15}$$

$$\frac{1}{2}c_2^L \geq \frac{1}{2}\left[y + (1 - T - y)\tau\right] - \varepsilon \tag{16}$$

Equations (15) and (16) guarantee that an agent has no incentive to deviate in the no-run equilibrium. Equation (15) is the incentive compatibility constraint while equation (16) guarantees that the benefit obtained by verifying and withdrawing when the outcome is inefficient, is lower than the expected utility achieved in the no-run equilibrium. Finally, the full-run equilibrium is always satisfied by assumption as $r > 1$. This is a standard problem in banking recognized as a self fulfilling prophecy, where if depositors believe that their bank is going to fail, even if this is not necessarily true due to its fundamental, the bank will finally fail given the unstable structure of the banking system where banks transform liquid funds (deposits) into iliquid funds (long-term loans/investments).[14]

We focus on parameters such that the no-run equilibrium will not take place, and so individuals will have an incentive to verify information about the bank. This implies that equation (16) does not hold. This happens when $R^L \leq \overline{R}^L$, where

$$\overline{R}^L = \frac{\{[y + (1 - T - y)]\tau - 2\epsilon\}(1 - \gamma)}{1 - T - \gamma r} \tag{17}$$

5 Interbank Linkages- Swaps

Banks are going to establish linkages ex ante, in order to insure against the technology shock. Let z_{ij} be defined as the loan that bank j receives from bank i (by assumption $z_{ij} = z_{ji}$). We assume that bank i spreads interbank loans for an amount of $\mathrm{z}_{ij} = \frac{1}{2}$. This interbank

[14]Note that as suggested in Allen and Gale (2007) this equilibrium can be prevented with suspension of convertibility.

loan pays $z_{ij}c_2^H$ if kept until $t = 2$, when the bank is of a good type, and $z_{ij}c_2^L$ when the bank is of a bad type.[15] If liquidated at $t = 1$, it will pay the same as other deposits withdrawn in the first period ($z_{ij}c_1$). Recall that the interbank loans are compensated simultaneously between banks, so if bank 1 decides to cancel its interbank loan at $t = 1$, it will also have to pay back its obligation to the other bank in that period.

Each bank receives one unit from its depositors and the interbank loan from the other bank.[16] Banks issue demand deposits contracts. These deposits pay c_1 if withdrawn in the first period, provided that the bank is solvent. In the second period all remaining assets are liquidated and allocated among deposit holders on a *pro rata* basis.

Each bank stores $y = \gamma c_1$ share of the period 0 deposit, and invests the rest in the illiquid technology. The amount of storage should be enough to just satisfy the liquidity needs of impatient agents.

The second period consumption will depend on the realization of the technology shock for both banks. There are four possible states of nature: In state I both banks receive the low shock, in state II both banks receive the high shock and in states III and IV one of the banks receives the high (low) and the other bank the low (high) shock. The values of second period consumption in the different states are detailed in the equations below:

$$c_2^L \leq \frac{(1 - T - y)[R^L \frac{1}{2} + R^L \frac{1}{2}]}{1 - \gamma} = \frac{(1 - T - y)R^L}{1 - \gamma}; \tag{18}$$

$$c_2^H \leq \frac{(1 - T - y)[R^H \frac{1}{2} + R^H \frac{1}{2}]}{1 - \gamma} = \frac{(1 - T - y)R^H}{1 - \gamma}; \tag{19}$$

$$c_2^* \leq \frac{(1 - T - y)[R^H \frac{1}{2} + R^L \frac{1}{2}]}{1 - \gamma} = \frac{(1 - T - y)R^*}{1 - \gamma}; \tag{20}$$

[15] This structure of interbank loan payments facilitates savings in monitoring costs while profiting from diversification. It may also be interpreted as banks buying securities issued by other banks in the system. See Hasman and Samartin (2008) for a more detailed description.

[16] Note that interbank loans cancel against each other at date 0.

where c_2^L is the consumption of a patient depositor in state I, and c_2^H is the consumption of a patient depositor in state II. Finally, c_2^* is the consumption in states III and IV.

The following propositions describe conditions for the existence of the different equilibria. In this case, the possible equilibria are: a verification equilibrium with partial runs (and contagion), a verification equilibrium with total runs, a full-run equilibrium and a no-run equilibrium. In the last two equilibria, depositors do not verify the type of banks. They either withdraw from all banks or do not acquire information and do not withdraw.

As shown in the previous section, depositors will always withdraw when they verify the type of banks and receive the negative signal in their bank, as $c_1 > c_{2L}$. As a result, in state I, impatient and patient depositors of both banks will withdraw and receive $y + (1 - T - y)\tau$. Similarly, in states III and IV depositors from the bad bank will withdraw. As a result, this bank has to liquidate its technology and the interbank loans, and will be able to pay a total amount of

$$\widehat{c_1} = \frac{y + (1 - T - y)\tau + \frac{1}{2}c_1}{1 + \frac{1}{2}} < r \tag{21}$$

Notice that the numerator represents assets available given by the storage technology, liquidation of the long term asset and liquidation of interbank loans with the other bank. The liabilities of the bank are given by the denominator of the equation. On the other hand, the good bank will have to liquidate part of its long term asset in order to pay its interbank loans to the bad bank; however it won't enter into a bank run as long as $\widehat{c_2} = \frac{R^H(1-\lambda)(1-T-y)}{(1-\gamma)} > r$, where λ is the proportion of the investment in the long term asset that has to be liquidated in the first date in the good bank in order to be able to guarantee the promised consumption of $c_1 = r$.[17]

Nevertheless, as second period consumption in the good bank is less than the promised one, that is, $\widehat{c_2} < c_2^H$, the good bank is affected by contagion and is contractually bankrupt. This is the case of a verification equilibrium with partial bank runs and contagion. There is contagion because the good bank, even if it does not experience a run, it cannot pay its

[17] with $\lambda = \frac{[c_1(\gamma + \frac{1}{2}) - \gamma c_1 - \frac{1}{2}\widehat{c_1}]}{(1-T-y)\tau}$. The expression for λ can be simplified to $\lambda = \frac{r(1-\gamma)}{3[1-T-y]\tau} - \frac{1}{3}$

promised consumption to its late consumers.

The following propositions describe conditions for the existence of the different equilibria.

Proposition 3 *In states III and IV, there is a verification equilibrium in which only the bad bank is liquidated and the good bank is affected by contagion, whereas in state I, all depositors will withdraw their deposits generating a financial crisis based on fundamentals.*

The previous statement is going to be true when the following conditions are satisfied:

$$c_1 \geq c_2^L \tag{22}$$

$$\left[c_2^H + \widehat{c}_2 + y + (1 - T - y)\tau + \widehat{c}_1\right] - \varepsilon \geq \left[c_2^H + \widehat{c}_2\right] \tag{23}$$

Equation (22) indicates that the lowest possible consumption in the second period is smaller than consumption promised to impatient depositors. Finally, equation (23) states that if all other depositors are playing the verification equilibrium it is optimal to play it. The intuition behind this idea is that even if depositors know that their bank is part of an interconnected financial system, and that some investments might be better than they evaluate, it is always better to withdraw if they have enough reasons to believe that their bank is involved in some bad investments, since waiting to see what the others do is never a good strategy. In this case, those banks connected to the troubled bank will have to liquidate part of their assets to respect their contracts with some pervasive effects.

The expected utility achieved is:

$$\begin{gathered}\mathrm{E}\, U^L = \frac{1}{4}\left\{[\gamma r + (1-\gamma)c_2^H] + [\widehat{c}_1 - \gamma\pi] + \right. \\ \left. [\gamma r + (1-\gamma)\widehat{c}_2] + [y + (1 - T - y)\tau - \gamma\pi]\right\} + \theta T - \varepsilon \end{gathered} \tag{24}$$

Additionally, we still have the traditional equilibria, which are given in the following proposition:

Proposition 4 *The no-run and full run are Nash Equilibria of this game, if the following conditions are satisfied:*

$$\frac{1}{2}\left(c_2^H + c_2^L\right) \geq c_1 \tag{25}$$

$$\frac{1}{2}\left(c_2^H + c_2^L\right) \geq \frac{1}{4}\left(c_2^H + \widehat{c}_2 + y + (1-T-y)\tau + \widehat{c}_1\right) - \varepsilon \tag{26}$$

$$c_1 > y + (1-T-y)\tau \tag{27}$$

Equations (25) and (26) guarantee that an agent has no incentive to deviate in the no-run equilibrium. Equation (25) is the incentive compatibility constraint while equation (26) guarantees that the benefit obtained by verifying and withdrawing when the outcome is inefficient, is lower than the expected utility achieved in the no-run equilibrium.

As in the previous section, we focus on parameters such that the no-run equilibrium will not take place, and so individuals will have an incentive to verify information about the bank. This implies that equation (26) does not hold and so $R^L \leq \widehat{R}^L$, where

$$\widehat{R}^L = \frac{\{\frac{1}{4}[\widehat{c}_2 + \widehat{c}_1 - c_2^H + y + (1-T-y)\tau] - \varepsilon\}2(1-\gamma)}{1-T-y} \tag{28}$$

6 Islands versus Linkages

The aim of this section is to examine whether banks are better off by creating linkages. This implies comparing the expected utilities in both scenarios.

The main result is summarized in the following proposition:

Proposition 5 *The island case dominates linkages, in the absence of additional policies.*

Proof: See Appendix A.

In a very interconnected world, risk does not disappear, it is transformed into higher systemic risk. In the context of the recent crisis, we have seen that the risk of a general failure has increased, and without government intervention the risk of a general collapse seems plausible. In this line, the recent guarantee provided by the Swiss government to UBS in order to acquire Credit Suisse shows how vulnerable the financial system is to a single failure and how reluctant banks are to establish links, without an explicit government guarantee, in the presence of turbulent markets.

However, in order to show the robustness of the comparison provided in proposition 5 we have derived a comparison of both scenarios with a more general utility function. The results are provided in Appendix B. For the parameters used in the simulations the island still dominates.[18]

7 Lender of last resort

In this section we consider the policy of a lender of last resort in order to avoid contagion in the state where the bad bank is affected by the bank run and is forced to liquidate its interbank deposits with the other bank. In this case, the central bank can intervene and avoid liquidation of the solvent bank, by injecting an amount of liquidity x so that the good bank is not forced to partially liquidate its resources in order to pay impatient depositors. The amount to be injected by the central bank is

$$x = \frac{r - \widehat{c_1}}{2} \tag{29}$$

or

$$x = \frac{r - \frac{y+(1-T-y)\tau+\frac{1}{2}c_1}{1+\frac{1}{2}}}{2} \tag{30}$$

Operating in the above condition we obtain

[18] We thank one of the reviewers for this suggestion.

$$x = \frac{r(1-\gamma) - \tau(1-T-y)}{3} \tag{31}$$

We assume this loan is paid in year 2 at a rate s. Therefore, second period consumption in the good bank becomes

$$c_2^{LLR} = \frac{(1-T-y)R^H - x(1+s)}{(1-\gamma)} \tag{32}$$

The expected utility with a lender of last resort is:

$$\mathrm{E}\,U^{LLR} = \frac{1}{4}\big\{[\gamma r + (1-\gamma)c_2^H] + [\widehat{c}_1 - \gamma\pi] +$$
$$[\gamma r + (1-\gamma)c_2^{LLR}] + [y + (1-T-y)\tau - \gamma\pi]\big\} + \theta T - \varepsilon \tag{33}$$

We will compare this expected utility with both the economy with linkages and the island case.

7.1 The lender of last resort versus linkages

It is straight forward to show that a lender of last resort improves over the economy where linkages are established. This requires comparing the expected utility with the lender of last resort and with linkages, that is, $\mathrm{E}\,U^{LLR} \geq EU^L$, which holds as long as

$$c_2^{LLR} \geq \widehat{c}_2 \tag{34}$$

or,

$$\frac{(1-T-y)R^H - x(1+s)}{(1-\gamma)} \geq \frac{(1-T-y)R^H(1-\lambda)}{(1-\gamma)} \tag{35}$$

which is guaranteed as long as the rate paid on the loan is lower than the return on asset in the high state, that is, $s \leq R^H$. Note also that $(1-T-y)\lambda > x$, as $\lambda = \frac{r-\widehat{c_1}}{2(1-T-y)\tau}$, $x = \frac{r-\widehat{c_1}}{2}$ and $(1-T-y)\tau < 1$. Therefore, the lender of last resort improves over the economy with linkages.

7.2 The lender of last resort versus the island Case

We show that the lender of last resort does not improve over the island case. This result is summarized in the proposition below.

Proposition 6 *The island case dominates over the lender-of-last-resort policy.*

Proof: See Appendix C.

The lender of last resort policy, typically implemented by a central bank, aims to provide liquidity support to banks or financial institutions in times of financial distress or systemic crises. While this policy serves an important purpose in stabilizing the financial system, there are potential problems associated with it that may make banks prefer to remain isolated. For instance, the presence of a lender of last resort can create moral hazard issues. Knowing that a central bank stands ready to provide liquidity support, banks may engage in riskier behavior, assuming that they will be rescued if they face financial difficulties. Additionally, banks that rely on this facility may be viewed as having underlying financial troubles, which could erode market confidence and potentially trigger a loss of depositor trust. Furthermore, central banks may impose requirements such as enhanced supervision, changes in management, or asset quality reviews as a condition for providing assistance eroding banks' charter value.

8 Capital requirements

We examine capital requirements, as an alternative policy that can allow the economy with linkages to survive. For that purpose, we introduce a third group of agents in the economy. They have a risk-neutral utility as follows:

$$U_k = c_1 + c_2 \tag{36}$$

We call these agents "investors". We assume there is an infinite supply of capital with an opportunity cost ρ greater or equal to the expected return $R^\star$.

$$\rho \geq R^\star. \tag{37}$$

These investors receive dividends from the bank at $t = 2$ if there are funds left after paying depositors. Investors are competitive and their dividend is such that the expected dividend at $t = 2$ equals their opportunity cost, that is

$$\frac{1}{2}d_2^H + \frac{1}{2}d_2^L = \rho k \tag{38}$$

where d_2^H is the dividend paid in the high state and d_2^L the dividend in the low one.

Given that capital is costly, the only motivation to issue capital in this model is to avoid runs in the bad state. Bank runs can be avoided if the following incentive compatibility constraint is satisfied

$$c_2^{Lk} = \frac{(1 + k - T - y)R^L - d_2^L}{1 - \gamma} \geq r \tag{39}$$

In equilibrium the incentive compatibility constraint will always hold with equality. Additionally, dividends will never be paid in the low state.[19]

The above condition can be expressed as follows:

$$1 + k - T - y = \frac{r(1 - \gamma)}{R^L} \tag{40}$$

[19]Note that the dividend in the low state of nature has to fulfill condition (39). Consequently, by increasing d_2^L we have to increase k by the same amount, and there is an opportunity cost of ρ. Therefore, banks will try to limit k to the minimum while avoiding bank runs. On the other hand, the expected return of investors just satisfies equation (38) and d_2^L=0.

If banks can issue this amount of capital, the expected utility is:

$$EU^C = \frac{1}{2}\left[\gamma r + (1-\gamma)c_2^{Hk} + r\right] + \theta T \tag{41}$$

where

$$c_2^{Hk} = \frac{(1+k-T-y)R^H - d_2^H}{(1-\gamma)} \tag{42}$$

is the second period consumption when the high state occurs

To avoid bank runs in the high state, it must be the case that

$$c_1 \leq c_{2h}^{Hk} \tag{43}$$

because otherwise all patient depositors will withdraw at $t = 1$, in which case the equilibrium is not feasible.[20]

We can compare the expected utility with capital requirements and in the island case, that is:

$$\begin{aligned} &\frac{1}{2}\left[\gamma r + (1-\gamma)c_2^{Hk} + r\right] + \theta T \geq \\ &\frac{1}{2}\left\{\left[\gamma r + (1-\gamma)c_2^{H}\right] + \left[y + (1-T-y)\tau - \gamma\pi\right]\right\} + \theta T - \varepsilon \end{aligned} \tag{44}$$

Making use of the fact that

$$c_2^{Hk} = c_2^H + \frac{kR^H - d_2^H}{(1-\gamma)} \tag{45}$$

the above expression can be simplified as follows:

$$\frac{1}{2}\left[r + kR^H\right] - \rho k \geq \frac{1}{2}\left[y + (1-T-y)\tau - \gamma\pi\right] - \varepsilon \tag{46}$$

[20]This inequality can be written as $R^H \geq \frac{r(1-\gamma)+d_2^H}{1+k-T-\gamma r}$

This condition states that when the net gains of using capital outweigh those obtained in the island case, capital would allow the economy with linkages to survive.

Solving for ρ in the above condition we obtain that for values of $\rho \leq \widehat{\rho}$, capital requirements dominates over the island case, where $\widehat{\rho}$ is

$$\widehat{\rho} = \frac{\frac{1}{2}\left\{r + kR^H - [y + (1-T-y)\tau - \gamma\pi]\right\} + \varepsilon}{k} \tag{47}$$

9 Recapitalization

An alternative policy is for the government to intervene by injecting public funds and in this way avoid the contagion effect that liquidation of the bad bank has on the good one.[21] Let δ denote the amount of money that the government of the region of the good bank injects into the banking system so as to stop partial liquidation of the good bank. Then,

$$\delta = \frac{r - \widehat{c_1}}{2} \tag{48}$$

If the government can inject this amount of money the good bank will not be affected by contagion and will be able to pay consumers their promised payment in both years. On the other hand, there will be less resources invested in public goods $(T - \delta)$. In this case, the expected utility is

$$\begin{aligned} \mathrm{E}\, U^R = & \frac{1}{2}\left[\gamma r + (1-\gamma)c_2^H\right] + \frac{1}{4}\left\{[\widehat{c_1} - \gamma\pi] + [y + (1-T-y)\tau - \gamma\pi]\right\} + \\ & \frac{1}{4}\theta(T-\delta) + \frac{3}{4}\theta T - \varepsilon \end{aligned} \tag{49}$$

We can also compare the expected utility with recapitalization to the island case, that

[21] Laeven and Valencia (2008) provide a new database on the timing of systemic banking crises and policy responses to resolve them, for the period 1970-2007, with detailed data on crisis containment and resolution policies for 42 crisis episodes. They document that in 33 out of the 42 selected crisis episodes, banks were recapitalized by the government.

is, recapitalization will be preferred when

$$\frac{1}{2}\left[\gamma r+(1-\gamma)c_2^H\right]+\frac{1}{4}\left\{[\widehat{c_1}-\gamma\pi]+[y+(1-T-y)\tau-\gamma\pi]\right\}+\frac{1}{4}\theta(T-\delta)+ \\ \frac{3}{4}\theta T-\varepsilon\geq\frac{1}{2}\left[\gamma r+(1-\gamma)c_2^H\right]+\frac{1}{2}\left[y+(1-T-y)\tau-\gamma\pi\right]+\theta T-\varepsilon \tag{50}$$

Solving for θ we obtain

$$\theta\leq\widehat{\theta}=\frac{\widehat{c_1}-(y+(1-T-y)\tau)}{\delta} \tag{51}$$

Therefore, recapitalization will be preferred when individuals do not assign a high value to the consumption of public goods, that is for values of $\theta\leq\widehat{\theta}$. Otherwise, the island case would be preferred.

Finally, we can also compare recapitalization versus capital requirements, that is, recapitalization will be preferred when

$$\frac{1}{2}\left[\gamma r+(1-\gamma)c_2^H\right]+\frac{1}{4}\left\{[\widehat{c_1}-\gamma\pi]+[y+(1-T-y)\tau-\gamma\pi]\right\}+\frac{1}{4}\theta(T-\delta) \\ \frac{3}{4}\theta T-\varepsilon+\geq\frac{1}{2}\left[\gamma r+(1-\gamma)c_2^{Hk}+r\right]+\theta T \tag{52}$$

And solving for ρ we obtain, that recapitalization will be preferred whenever $\rho\geq\rho^\star$, where

$$\rho^\star=\frac{\frac{1}{2}(r+kR^H)-\frac{1}{4}[\widehat{c_1}-\gamma\pi+(y+(1-T-y)\tau-\gamma\pi)]+\frac{1}{4}\theta\delta+\varepsilon}{k} \tag{53}$$

This means that when the opportunity cost of capital is sufficiently high, recapitalization is the preferred policy. It can be shown that in the level curve $\rho^\star(\theta)$, given by equation (53), if we substitute θ by $\widehat{\theta}$, defined in equation (51), then $\rho^\star(\widehat{\theta})=\widehat{\rho}$. So there is one critical point where the three cases yield the same expected utility.

10 Numerical example

This section provides a numerical example. Table 1 summarizes the calibration of the model.

r	T	γ	R^L	R^H	ε	τ	π
1.01	0.12	0.5	0.4	3.5	0.02	0.3	0.5

Table 1: *Calibration*

These parameter values, satisfy all the conditions of the model. For these parameter values $\widehat{\theta} = 1$ and $\widehat{\rho} = 2.58$.

Figure 2 displays the comparison between the island case, recapitalization or capital requirements, for different values of θ and ρ. It can be observed that at the critical point $(\widehat{\theta}, \widehat{\rho})$ the three cases yield the same expected utility of 1.16. On the other hand, the expected utility achieved with the social optimum is 1.26. The northeast region represents combinations (θ, ρ) for which the island case dominates, whereas in the northwest region recapitalization is the dominant policy.

The intuition is that when individuals highly value public services (θ is high), then the best policy in terms of welfare is to allow banks to remain isolated as the opportunity cost of impeding contagion is very high in terms of the consumption of public services. Conversely, when θ is low, recapitalization is the optimal policy. On the other side, in the southern region capital requirements would be the dominant policy, as the cost of capital is low.

Table 2 shows how this critical point is affected by different parameters of the model, as the change in the return on the technology in the high state, the level of taxes, the interest rate paid in year 1, the liquidity loss suffered by impatient depositors or the liquidation value of the technology. It can be observed that an increase in the high return moves the critical point up. Similarly, when the level of taxes, the interest rate paid in year 1 or the liquidity loss increase, the critical point also moves up. Finally, if the liquidation value increases, the critical point moves down.

It can also be observed that the critical point $\widehat{\theta}$ is independent of the parameters of the

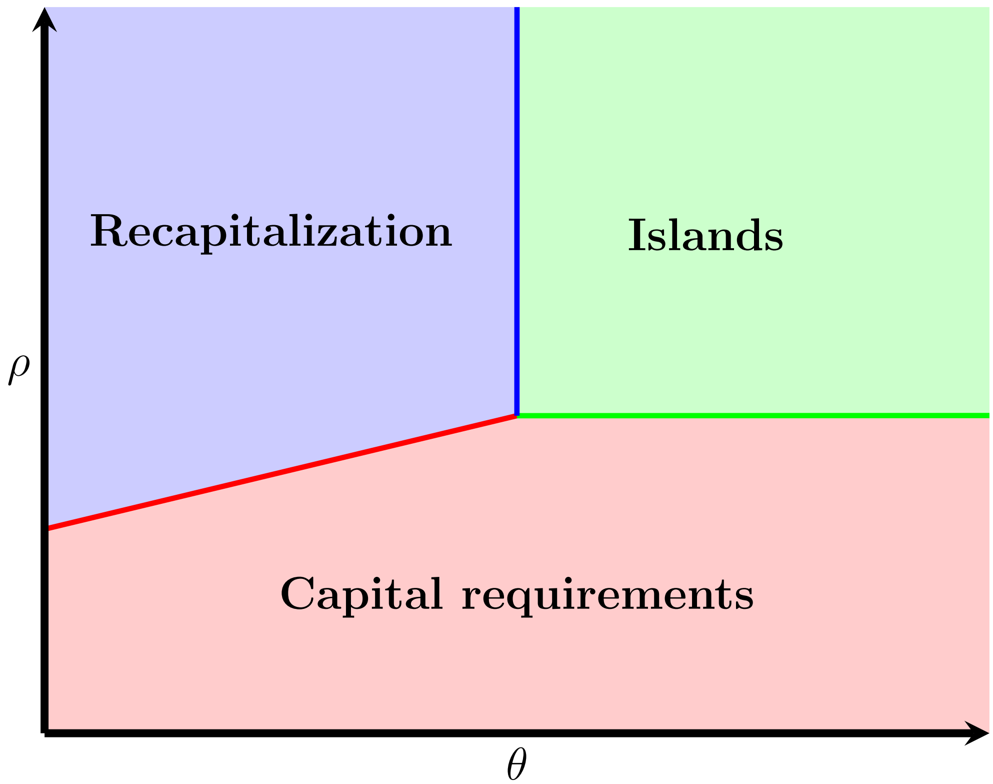

Figure 2: Expected profits for the different financial structures

Parameters	C
1. R^H	$+$
2. T	$+$
3. r	$+$
4. π	$+$
5. τ	$-$

Table 2: Comparative Statics

model. For that purpose, we re-arrange equation (51) by calling $Z = y + (1 - T - y)\tau$ and by substuting the value of δ defined in equation (48) :

$$\widehat{\theta} = \frac{\widehat{c_1} - Z}{\frac{c_1 - \widehat{c_1}}{2}} \tag{54}$$

We substitute the value of $\widehat{c_1}$ given in (21) and operate to obtain $\widehat{\theta} = 1$.

11 Conclusion

The aim of this paper is to examine how financial integration affects financial stability in a model where banks establish links in order to diversify their investments and in this way offer more attractive contracts to their depositors. As there is imperfect information, depositors can just obtain information on the quality of investments in their own bank and they will try to withdraw their deposits when they observe that the expected profitability in their bank is low. This will lead to a contagion problem as troubled banks may be forced to liquidate their investments in other banks. This risk of contagion means that banks prefer to remain isolated rather than see their activities affected. To prevent this contagion risk and reduce the costs of crises, we look at various policies governments can use, such as recapitalizing troubled banks, increasing capital requirements, or a lender-of-last-resort policy.

The numerical simulations show that there exist three clear regions in terms of policy choices: recapitalization dominates the other policies in the region where individuals do not give a high value to public services (low θ) and the cost of capital is high, whereas capital requirements should be used when its cost is low. We also find that when individuals highly value public services and the cost of capital is also high, banks should remain isolated. Finally, the-lender-of-last-resort policy is never an optimal policy. These results have very important policy implications, since those countries where agents are used to a centralized provision of public services and where the opportunity cost of investing is high, it is optimal to have more disintegrated financial systems. While in other regions where the opportunity cost of capital is still high but agents are less accustomed to obtain central services, the optimal policy should be bank recapitalization and a more integrated financial system. Finally, in more developed countries where agents value the provision of central services but the opportunity cost of capital is not that high, then capital requirements should be applied.

We also demonstrate that in the absence of additional policies, banks might prefer to remain isolated.

Future research might be devoted to extending the model to multiple banking systems, successive periods and imperfect competition for depositors.

Appendix A

Islands are preferred to linkages if and only if $EU^I \geq EU^L$, that is:

$$\frac{1}{2}\{\left[\gamma r+(1-\gamma)c_2^H\right]+[y+(1-T-y)\tau-\gamma\pi]\}+\theta T-\varepsilon \geq$$
$$\frac{1}{4}\{\left[\gamma r+(1-\gamma)c_2^H\right]+[\widehat{c_1}-\gamma\pi]+[\gamma r+(1-\gamma)\widehat{c_2}]+[y+(1-T-y)\tau-\gamma\pi]\}+\theta T-\varepsilon \tag{55}$$

or after some simplifications

$$\frac{1}{4}[(1-\gamma)c_2^H+y+(1-T-y)\tau] \geq \frac{1}{4}[\widehat{c_1}+(1-\gamma)\widehat{c_2}] \tag{56}$$

we substitute the value of c_2^H and $\widehat{c_2}$ in the above equation

$$y+(1-T-y)\tau \geq \widehat{c_1}-\lambda(1-T-y)R^H \tag{57}$$

And solving for R^H

$$R^H \geq \frac{\widehat{c_1}-[y+(1-T-y)\tau]}{(1-T-y)\lambda} \tag{58}$$

We need to show that the right hand side of this expression is always less than one, and therefore islands always dominate, in the absence of additional policies.

In order to prove it we show that the numerator is less than the denominator, that is:

$$\widehat{c_1}-[y+(1-T-y)\tau] < (1-T-y)\lambda \tag{59}$$

We will first substitute the value of λ and $\widehat{c_1}$ in the above equation

$$\frac{y+(1-T-y)\tau+\frac{1}{2}c_1}{1+\frac{1}{2}}-[y+(1-T-y)\tau]<(1-T-y)\left(\frac{r(1-\gamma)}{3(1-T-y)\tau}-\frac{1}{3}\right) \quad (60)$$

Operating on both sides we obtain

$$\frac{r-[y+(1-T-y)\tau]}{3}<\frac{r(1-\gamma)-(1-T-y)\tau}{3\tau} \quad (61)$$

or

$$\frac{r-[y+(1-T-y)\tau]}{\frac{r(1-\gamma)-(1-T-y)\tau}{\tau}}<1 \quad (62)$$

We next substitute $y=\gamma r$

$$\frac{r-[\gamma r+(1-T-\gamma r)\tau]}{\frac{r(1-\gamma)-(1-T-\gamma r)\tau}{\tau}}<1 \quad (63)$$

And the above equation simplifies to

$$\tau<1 \quad (64)$$

This equation is always satisfied. Q.E.D

Appendix B

In order to analyze the robustness of our comparison between islands and linkages, provided in proposition 5, we solve both problems with a more general utility function.

Let us assume that the agents' utility functions are as follows:[22].

[22]On the other hand, our utility function allows for a simple characterization of the optimal contract for the type-1 consumer.

$$U(c_1, c_2) = \begin{cases} u(c_1) & \text{with probability } \gamma \quad \text{(Type 1)} \\ u(c_2) & \text{with probability } (1-\gamma) \quad \text{(Type 2)} \end{cases} \tag{65}$$

Where the utility function $u(.)$ is defined over non-negative levels of consumption, is strictly increasing, strictly concave, twice continuously differentiable, and satisfies Inada conditions (this is the standard utility function assumed in most banking models, as introduced by Diamond and Dybvig (1983).

We define the banks' problems both in the island case and in the case of interbank linkages

In the island case, the problem to be solved is:

$$\mathrm{E}\, U^I = \frac{1}{2}\left\{\left[\gamma u(c_1) + (1-\gamma)u(c_2^H)\right] + u(y + (1-T-y)\tau)\right\} + \theta T \tag{66}$$

subject to

$$\gamma c_1 = y; \tag{67}$$

$$c_2^H = \frac{(1-T-y)}{1-\gamma} R^H; \tag{68}$$

$$\tag{69}$$

Similarly, in the case of interbank linkages, banks maximize:

$$\mathrm{E}\, U^L = \frac{1}{4}\left\{[\gamma u(c_1) + (1-\gamma)u(c_2^H)] + [u(\widehat{c_1})] + \right.$$
$$\left. [\gamma u(c_1) + (1-\gamma)u(\widehat{c_2})] + u([y + (1-T-y)\tau])\right\} + \theta T \tag{70}$$

subject to

$$\gamma c_1 = y; \tag{71}$$

$$c_2^H = \frac{(1-T-y)}{1-\gamma} R^H; \tag{72}$$

$$\widehat{c_1} = \frac{y + (1-T-y)\tau + \frac{1}{2}c_1}{1+\frac{1}{2}}; \tag{73}$$

$$\widehat{c_2} = \frac{R^H(1-\lambda)(1-T-y)}{(1-\gamma)}; \tag{74}$$

$$\tag{75}$$

and λ defined by footnote (17).

In order to compute some numerical simulations, we assume that the utility functions is given by:

$$u(c) = \frac{c^{1-k}}{1-k} \tag{76}$$

Figure 3 shows the difference in expected utility between the island case and linkages for different parameters of the model. The radius of the circle displays the difference in utilities divided by 30. This difference is always positive and therefore the island case dominates for different values of the liquidation value of the asset τ and of the high return R^H. The rest of the parameters of the model are those displayed in table 1. We assume a relative risk aversion coefficient, $k = 2.5$.

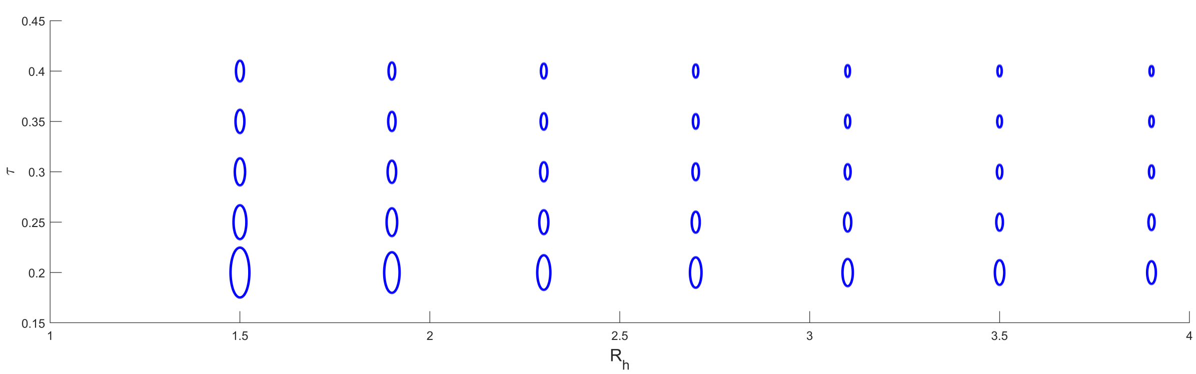

Figure 3: Differences in utility: Island case minus Interbank Linkages

Appendix C

In order to show that the island case dominates over the lender of last resort we compare the expected utilities in both scenarios. The island case is preferred to the lender of last resort if and only if $EU^I \geq EU^{LLR}$, that is:

$$\frac{1}{2}\{\left[\gamma r + (1-\gamma)c_2^H\right] + [y + (1-T-y)\tau - \gamma\pi]\} + \theta T - \varepsilon \geq$$
$$\frac{1}{4}\{\left[\gamma r + (1-\gamma)c_2^H\right] + [\widehat{c_1} - \gamma\pi] + \left[\gamma r + (1-\gamma)c_2^{LLR}\right] + [y + (1-T-y)\tau - \gamma\pi]\} + \theta T - \varepsilon \tag{77}$$

or after some simplifications

$$\frac{1}{4}[(1-\gamma)c_2^H + y + (1-T-y)\tau] \geq \frac{1}{4}[\widehat{c_1} + (1-\gamma)c_2^{LLR}] \tag{78}$$

we substitute the value of c_2^H and c_2^{LLR} in the above equation

$$y + (1-T-y)\tau \geq \widehat{c_1} - x(1+s) \tag{79}$$

And solving for $1+s$

$$1 + s \geq \frac{\widehat{c_1} - [y + (1-T-y)\tau]}{x} \tag{80}$$

It can be shown that the right hand side of this expression is equal to one, and therefore islands always dominate.

In order to prove it we need to show that the numerator is equal to the denominator, that is:

$$\widehat{c_1} - [y + (1-T-y)\tau] = x \tag{81}$$

We will first substitute the value of x derived in equation (31) and $\widehat{c_1}$ given in (21) in the above equation

$$\frac{y + (1 - T - y)\tau + \frac{1}{2}r}{\frac{3}{2}} - [y + (1 - T - y)\tau] = \frac{r(1 - \gamma) - \tau(1 - T - y)}{3} \tag{82}$$

Operating on both sides we obtain

$$\frac{r - [y + (1 - T - y)\tau]}{3} = \frac{r(1 - \gamma) - \tau(1 - T - y)}{3} \tag{83}$$

or

$$\frac{r - [y + (1 - T - y)\tau]}{r(1 - \gamma) - \tau(1 - T - y)} = 1 \tag{84}$$

We next substitute $y = \gamma r$

$$\frac{r - [\gamma r + (1 - T - \gamma r)\tau]}{r(1 - \gamma) - \tau(1 - T - \gamma r)} = 1 \tag{85}$$

And the above equation simplifies to

$$\frac{r(1 - \gamma) - \tau(1 - T - \gamma r)}{r(1 - \gamma) - \tau(1 - T - \gamma r)} = 1 \tag{86}$$

Q.E.D

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