



# Essays on the Economics of Banks and Markets

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## Abstract

### **A Theory of Bank Illiquidity and Default with Hidden Trades.**

I develop a theory of financial intermediation to explore how the availability of trading opportunities affects the link between the liquidity of financial institutions and their default decisions. In this framework, banks hedge against liquidity shocks either in the interbank market or by using a costly bankruptcy procedure, and depositors trade in the asset market without being observed. In equilibrium, the competitive pressure from the asset markets makes the banks distort their asset portfolios. I show three results. First, illiquid banks default only in the presence of systemic risk, and when an unpredicted crisis hits the economy. Second, in contrast to the previous literature, the allocation at default is not constrained efficient. Third, the constrained efficient allocation can be decentralized with the introduction of countercyclical liquidity requirements.

**Financial Liberalization with Hidden Trades.** How does the availability of unregulated market-based channels for the circulation of liquidity in the financial system affect the process of financial integration? To answer this question, I develop a two-country model of banking, where the banks have access to country-specific investment technologies, and agents can borrow and lend liquidity in a hidden market. I characterize the competitive equilibria at different levels of integration (both in the banking system and in the hidden market) and show that the only level of integration which the two countries are able to coordinate is the one where the two banking systems are autarkic, but international hidden trades are possible. In contrast to the previous literature, I also find that the resulting consumption allocation is constrained efficient.

**Bank Liquidity, Stock Market Participation, and Economic Growth.** We develop a dynamic growth model with fully microfounded banks and markets to reconcile the observed decreasing trend in the relative liquidity of many financial systems around the world with the increasing household participation in direct market trades. At low levels of economic development, the presence of fixed entry costs prevents the agents in the economy from accessing the market, and pushes them to open a bank account, which provide high relative liquidity. We characterize the threshold after which the agents are rich enough to access the market, where the relative liquidity is lower, and show that the relative liquidity of the whole financial system (banks *and* markets) drops because of the increasing market participation. We provide some evidence consistent with this theoretical prediction: a one-unit increase in an index of securities market liberalization leads to a drop in the relative liquidity of between 13 and 22 percentage points.

Alla mia famiglia



*Until you attain the truth,  
you will not be able to amend it.  
But if you do not amend it,  
you will not attain it. Meanwhile,  
do not resign yourself.*

from *The Book of Exhortations*





## Acknowledgments

“This thesis does not belong to me”. If I go back in time, this has always been the way I thought that these acknowledgments would start. However, this thesis *does* belong to me, and this means accepting the paternity of the mistakes that I have made on the way. But that is ok: I believe that a great part of the work of an economist is about making mistakes, and I realized I am pretty good at it! The problem is that making mistakes is a necessary, but not sufficient condition to be an economist: you need to correct them, too. And that would have been impossible without the help of the many people that I have met in these years.

I am deeply indebted to my supervisor, Per Krusell. He gave me the opportunity and the freedom to pursue my research interests, even if they were far from his, and he has always been supportive all the way. What astonishes me is his almost magical ability to foresee issues in my work, months, sometimes even years before me. He did not teach me how to do that but, fortunately, he taught me the importance of being rigorous, and that is the most important lesson that I learnt in these years.

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Stockholm, September 2013

Ettore Panetti



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# Chapter 1

## Introduction

This thesis consists of three essays on the economics of banks and markets. Despite being self-contained, each chapter shares a common theme and a common methodology with the others.

The common theme is the analysis of the mix of financial intermediaries (or, more commonly, banks) and markets – also known as “financial architecture” – in the financial systems of many developing and developed countries. Berger et al. (1995), for example, argue that the U.S. banking system has evolved from being a protected monopsony, where the banks were the only institutions allowed to collect and invest the savings of the households, into a market-oriented system, where new institutions, generally labeled as “new financial intermediaries”, have developed an offer of banking services without being regulated as banks. Examples of new financial intermediaries include hedge funds, money market mutual funds, and investment banks, to name just a few. More generally, the growth of these instruments and institutions, which took the name of “disintermediation” of the financial system, has manifested itself through an increasing diversification of the household portfolios. Guiso et al. (2002) show that, in the last twenty years, the U.S., as well as many other countries in the world, have experienced a dramatic increase in the proportion of direct and indirect stockholding by individual investors.

Methodologically, the aim of this thesis is to study how banks and markets interact among themselves from a theoretical perspective. To this end, the preliminary step in the identification of a modeling strategy starts from a more fundamental question: what do banks do in a modern economy? According to Freixas and Rochet (1999), the banking system offers four main services to the public:

- Liquidity and payment services;
- Transformation of assets;
- Risk management;
- Processing of information and monitoring of borrowers.

In the present thesis, I take a stance on what is the most important role played by the banks, and focus on the management of risk: this is due to the fact that liquidity, payment services and asset transformation are instrumental to this, while information processing and monitoring do not unequivocally characterize the banking activity, as many different institutions (e.g., rating agencies, credit history agencies, etc.) perform these activities without operating as actual banks.

In order to model the banks as risk managers, I take inspiration from the work of Diamond and Dybvig (1983). This has become the standard framework for the analysis of the economics of the banking system, as it provides a clear and fully microfounded rationale for its existence, as a mechanism for decentralizing the efficient allocation of liquidity risk. In this theory, the banks operate as coalitions of risk-averse individuals who pool risk and mutually insure against some idiosyncratic liquidity shock. For this purpose, the banks collect deposits, and invest them on behalf of their customers, thus providing maturity and liquidity transformation.

The interest in this framework also resides in the fact that it is the right environment to answer some normative questions. In fact, in chapters 2 and 3, it is used to study how the interaction of banks and markets affects the way the government should regulate the financial system. This is a hot topic, especially after the financial crisis of 2007-2009 showed how the development of the so-called “shadow banking system” has broadened



the lag between the financial system and the public regulators, and how the lack of correcting actions can lead to near-fatal consequences for the economy as a whole.

In this thesis, I follow the view that the only justification for a government intervention in the financial system is when the market allocation does not satisfy the First Theorem of Welfare Economics. In other words, the introduction of any form of financial regulation is exclusively justified when the outcome of the decentralized economy is not Pareto-efficient, due to the presence of some market failure. This means that the preliminary step in the analysis of optimal regulation is the full characterization of the equilibrium of a social planner problem, where a planner collects all resources in the economy, and allocates them among the agents, subject to the very same frictions and constraints that the banks face. In that sense, we see the optimal regulation as a mechanism designed and imposed by an external authority to enforce the efficient allocation of resources, when the coordination between atomistic agents in the economy is impossible.

I now move onto a more detailed description of the chapters of the thesis.

In chapter 2, titled **A Theory of Bank Illiquidity and Default with Hidden Trades**, I explore how the availability of trading opportunities for both banks and individual investors affects the connection between illiquidity and default in the financial system.

The motivation for this work lies in the observation that, in the real world, the connection between illiquidity and default is far from obvious: in principle, we would expect that the more illiquid banks are, the more prone to crises they should be, when hit by negative shocks. However, if we look at the data, the U.S. banking system was more illiquid during the recession of 2001 than during the recession of 2007-2009, and still defaults were way more numerous in the second case than in the first. My claim in this chapter is that, in order to explain this, we should focus on the availability of markets, and it is based on the fact that, in

the last decades, interbank markets have become the main channel for the circulation of liquidity around the economy and, at the same time, financial liberalization has made available a whole new set of institutions and instruments that allow the individual investors to bypass the banking system to make their own investments.

To formally assess these issues, I develop a theory of financial intermediation with idiosyncratic and aggregate liquidity shocks. The idiosyncratic shocks are private information to the agents in the economy, and affect whether they are in liquidity need or not, leading them to open a bank account to pool this risk. The banks, which operate in a perfectly competitive environment, collect the deposits, and invest them on behalf of their customers in a liquid asset (i.e., a storage technology) and in a long-term asset, that yields an exogenous return which can be seen as the marginal rate of transformation of a production technology. After the banks have made these investment decisions, an aggregate state of the world is revealed, affecting the fraction of depositors in liquidity need. This means that the amount of bank liquidity can be inadequate or excessive with respect to the actual demand from the depositors, which pushes the banks to borrow or lend in the interbank market. However, in order to hedge against these shocks, the banks also have two alternative strategies. If the amount of liquidity in the portfolio is excessive, they can store it and move it to the following period, which comes at the opportunity cost of storage. If the amount of liquidity is instead inadequate, and the banks are unable to service their debts with the depositors, they can file for bankruptcy, using a costly default technology.

The key assumption that I make in this chapter is the presence of hidden trades. That is, I assume that the depositors can borrow and lend among themselves, without being observed by their banks. This is achieved through the emission or purchase of a bond, whose return is determined in equilibrium and is equivalent to the (endogenous) interest rate of the economy. The introduction of the hidden trades is a way of modeling the non-exclusivity of financial contracts that stems from financial liberalization, and creates a distortion in the equilibrium allocation.

In fact, by the Revelation Principle, the banks must choose a contract satisfying an incentive compatibility constraint in order to ensure truth-telling: the present value of the consumption bundle that the agents get (evaluated at the endogenous interest rate) must be the same, regardless of whether they are in liquidity need or not.

In this environment, I prove a series of results. When there is no systemic risk, i.e. when the aggregate shocks hitting the banks are negatively correlated among themselves, the banks are illiquid in equilibrium, in the sense that they are less liquid than a social planner. This is due to the fact that the planner engages in the cross-subsidization of the depositors in liquidity need: she provides them with a consumption bundle whose present value (evaluated at the marginal rate of transformation) is higher than the one that the other agents in the economy receive and, to finance this arrangement, she invests relatively more in liquidity than in the long-term asset. However, this allocation would not be incentive-compatible: an agent *not* hit by the liquidity shock would try to misreport her type, get the more valuable consumption bundle of the agents in liquidity need, and retrade in the hidden market. Thus, the planner ensures incentive compatibility by lowering the interest rate on the hidden bond below the marginal rate of transformation, so as not to make retrading attractive.

In contrast, in the competitive equilibrium, the marginal rate of transformation and the interest rate on the hidden bond must be equal, because both the agents and the banks must be ex ante indifferent between the long-term asset and the hidden bond for the markets to clear. Hence, cross-subsidization is not incentive-compatible, and the banks need to invest relatively less in liquidity than the planner: they must pay the same present value of consumption (evaluated at the marginal rate of transformation) to all agents, irrespective of whether they are in liquidity need or not. In this environment, I show that illiquid banks never default or store liquidity ex post: the presence of negatively correlated shocks ensures that the interbank markets always clear and are a cheaper option to cover the budget imbalances than the storage or the

default technology. Moreover, we can decentralize the efficient allocation and solve the equilibrium illiquidity with the imposition of minimum liquidity requirements, very much similar to those imposed as part of the Basel III Accord, which effectively reshuffles resources across time and reduces the interest rate on the hidden bond to its efficient level.

There is a dramatic change in these results when I instead introduce systemic risk, in the form of positively correlated aggregate shocks hitting the banks. Here storage and default are the only instruments that the banks can use to rebalance their budgets, and ensure that the allocation is incentive-compatible, since the interbank markets do not clear. Thus, the banks choose the amount of liquidity to hold in portfolio so as to equalize its expected marginal benefits to the expected marginal costs, taking into account the deadweight losses from storage and default. Importantly, I show that corner solutions can also emerge: if the probability of a future bad shock is sufficiently high, the banks choose very high liquidity to avoid default, and when the probability of a future bad shock is instead sufficiently low, they choose very low liquidity, and then default if a crisis is actually realized.

The chapter ends with the analysis of the efficiency of the competitive equilibrium. Interestingly, I find that the equilibrium allocation in the presence of systemic risk is not constrained efficient, because the planner still imposes a wedge between the marginal rate of transformation and the interest rate on the hidden bond, so as to rebalance her portfolio in an incentive-compatible way, without using storage and default. This is the key result of the chapter, because it disproves the constrained efficiency of bankruptcy that emerges in many places in the literature. Allen and Gale (2004) show that default emerges in the equilibrium of a Diamond-Dybvig model with aggregate shocks when the banks are *exogenously* constrained from offering a state-contingent contract to their customers, because default, intuitively, adds state-contingency when there is none. Moreover, since, in their framework, the constraint on the banking contract is completely exogenous, the planner is subject to it in the very same way as the banks and, therefore, cannot improve the outcome of

the decentralized environment: the competitive equilibrium with default is constrained efficient. Here, instead, the banks are *endogenously* constrained from offering a state-contingent contract because the presence of hidden trades makes the endogenous interest rate equal to the exogenous marginal rate of transformation. However, the planner can improve the total welfare of the economy by imposing a wedge between the two, which means that she can choose a lower amount of liquidity when the probability of a future bad shock is high (because she is less afraid of the expected deadweight losses from default), and a higher amount of liquidity when the probability of a future bad shock is low (because she is less afraid of the expected deadweight losses from storage). Hence, I conclude the chapter by arguing that the efficient allocation can be decentralized with the introduction of countercyclical liquidity requirements.

The main theme of chapter 2 is the fact that the hidden markets represent a distortion in the competitive equilibrium: in fact, were they completely forbidden, the banks would be able to offer the first-best allocation, even in the presence of systemic risk and asymmetric information. However, in many cases in the real world, hidden trades can be beneficial to the economy, especially when they operate as a substitute for some missing channels for the circulation of liquidity. This is one of the points that I make in chapter 3, titled **Financial Liberalization with Hidden Trades**.

The aim of this chapter is to study how the the availability of unregulated market-based channels for the circulation of liquidity in the financial system affects the process of financial liberalization. The motivation for this work lies in the observation that, despite its well-known importance, the integration and expansion of the financial system around the world have come to a halt in the last twenty years, as showed by the IMF (Abiad et al., 2008). To explain this observation, I extend the Diamond-Dybvig model with hidden trades of the previous chapter (but without aggregate uncertainty) to a two-country environment. The two countries (Home and Foreign) are exactly symmetric, except for the available tech-

nologies: Foreign enjoys a higher yield on the long-term asset than Home. This means that Home has a comparative advantage in the storage technology, as the opportunity costs of holding liquidity versus the long-term asset are lower than in Foreign and, conversely, Foreign has a comparative advantage in the long-term asset. This difference can stem from different regulatory environments, or different production technologies that are available in the two countries, and is introduced to rationalize the need for financial integration.

I further assume that the governments of the two countries cannot observe the trades of the agents in the hidden markets, but can coordinate the level of cross-country capital mobility between them: that is, the two countries use a welfare criterion to find an agreement over the level of financial integration (in the official banking system and in the hidden market) that they want to achieve.

In this environment, I show that, despite the fact that the presence of hidden trades obliges the banks to satisfy an incentive compatibility constraint, as in the previous chapter, the opening of an international hidden market is always welfare-improving with respect to complete financial autarky. In the equilibrium with two separated banking systems and an international hidden market, each country specializes in the asset in which it holds a comparative advantage (Home in liquidity, and Foreign in the long-term asset), and lets the agents borrow and lend liquidity unobservably. Thus, the bank portfolio strategies, and as a consequence the demand and supply of liquidity in the hidden market, characterize the equilibrium interest rate on the hidden bond, and the agents can enjoy the gains from “hidden” financial integration.

More interestingly, I also show that Home and Foreign are not able to coordinate a deeper level of integration than that. This is because the move from an autarkic to an integrated banking system, in the presence of an already-integrated hidden market, generates an increase in the equilibrium interest rate that has a different effect on the welfare of the two countries: Home (the country specializing in liquidity) is better off, because its intertemporal terms of trade, at which is lending liquidity,

have improved; in contrast, Foreign (the country specializing in the long-term asset) is worse off, because its intertemporal terms of trade have worsened. In other words, financial integration is not welfare-improving for the whole economy, but creates winner and loser countries, depending on their comparative advantages. The necessary agreement to coordinate financial integration breaks off.

In the second part of chapter 3, I instead analyze the constrained efficiency of the competitive banking equilibrium, and study how this is affected by the level of integration in the banking system and in the hidden markets. For this purpose, I crucially assume that a social planner can collect the endowments of the agents in the economy and choose the best allocation to maximize their welfare, but takes as given the level of integration in the banking system and in the hidden markets. In this environment, I show that, when the cross-country hidden trades are constrained to be exclusively domestic, or when both the banking system and the hidden markets are perfectly integrated, the result of chapter 2 still holds: the planner is able to improve the market allocation and offer a contract equivalent to the first best. For this purpose, she compresses the ex post income profiles of the agents, by cross-subsidizing the consumption of those in liquidity need, and ensures that the allocation is incentive-compatible by imposing a wedge between the return on the long-term asset and the interest rate on the hidden bond.

In contrast, when the two banking systems are not integrated, but the international hidden trades are possible, the planner cannot improve the welfare of the agents above the level provided by the banks in the competitive equilibrium. Put differently, the competitive equilibrium is constrained efficient. Intuitively, this is a consequence of the fact that, differently from all other levels of integration, the planner would like to incentivize the hidden trades, for the agents to enjoy the gains from hidden financial integration, in the same way as the banks do. This is an interesting result, because it disproves the classic conclusions of Jacklin (1987) and Allen and Gale (2004) who show that the possibility for the agents of trading in the market distorts the efficiency of the banking

equilibrium in Diamond-Dybvig environments. Moreover, at all other levels of financial integration, the differences between the competitive equilibria and the corresponding constrained efficient allocations provide the rationale for the introduction of minimum liquidity requirements. However, when the two banking systems are separated, and cross-country hidden trades are allowed, there is no way in which the regulation can improve the outcome of the decentralized economy.

Chapters 2 and 3 share a common focus on the static interaction between banks and markets. I move into the analysis of the dynamics in chapter 4, titled **Bank Liquidity, Stock Market Participation, and Economic Growth**.

In this last chapter, which is joint work with Elena Mattana, we develop a theory of banks and markets to reconcile the observation that the relative liquidity (total liquid assets as a percentage of total liabilities) of many financial systems around the world exhibits a long-term decreasing trend with the increasing household participation in direct market trades. To this end, we embed a fully microfounded theory of banks and markets into a two-period overlapping-generations growth model. As in the previous chapters, the agents, who are born in every period, are hit by some idiosyncratic liquidity shock that can put them in liquidity need, and against which they would like to insure. For this purpose, they can invest in capital, which is transferred to the production sector in the form of loans, and in a liquid asset, that is equivalent to the storage technology of the previous chapters. In order to access these technologies, the agents engage in a discrete investment decision: they can open a bank account, or trade directly in the market. When opening a bank account, the agents make a deposit, and let the bank invest in liquidity and production capital on their behalf. When instead directly entering the market, the agents independently decide their own asset portfolios, and adjust them by retrading in a secondary market, that opens after the idiosyncratic shocks have been revealed.

In order to model the intuition, which goes back to Berger et al.



(1995), that the evolution of the banking system in the U.S. has mainly been a consequence of market factors and innovation, we introduce two key features in the theory. First, the agents can open a bank account at zero cost, but the banks have to pay an iceberg-type cost on the deposit interests. This cost can emerge from regulation, or from a technological constraint, and replicates the preferential tax treatment enjoyed by capital gains with respect to deposit interests, which is typical of many countries around the world. Second, the agents who invest directly in the market must pay a fixed entry cost. We see this as a transaction cost or an institutional impediment that prevents the agents from accessing the market, and it is a tool that has been extensively used in the finance literature (Vissing-Jorgensen, 2003; Guiso et al., 2008) and in macroeconomics (Acemoglu and Zilibotti, 1997; Townsend and Ueda, 2006), while also having some strong empirical support (Guiso et al., 2002).

The interplay between the bank iceberg-type costs and the market entry costs constitutes the cornerstone of the analysis of this chapter. Technically, we solve a banking problem, augmented by the imposition of a participation constraint: the banking contract must be such that the depositors are, in expectation, at least as well off as they would be by trading in the market. In the unconstrained problem (i.e. without the participation constraint), we show that the banks provide higher relative liquidity than what the agents would get in the market. Moreover, with CRRA utility, the bank liquidity ratio (liquidity as a percentage of total deposits) is decreasing in the transition towards the steady state but, contrary to what we observe in the real world, constant in the long run, because deposits (i.e. the liabilities of the bank balance sheets), on one side, and liquidity and production capital (i.e. the assets of the bank balance sheets), on the other, must grow at the same rate.

In the constrained problem, the liquidity ratio of the whole financial system instead exhibits a non-increasing trend. The reason is that, in equilibrium, the banks always offer the unconstrained contract, regardless of whether the participation constraint binds or not. Thus, at low levels of economic development, that is, as long as the income of

the agents is below a threshold which is a function of the market entry costs and the tax on deposit interests, the participation constraint is slack: the expected welfare of the agents is higher within the banking arrangement than in the market, as the banks offer cross-subsidization and high relative liquidity, like in the unconstrained problem. However, above this threshold, the banks are not able to offer a contract that enforces participation, because of the tax on deposit interests and because the fixed market entry costs become increasingly negligible as the economy develops. In other words, the banking equilibrium collapses, and the agents optimally choose to directly access the market, where the relative liquidity – as mentioned above – is lower.

Finally, in the second part of the chapter, we validate our theory by testing the prediction that the easier is the access to markets, the lower is the relative liquidity of the financial system. To this end, we proxy relative liquidity with a panel of bank liquid reserves, constructed by the World Bank for around 100 different countries for the period 1970-2010, and take an index of securities market policy, provided by the IMF, to account for the availability of external investment opportunities. Our results show that a one-unit increase in this index is correlated with a drop in the liquidity ratio of between 13 and 22 percentage points. Moreover, we show that the effect is stable when controlling for other types of financial liberalizations.

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## Chapter 2

# A Theory of Bank Illiquidity and Default with Hidden Trades\*

### 2.1 Introduction

The connection between the illiquidity of financial institutions and their default is far from obvious: in principle, we would expect banks to be more prone to crises the more illiquid they are. However, as shown in figure 2.1, the relative liquidity of the U.S. banking system was way lower in 2001 than in 2007-2009, and still the U.S. economy endured a much deeper financial crisis in the second than in the first case.

The aim of the present work is to show that the relationship between the liquidity of financial institutions and their default decisions crucially depends on the availability of trading opportunities, for both banks and

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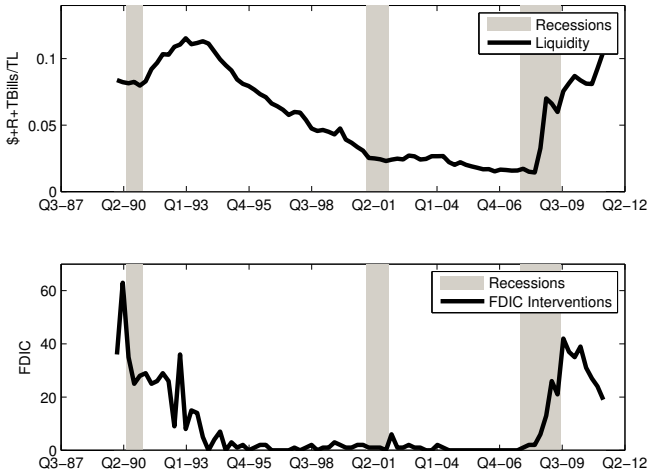


Figure 2.1: Relative liquidity of U.S. chartered commercial banks versus the number of interventions by the FDIC. Relative liquidity is defined as the sum of vault cash, reserves and Treasury securities as a percentage of total liabilities. Source: *Board of Governors of the Federal Reserve System*, *Flow of Funds Accounts of the United States*, and FDIC.

individual investors. The claim that markets play a key role in the financial system stems from two well-known facts: first, wholesale interbank funding has become the main channel for the circulation of liquidity in the U.S. economy; second, in the last thirty years, financial liberalization has made available a whole new series of instruments – off-shore tax havens, international stock markets, hedge funds, and so on – that allow investors to by-pass the banking system.

To formally assess the microfoundations of default and its connection with markets and illiquidity, I develop a model of financial intermediation with both idiosyncratic and aggregate uncertainty. The economy is populated by risk-averse depositors and risk-neutral intermediaries or banks. The first are hit by private idiosyncratic liquidity shocks, affecting the point in time (early or late) at which they are willing to consume, which makes them either “impatient” or “patient” as in Diamond and Dybvig

(1983). The second provide insurance against these shocks by investing the total deposits in short-term (liquid) and long-term (illiquid) assets. After the banks have chosen this initial portfolio strategy, an aggregate state of the world is revealed: the banks are hit by asymmetric liquidity shocks, all happening with an *ex ante* known probability. These shocks affect the total fraction of depositors who turn out to be impatient, and might create an *ex post* budget imbalance, when the liquidity chosen *ex ante* is inadequate or excessive with respect to the actual liquidity demand from customers. Thus, in order to cover for these imbalances, the banks trade among themselves in an economy-wide interbank market, that opens after the aggregate state of the world has been revealed.

I make two extensions to this basic environment. First, the banks have two alternative strategies to interbank funding to transfer resources across states: when the liquidity is higher than expected, they can store it by using the short-term asset. When liquidity is instead insufficient, and the banks are unable to service their debts with the depositors, they can file for bankruptcy: in this case, the banks use a costly liquidation technology to throw away the long-term assets in their portfolios and generate the extra cash they need. This can be seen as an expensive insolvency procedure through courts (similar to Chapter 11 in the U.S.) or a clearance scheme where part of the capital gets lost, and is a way of i) clearly embedding bankruptcy costs in banks' budgets; ii) distinguishing between partial and full default; and iii) explicitly showing how illiquidity issues can lead to insolvency (when the bank is forced to fire sell all its assets).

The second feature that I introduce is instead an informational friction: I assume that the depositors can engage in trades in the asset markets, without being observed by their banks. I model these asset markets as institutions where the agents issue or buy uncontingent bonds, whose return is determined in equilibrium (and is indeed equivalent to the endogenous interest rate of the economy). The unobservability of the exchanges implies that the terms of the banking contract must satisfy an incentive compatibility constraint in equilibrium: the present value of

the consumption bundle that each depositor is entitled to receive by the banks must be constant across types when evaluated at the interest rate on the “hidden” bond, so that no agent has incentives to retrade.

With these hypotheses in hand, in the first part of the paper I characterize the planner solution and the decentralized banking equilibrium when the aggregate liquidity shocks hitting the banks are negatively correlated, i.e. when there is no systemic risk. The competitive pressure from the asset markets makes the banking system under-invest in liquidity: on one side, the planner provides insurance to the agents against the risk of being impatient by offering a higher present value of consumption (evaluated at the return on the long-term asset) to the impatient depositors than to the patient ones. Then, to lower the incentives for the patient depositors to misreport their liquidity needs, the planner imposes a wedge between the interest rate on the hidden bond and the return on the bank long-term asset. On the other side, market clearing considerations imply that these two returns must be equal in the competitive equilibrium; hence, by incentive compatibility, the banks are forced to equalize early and late consumption (when evaluated at the return on the long-term asset). Put differently, the banking system is illiquid from an efficiency perspective, because the possibility of hidden trades in the asset markets makes it hold relatively less liquid assets than the planner.

In this environment, I prove my main result: lower liquidity buffers do not lead to default when banks trade in the interbank markets, because they co-insure against liquidity shocks, but this conclusion dramatically changes in presence of systemic risk, i.e. when the aggregate shocks are all positively correlated and the interbank markets cease to function (but asset markets are still open): the banks must now use ex post storage or default to transfer resources across states of the world and ensure that the interest rate on the hidden market, by incentive compatibility, is equal to the return on the long-term asset. In this case, the banks choose their initial portfolio strategy such that the expected marginal benefit of having one more unit of liquidity (in terms of avoiding future default) is equal to the expected marginal cost of that one unit (in terms



of the opportunity cost of storage). As shown in the numerical solution, corner solutions can emerge, too. If the probability of having a high fraction of impatient depositors in the future is sufficiently low, the banks choose a completely illiquid portfolio strategy: they default to provide consumption to early depositors, and choose full bankruptcy when an unexpected bad shock hits them. If instead the probability of having a high fraction of impatient depositors is sufficiently high, banks do the opposite: they “fly to liquidity”, i.e. invest all their capital in short-term assets to completely avoid default.

This result shows that default emerges as an equilibrium phenomenon only when the interbank markets are shut down and, at the same time, the depositors can trade unobservably in the asset markets (i.e., when the interest rate of the economy is endogenous): in fact, without private trades, the banks would be able to offer a consumption plan contingent on the realization of the aggregate state of the world, and avoid bankruptcy. Moreover, contrary to some key results in the literature (Allen and Gale, 2004), the allocation at default is not constrained efficient: even when the liquidity shocks are positively correlated, the planner is able to tilt incentives by affecting the interest rate in the hidden market and provide higher welfare. Therefore, by introducing private trades, I provide a rationale for government intervention to mitigate the negative effects of a financial crisis when markets are not well-functioning.

In my second result, I explicitly develop these considerations, and characterize the optimal government intervention to solve the inefficiency of the competitive equilibrium. Despite the fact that the main distortion on the system stems from the *asset markets* (the interest rate on the hidden bonds is higher than its socially optimal level), in presence of fully functioning markets the planner’s solution can be decentralized with an intervention on the *banks*. Such a rule takes the form of a minimum liquidity requirement, i.e. a weighted average of future liquidity needs, weighted with both economy-wide and bank-specific factors. Thus, this result provides a theoretical background for the “Liquidity Coverage Ratio”, introduced as part of the new architecture for macroprudential reg-

ulation in the Basel III Accord. On the contrary, when the interbank markets are not functioning, the Liquidity Coverage Ratio is not enough to generate welfare improvements to the decentralized outcome: that is because banks tend to hoard liquidity when the probability of a future crisis is relatively high, hence the constraint is binding only in those states where there is a low probability of crisis (i.e. a high probability of storing liquidity). This result calls for further tailoring financial regulations to periods of aggregate uncertainty, through the introduction of countercyclical liquidity requirements: a *minimum* liquidity requirement when the probability of a future crisis is low, and a *maximum* liquidity requirement when the probability of a future crisis is high.

The rest of the paper is organized as follows. In section 2.2, I summarize part of the literature related to my work. In section 2.3, I define the environment of the model. I characterize the decentralized equilibrium with negatively correlated liquidity shocks in section 2.4. The competitive equilibrium with positively correlated liquidity shocks and the correspondent socially optimal allocation are analyzed in section 2.5. Finally, section 2.6 concludes with some open issues for future research.

## 2.2 Related Literature

The present paper finds inspiration in a recent and growing microeconomic literature on the economics of financial crises. Although a consensus exists that one of the main reasons for the current period of financial distress lies in excessive risk-taking by financial intermediaries, many different explanations have been proposed for why this behavior emerges. Farhi and Tirole (2011) focus their attention on strategic complementarities among banks that all expect to be bailed out ex post. In that sense, a crisis occurs because of an external ex post (and inefficient) government intervention. Diamond and Rajan (2010) provide a formal microfoundation of banks' behavior by assuming risk neutrality: financial institutions know that, with some probability, there will be a crisis, and they can insure against that by building up a buffer of liquidity ex ante. On the

other hand, they also know that when a crisis hits, with some probability they will go bankrupt, but with some other probability they will survive and make profits, because asset values revamp precisely in those states. Risk neutrality then implies that banks will not create buffers, with disastrous consequences for the whole system. In that sense, risk neutrality is clearly key for their results, but if we think that financial markets ultimately exist because investors are willing to hedge risk (i.e., because they are risk averse), then we might ask why intermediaries do not insure against shocks at all.

This last question has been the center of analysis of a long-lasting line of research on financial intermediaries and markets that finds its cornerstone in the work of Diamond and Dybvig (1983). The authors develop an environment where banks provide insurance to their depositors against unexpected liquidity shocks via demand deposits. Following their lead, Bhattacharya and Gale (1987) were the first to highlight how banks hit by shocks might avoid an unnecessary liquidation of long-term investments by exchanging resources in the interbank market. In particular, the authors account for the case where financial institutions have private information about the liquidity of their portfolios, and show how this leads them to over-invest in illiquid assets. The role of financial imperfections affecting the allocation of resources in the banking system has also been the center of more recent contributions. Freixas and Holthausen (2005) develop an environment with noisy cross-country information among banks to show how “peer monitoring” helps improve the decentralized equilibrium outcome, and how the quality of information critically matters for the existence of an integrated interbank market. Freixas and Jorge (2008) address the role of asymmetric information in explaining the transmission of monetary policy in the economy. Heider et al. (2010) focus on counterparty risk and its effect on the pricing of liquidity.

In a Diamond-Dybvig environment with a neoclassical definition of financial markets as trades in state-contingent claims, Allen and Gale (2004) prove some interesting results, in particular regarding the effi-

ciency of the intermediated equilibrium. Their key conclusion is that when banks are *exogenously* constrained to offer incomplete (uncontingent) contracts to their customers (like the standard deposit contracts that we observe in reality), they might choose in equilibrium to use a bankruptcy procedure, because in this way they improve the contingency of the consumption allocation. In addition, such an equilibrium is constrained efficient: no government intervention can improve the market outcome. The present paper builds on this analysis, but delivers a completely opposite result: when banks are *endogenously* constrained to offer incomplete contracts, they might choose to default, but the resulting allocation is *not* constrained efficient. The main reference for endogenizing illiquidity in a banking equilibrium goes back to what has become a “folk theorem” in the theory of financial intermediation: the possibility that depositors might invest directly in the asset markets undermines banks’ ability to implement the first best contract via demand deposits. This point, already made in some seminal papers (Jacklin, 1987; Diamond, 1997; von Thadden, 1999), has recently been restated by Farhi et al. (2009). The authors develop a version of the Diamond-Dybvig model without aggregate uncertainty, where agents can engage in unobservable trades. This complex game of asymmetric information is then solved with some mechanism design tools to show that private trades restrain banks from offering the efficient incentive-compatible contract.

## 2.3 Environment

The basic structure of the model is a Diamond-Dybvig model of financial intermediation with idiosyncratic and aggregate shocks. The economy lasts for three periods, labeled  $t = 0, 1, 2$ , and is divided into  $n$  sectors<sup>1</sup> of equal unitary dimension, each populated by a continuum of agents. These are all *ex ante* identical, and at date 0 receive as endowment an homogeneous consumption good  $e = 1$ . In every sector, there is also a

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<sup>1</sup>In this environment, sectors can also be seen as regions of the same country, or countries in the world economy.

continuum of Bertrand-competitive risk-neutral financial institutions (or banks), which operate in a market with free entry and offer real contracts to the agents. The relationship between customers and banks is *exclusive*, in the sense that agents can only deposit their endowments into a bank in their own sector.

The banks in the economy have access to two technologies to transfer resources across time: the first is a “short asset”, which is essentially a way of storing the consumption good for one period. The second is a “long asset” that delivers a return  $\hat{R} > 1$  (equivalent to the marginal rate of transformation of firms producing the consumption good) units of consumption in period  $t = 2$  for each unit invested in  $t = 0$ .<sup>2</sup> This long asset is partially illiquid, as there exists a liquidation technology through which banks can throw away part or all of its holdings before its natural maturity. That comes at a cost, as for each unit of the long asset only a fraction  $r < 1$  can be recovered.

### 2.3.1 Uncertainty

The economy is affected by two types of uncertainty. An aggregate shock is defined over a finite set of states of the world, labeled by  $s = 1, \dots, S$ . Each state is realized with probability  $\nu(s) > 0$  and  $\sum_s \nu(s) = 1$ . Aggregate uncertainty is resolved at the beginning of date 1, and affects the sectoral distribution of a preference shock. This shock is an idiosyncrasy affecting all the agents. Being *ex ante* equal, in  $t = 1$  every consumer draws a type  $\theta \in \{0, 1\}$  which is private information to herself. The types affect the point in time at which the agents enjoy consumption according to the utility function  $U(c_1, c_2, \theta) = (1 - \theta)u(c_1) + \beta\theta u(c_2)$ . Clearly, if  $\theta = 0$  the agent is willing to consume only at date 1, while if  $\theta = 1$  she will consume only at date 2. As is customary in this line of research, I then refer to type-0 and type-1 agents as early (or impatient)

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<sup>2</sup>In order to keep the focus on liquidity provision, here I do not model the supply side of the economy. The fact that the return is constant across sectors might be seen as an implicit consequence of integrated product markets. I analyze the case where technologies in different sectors yield different returns in Panetti (2013).

and late (or patient) consumers, respectively. The felicity function  $u(c)$  is increasing, twice continuously differentiable, strictly concave, and satisfies Inada conditions. Moreover, I restrict myself to the class of functions with relative risk aversion larger than or equal to unity. The discount factor  $\beta$  is such that  $\beta\hat{R} > 1$ .

The probability of being of type  $\theta$  in sector  $i$  and state  $s$  is labeled  $\pi^i(\theta, s)$ . Preference shocks are independent across agents so, by the law of large numbers, the cross-sectional distribution of types is equivalent to the probability distribution. Hence,  $\pi^i(\theta, s)$  is equal to the fraction of agents that turn out to be of type  $\theta$  in state  $s$ , and  $\sum_{\theta} \pi^i(\theta, s) = 1$  in every sector. Importantly, here I assume that  $\sum_i \pi^i(\theta, s) = \Pi(\theta, s) = \Pi(\theta, s') \equiv \Pi(\theta)$  for any  $s, s'$ : the total fraction of agents in liquidity need *in the whole economy* is constant. Therefore, each state of the world is different from the others only with respect to the distribution of consumers' types across sectors, i.e. there is no systemic risk.

### 2.3.2 The Banking Contract

At the beginning of date 0, agents deposit their endowment into banks in their own sector, and sign a banking contract. This indicates the amount of consumption goods  $\{w_t^i(\theta, s)\}$  that each depositor is entitled to withdraw at dates 1 and 2, depending on the reported type and the realization of the aggregate state. In order to finance the contract and allocate resources across time, banks buy short and long assets in amounts  $X^i$  and  $Y^i$ , respectively.

Banks have three instruments to transfer resources across states of the world at date 1, after the aggregate state of the economy has been revealed. First, they can trade in an intersectoral interbank market. This is modeled as a market for a bond  $Z^i(s)$  yielding a return  $\tilde{R}(s)$  to be determined in equilibrium in each state.<sup>3</sup>

As an alternative to market trades, banks can use two other chan-

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<sup>3</sup>The uncontingency of the securities traded is a direct consequence of the fact that this market opens after the aggregate state of the world is revealed.

nels. If they have too much liquidity, because total demand from their depositors is unexpectedly low, they can move it forward to date 2 by using the short asset for an amount  $M^i(s) \geq 0$ . If instead their liquidity turns out to be inadequate, they can file for bankruptcy. In this case, the bank can employ the liquidation technology to get rid of an amount  $D^i(s) \geq 0$  of the long assets (by giving up on  $\hat{R}$  units of consumption at date 2 to get an amount  $r$  at date 1). Notice that, since the probability distribution of the aggregate state is known at date 0, the banks choose these strategies *ex ante*, with full commitment. If the liquid resources cumulated at date 0 are sufficient to cover for the consumption needs of the depositors who report to be impatient, then the banks are “liquid”. If instead the available cash is inadequate, but banks are able to borrow in the market, they are “illiquid but solvent”. Finally, if they choose the default procedure, they are in financial distress, i.e. “insolvent”.

I summarize the set of policy decisions and consumption allocations in a compact vectorial definition:

**Definition 1.** *A banking contract is a vector  $C^i(\theta, s) = \{w_t^i(\theta, s), X^i, Y^i, Z^i(s), D^i(s), M^i(s)\}$  for any type  $\theta \in \{0, 1\}$  and state of the world  $s = 1, \dots, S$ . A banking contract is feasible if:*

$$\sum_i \sum_{\theta} \pi^i(\theta, s) \left[ w_1^i(\theta, s) + \frac{w_2^i(\theta, s)}{\hat{R}} \right] \leq n. \quad (2.1)$$

### 2.3.3 Hidden Trades

At date 1, after the state of the world has been revealed to everyone, agents can withdraw the amount of consumption good stated in the contract from their banks and eventually engage in private trades in an asset market. I model this feature of the economy as unobservable exchanges across sectors, through which the agents can freely borrow and lend via an uncontingent bond, yielding a “hidden” interest rate  $R(s)$  to be determined in equilibrium. Notice three things. First, the fact that agents trade only uncontingent bonds is not an a priori restriction on the completeness of the market, but an endogenous feature of the

environment, as I show in appendix A. Second, I follow Farhi et al. (2009) and assume that asset markets only open ex post and work as a secondary borrowing/lending channel for the agents. Third, the results proposed here hinge neither on the fact that banks cannot access this market themselves nor on the date that the market opens, but only on the fact that the depositors can borrow and lend without being observed.

More formally, the investor's problem in the asset market reads:<sup>4</sup>

$$V(C^i(\theta, s), R(s), \theta, s) = \max_{\substack{c_1^i(\theta, s), c_2^i(\theta, s), \\ b^i(\theta, s), \theta'(\theta, s)}} U(c_1^i(\theta, s), c_2^i(\theta, s), \theta), \quad (2.2)$$

subject to:

$$c_1^i(\theta, s) + b^i(\theta, s) = w_1^i(\theta'(\theta, s), s), \quad (2.3a)$$

$$c_2^i(\theta, s) - R(s)b^i(\theta, s) = w_2^i(\theta'(\theta, s), s). \quad (2.3b)$$

Given the terms of the banking contract  $C^i(\theta, s)$ , the interest rate  $R(s)$ , and the realizations of the idiosyncratic and aggregate states, each agent decides which type  $\theta'(\theta, s)$  to report, how much to consume in the two periods ( $c_1^i(\theta, s)$  and  $c_2^i(\theta, s)$ ) and how much to borrow or lend ( $b^i$ ) in order to maximize her welfare, subject to her budget constraint. At date 1, after reporting type  $\theta'(\theta, s)$ , the depositor receives consumption  $w_1^i(\theta'(\theta, s), s)$  from her bank. She can then borrow or lend an amount  $b^i$  and consume the remaining part  $c_1^i$ . At date 2, the depositor then gets  $w_2^i(\theta'(\theta, s), s)$ , pays back the bond (or earns the proceedings on the amount lent at date 1) and consumes what is left.

The environment so far describes a complex game of asymmetric information between the banks and their customers. Nevertheless, by the Revelation Principle, I can focus on direct mechanisms where depositors truthfully report their types. The incentive compatibility constraint can

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<sup>4</sup>To simplify the notation, I explicitly write the final consumption allocation, the reported type and the bond trades only as functions of the realization of the uncertainty  $(\theta, s)$ , but formally they also depend on the contract  $C^i(\theta, s)$  and on the interest rate  $R(s)$ .



then be defined in the following way:

**Definition 2.** *A banking contract  $C^i(\theta, s)$  is incentive-compatible if:*

$$V(C^i(\theta, s), R(s), \theta, s) \geq V(C^i(\theta', s), R(s), \theta, s), \quad (2.4)$$

for any  $\theta, \theta' \in \{0, 1\}$  and any realization of the aggregate state  $s = 1, \dots, S$ .

Incentive compatibility states that each agent should find it optimal to truthfully report her type, but given the presence of only two of them, this can be simplified. To see this, consolidate the budget constraints in (2.3a) and (2.3b) in:

$$c_1^i(\theta, s) + \frac{c_2^i(\theta, s)}{R(s)} = w_1^i(\theta'(\theta, s), s) + \frac{w_2^i(\theta'(\theta, s), s)}{R(s)}. \quad (2.5)$$

For type-0 and type-1, the incentive compatibility constraint reads, respectively:

$$V(C^i(0, s), R(s), 0, s) \geq V(C^i(1, s), R(s), 0, s), \quad (2.6)$$

$$V(C^i(1, s), R(s), 1, s) \geq V(C^i(0, s), R(s), 1, s), \quad (2.7)$$

which can be rewritten as:

$$u\left(w_1^i(0, s) + \frac{w_2^i(0, s)}{R(s)}\right) \geq u\left(w_1^i(1, s) + \frac{w_2^i(1, s)}{R(s)}\right), \quad (2.8)$$

$$u(R(s)w_1^i(1, s) + w_2^i(1, s)) \geq u(R(s)w_1^i(0, s) + w_2^i(0, s)), \quad (2.9)$$

because  $c_2^i(0, s) = c_2^i(1, s) = 0$ . Thus, it is easy to see that:

**Lemma 1.** *A banking contract  $C^i(\theta, s)$  is incentive-compatible if:*

$$w_1^i(0, s) + \frac{w_2^i(0, s)}{R(s)} = w_1^i(1, s) + \frac{w_2^i(1, s)}{R(s)}, \quad (2.10)$$

for any realization of the aggregate state  $s = 1, \dots, S$ .

Truth-telling implies that the banking contract should give the same present value of consumption to each type, evaluated at the interest rate on the hidden investment. In this way, agents have no incentive to retrade in the asset market. An obvious consequence of the lemma is that, in this environment, the agents only care about the present value of their consumption. This feature will be crucial in what follows.

### 2.3.4 Timing

In the rest of the paper, I will focus on pure-strategy symmetric equilibria, where banks of the same sector make the same investment choices. Therefore, without loss of generality, I can restrict myself to the analysis of a representative bank for each sector.

The timing of actions and events is the following: at date 0, agents deposit their endowments; hence, the size of each representative bank is 1. Banks then set up fully state-contingent incentive-compatible contracts  $C^i(\theta, s)$ . At date 1, the aggregate state is revealed to everyone, and agents get to know their private types. Banks then trade among themselves across sectors, store or declare (partial) bankruptcy, and pay consumption to those depositors who report being impatient. After that, asset markets open and agents can engage in unobservable trades across sectors. Finally, at date 2, agents are paid the amount stated in the banking contract and, eventually, the interest rate on their hidden investment.

### 2.3.5 Planner's Problem

As a benchmark for the decentralized environment of the next sections, I start my analysis with the characterization of the constrained efficient allocation, provided by a planner who maximizes the ex ante welfare of the agents:

$$\sum_s \nu(s) \pi^i(\theta, s) U(c_1^i(\theta, s), c_2^i(\theta, s), \theta), \quad (2.11)$$

subject to the feasibility constraint (2.1) and to a “no-retrade constraint”, i.e. the allocation must be such that the utility for each type is larger

Table 2.1: Timeline of actions and events

t = 0	The agents make the deposits The banks set up the banking contracts The banks buy short and long assets
t=1	The short asset matures The uncertainty is realized The interbank market opens Storage/default The agents report their types Early withdrawals The asset market opens Early consumption
t=2	The long asset matures The interbank market clears Late withdrawals The asset market clears Late consumption

than or equal to the one she would get by retrading:

$$U(c_1^i(\theta, s), c_2^i(\theta, s), \theta) \geq V(C^i(\theta, s), R(s), \theta, s), \quad (2.12)$$

for any  $i = 1, \dots, n$ ,  $\theta \in \{0, 1\}$  and  $s = 1, \dots, S$ .

It is important to highlight that, without unobservable trades (but with private individual types), the planner would be able to ensure perfect risk sharing both within and between sectors. Moreover, in such an environment, a version of the First Welfare Theorem holds: the decentralized competitive equilibrium is efficient and equivalent to the first best (Allen and Gale, 2004). I summarize these results in appendix B.

Farhi et al. (2009) show that, in the presence of hidden trades, the planning problem is equivalent to one where the planner chooses a present value of consumption  $\mathcal{I}^i(s)$  for all the types and the interest rate  $R(s)$  on the hidden bond (i.e. the interest rate) so as to maximize the *ex post* welfare of the agents in the economy, subject to feasibility. Intuitively, this means that the planner is not subject to arbitrage between the of-

ficial financial system and the hidden market, but only takes care that the proposed allocation does not give incentives to retrade. Thus, she does not take the interest rate on the hidden bond as given, but is able to indirectly choose it by manipulating the aggregate allocation of the available resources between date 1 and date 2.

The problem in the hidden market for a type- $\theta$  agent reads:

$$V(C^i(\theta, s), \hat{R}, \theta, s) = \max U(c_1^i(\theta, s), c_2^i(\theta, s), \theta), \quad (2.13)$$

subject to:

$$c_1^i(\theta, s) + \frac{c_2^i(\theta, s)}{R(s)} \leq w_1^i(\theta, s) + \frac{w_2^i(\theta, s)}{R(s)} \equiv \mathcal{I}^i(s). \quad (2.14)$$

Then, it is easy to see that  $V(C^i(0, s), \hat{R}, 0, s) = u(\mathcal{I}^i(s))$  and  $V(C^i(1, s), \hat{R}, 1, s) = u(R(s)\mathcal{I}^i(s))$  because  $c_2^i(0, s) = c_1^i(1, s) = 0$  for every  $i$  and  $s$ , so the planning problem reads:

$$\max_{\{\mathcal{I}^i(s), R(s)\}_{s=1, \dots, S}} \sum_{i=1, \dots, n} \sum_s \nu(s) [\pi^i(0, s)u(\mathcal{I}^i(s)) + \beta\pi^i(1, s)u(R(s)\mathcal{I}^i(s))], \quad (2.15)$$

subject to the intertemporal resource constraint:

$$\sum_i \pi^i(0, s)\mathcal{I}^i(s) + \pi^i(1, s)\frac{R(s)\mathcal{I}^i(s)}{\hat{R}} \leq n, \quad (2.16)$$

that must hold in every state of the world  $s = 1, \dots, S$ . The planner chooses a consumption profile to maximize the ex ante welfare of the economy. In order to do that, she employs all resources available (equal to  $n$ ) to finance a consumption bundle whose present value is evaluated at the marginal rate of transformation. Notice that neither bankruptcy nor storage emerges in equilibrium, because the planner knows that the total fraction of agents in early liquidity need is constant and equal to  $\Pi(0)$  in any state.

The following proposition characterizes the efficient allocation with

private trades:

**Lemma 2.** *In any state  $s = 1, \dots, S$  and sector  $i = 1, \dots, n$ , the constrained efficient allocation  $\{R^P, \mathcal{I}^P\}$  is the solution to:*

$$\beta \hat{R} u'(R^P \mathcal{I}^P) = u'(\mathcal{I}^P), \quad (2.17)$$

$$\mathcal{I}^P = \frac{n}{\Pi(0) + \frac{R^P}{\hat{R}} \Pi(1)}. \quad (2.18)$$

and  $b^i = 0$ .

*Proof.* In the appendix C. ■

The planner allocates the resources so as to ensure perfect cross-sectoral risk sharing: agents of the same types are entitled to the same amount of consumption, regardless of the sector to which they belong. At the same time, she chooses the intertemporal allocation so that an Euler equation holds, i.e. such that the marginal rate of substitution between early and late consumption is equal to the marginal rate of transformation of the economy. Hence, the equilibrium characterized here is equivalent to the one that emerges in the constrained problem with private types only which, in turn, is equivalent to the unconstrained optimum. This is the multi-sectoral version of the main proposition in Farhi et al. (2009), and states that the planner can tilt incentives and (implicitly) prices so as to implement the first best.

More importantly for the results of the next sections, the planner chooses the efficient allocation such that the spread between the hidden and the official return on assets  $R^P/\hat{R}$  is strictly less than unity, as by rearranging the Euler equation I can show that:

$$1 < R^P \leq \beta \hat{R} < \hat{R}, \quad (2.19)$$

in every state of the world.<sup>5</sup> The intuition for this result is straightforward. As previously mentioned, the planner knows that without hidden

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<sup>5</sup>Notice that  $R^P$  must also be uncontingent.

savings the first best is achievable. Therefore, she finds it optimal to close down the private market by imposing a wedge between the return on bank assets and the return on the private technology. The planner is then able to efficiently allocate resources and provide optimal insurance. Because early consumers are valued more than late consumers ( $\beta\hat{R} > 1$ ), the planner compresses the ex post income profile by transferring resources from patient to impatient agents. Although that would not be incentive-compatible (the consumption bundle of the impatient depositors  $\mathcal{I}^P > 1$  is more valuable than that of the patient ones  $R^P\mathcal{I}^P/\hat{R} < \mathcal{I}^P$ ), the imposition of a wedge between the two returns ensures that patient depositors do not mis-report their types and retrade.

## 2.4 Banking Equilibrium without Systemic Risk

### 2.4.1 Competitive Equilibrium

In this section, I define and characterize the equilibrium of the decentralized environment, that I call “banking equilibrium”, where the only aggregate uncertainty pertains the distribution of the bank liquidity shocks across sectors. Here, the banks, operating in a perfectly-competitive system, only care about the expected welfare of their own customers, and allocate resources across time and states of the world by buying assets (short and long technologies), trading claims in the interbank market, and by defaulting/storing ex post.<sup>6</sup> More formally, the representative bank of each sector solves the dual problem:

$$\max_{\{C^i(\theta,s)\}_{\theta \in \{0,1\}}} \sum_{s=1,\dots,S} \nu(s) \sum_{\theta} \pi^i(\theta,s) V(C^i(\theta,s), R(s), \theta, s), \quad (2.20)$$

---

<sup>6</sup>Notice that here I am neglecting the existence of a “run equilibrium”, where every agent withdraws at date 1, irrespective of the realization of her idiosyncratic type, because she expects that everybody else is doing the same. One way of rationalizing this is by assuming that the banks can impose the suspension of convertibility in case of a run.

subject to the incentive compatibility constraint (2.10), the date-0 budget constraint:

$$X^i + Y^i \leq 1, \quad (2.21)$$

and the budget constraints at date 1 and 2, which must hold for any state:

$$X^i + rD^i(s) \geq \sum_{\theta} \pi^i(\theta, s) w_1^i(\theta, s) + Z^i(s) + M^i(s), \quad (2.22a)$$

$$\hat{R}(Y^i - D^i(s)) + \tilde{R}(s)Z^i(s) + M^i(s) \geq \sum_{\theta} \pi^i(\theta, s) w_2^i(\theta, s), \quad (2.22b)$$

$$0 \leq D^i(s) \leq Y^i, \quad (2.22c)$$

$$0 \leq M^i(s) \leq X^i + rD^i(s) - Z^i(s). \quad (2.22d)$$

A representative bank maximizes the total expected welfare of its depositors by choosing the best possible banking contract. In order to do so, it allocates the total deposits among short and long assets at date 0 (equation (2.21)). Then, at date 1 (equation (2.22a)) it receives the return on the storage technology  $X^i$  and, if it files for bankruptcy, the return on the liquidation technology  $rD^i(s)$ . These resources are used to pay for the early consumption, borrow or lend an amount  $Z^i(s)$  in the interbank market, and possibly store an amount  $M^i(s)$  for the next period. Finally, at date 2 (equation (2.22b)), the bank receives the net return on the long assets still in the portfolio ( $\hat{R}(Y^i - D^i(s))$ ), clears its trades in the interbank market ( $\tilde{R}(s)Z^i(s)$ ), and uses the storage from the previous period to finance late consumption.

The last two constraints need some more thoughts. The expression in (2.22c) states that the bank can neither liquidate a negative amount of assets, nor throw away more long assets than the amount that it holds. Similarly, the expression in (2.22d) states that the bank can neither store a negative amount from date 1 to date 2, nor store more than the maximum available resources: total liquidity plus the amount defaulted minus what they lent to other banks in the wholesale market.

The definition of the equilibrium is the following:

**Definition 3.** *Given an endowment  $e = 1$  for each agent and a probability distribution  $\{\nu(s)\}$  for the aggregate states, a banking equilibrium without systemic risk is an interest rate on the hidden bonds  $R^B(s)$ , a return on the interbank bonds  $\tilde{R}^B(s)$ , a set of feasible banking contracts  $\{C^i(\theta, s)\}$ , a set of final consumption allocations  $\{c_1^i(\theta, s), c_2^i(\theta, s)\}$ , and hidden bonds  $b^i(\theta, s)$  traded in the asset market by the agents, for any state  $s = 1, \dots, S$ , sector  $i = 1, \dots, n$  and type  $\theta = \{0, 1\}$ , such that:*

- *For given prices, the allocation solves the banking problem (2.20) in each sector;*
- *For given prices, the allocation solves the asset market problem (2.2) for every agent;*
- *Markets clear:*

$$\sum_i Z^i(s) = 0, \quad (2.23)$$

$$\sum_i \sum_{\theta} \pi^i(\theta, s) b^i(\theta, s) = 0. \quad (2.24)$$

The characterization of the competitive equilibrium starts from the price system. In particular, it must be the case that the equilibrium interest rate on the hidden bonds  $R^B(s)$  is equal to the marginal rate of transformation  $\hat{R}$  in any state of the world. The rationale for such a result comes from a market-clearing consideration. Suppose that  $R^B(s) < \hat{R}$ . Then, the investment in the long asset would be more profitable ex ante than the investment in the short asset. Every bank would only invest in long assets, and give consumption to early consumers at time 2. These would accept the offer, because they only care about the present discounted value of their consumption bundle. However, there would only be borrowers and no lenders in the asset market, and the equilibrium interest rate  $R^B(s)$  would go to infinity, which is clearly a contradiction. Similar lines of reasoning lead us to exclude the possibility that  $R^B(s) > \hat{R}$ : if that were the case, the banks would only invest ex ante in the short asset, and the patient depositors would like to lend liquidity (buy bonds in the asset market) to consume at date 2. However, the fact



that there are no borrowers in the asset market implies that the equilibrium interest rate  $R^B(s)$  would go to 1 (the return on the short asset), which is, again, a contradiction.

With this result in hand, I can complete the characterization of the equilibrium by backward induction. The problem in the asset market for a type-0 agent reads:

$$V(C^i(0, s), \hat{R}, 0, s) = \max u(c_1^i(0, s)), \quad (2.25)$$

subject to:

$$c_1^i(0, s) + b^i(0, s) = w_1^i(0, s), \quad (2.26a)$$

$$c_2^i(0, s) - \hat{R}b^i(0, s) = w_2^i(0, s), \quad (2.26b)$$

where I used the fact that the agent takes as given the equilibrium interest rate  $R^B(s) = \hat{R}$ . Clearly, it must be the case that  $c_2^i(0, s) = 0$  (because a type-0 agent does not enjoy utility from consuming at date 2), and therefore  $b^i(0, s) = -w_2^i(0, s)/\hat{R}$  and:

$$c_1^i(0, s) = w_1^i(0, s) + \frac{w_2^i(0, s)}{\hat{R}}. \quad (2.27)$$

In a similar way, a type-1 agent would not consume at date 1, and lend at the equilibrium rate  $\hat{R}$  the amount  $w_1^i(1, s)$  that she receives from the bank at date 1, so as to consume:

$$c_2^i(1, s) = \hat{R}w_1^i(1, s) + w_2^i(1, s) \quad (2.28)$$

at date 2. Thus, the clearing condition in the asset market (2.24) reads:

$$\sum_i \pi^i(0, s) \frac{w_2^i(0, s)}{\hat{R}} = \sum_i \pi^i(1, s) w_1^i(1, s). \quad (2.29)$$

I use the expressions in (2.27) and (2.28) to rewrite the bank objective function as:

$$\max \sum_s \nu(s) \left[ \pi^i(0, s) u \left( w_1^i(0, s) + \frac{w_2^i(0, s)}{\hat{R}} \right) + \beta \pi^i(1, s) u(\hat{R} w_1^i(1, s) + w_2^i(1, s)) \right]. \quad (2.30)$$

The simultaneous presence of interbank markets and asset markets is key for the characterization of the competitive equilibrium.

**Proposition 1.** *In the banking equilibrium without systemic risk, the ex ante bank investment strategies must satisfy:*

$$\sum_i X^i = \Pi(0), \quad (2.31a)$$

$$\sum_i Y^i = \Pi(1). \quad (2.31b)$$

*The final consumption allocations of the agents are:*

$$c_1^i(1, s) = c_2^i(0, s) = 0, \quad (2.32a)$$

$$c_1^i(0, s) = 1, \quad (2.32b)$$

$$c_2^i(1, s) = \hat{R}, \quad (2.32c)$$

*in any state of the world  $s = 1, \dots, S$  and sector  $i = 1, \dots, n$ . The interest rate on the bonds exchanged in the interbank market is  $\tilde{R}(s) = \hat{R}$  in any state. The equilibrium ex post strategies are  $D^i(s) = M^i(s) = 0$  in any state of the world and sector.*

*Proof.* In Appendix C. ■

Given all the possible investment strategies available to the banks (that I plot in figure 2.2), the only possible equilibrium is the one where the market yields are all the same, and equal to the exogenous marginal rate of transformation:  $R^B(s) = \tilde{R}^B(s) = \hat{R}$ . This implies two things: first, the banks are indifferent between investing in the long and in the short asset, and therefore we cannot solve for the equilibrium banking contracts and for the amounts  $b^i(\theta, s)$  traded in the hidden market. Second, the ex post strategies of storage and default are always dominated

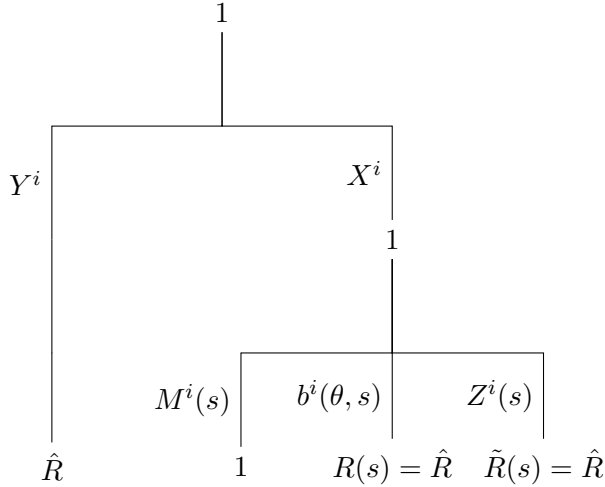


Figure 2.2: How to finance  $w_2^i(\theta, s)$  with 1 unit of consumption at date  $t = 0$  in the presence of interbank markets and hidden trades.

by the market channels, that are a cheaper way to transfer resources across time:  $M^i(s) = D^i(s) = 0$  in every sector and state of the world.

These considerations allow me to consolidate the budget constraints of each representative bank in an intertemporal budget constraint of the form:

$$\sum_{\theta} \pi^i(\theta, s) \left[ w_1^i(\theta, s) + \frac{w_2^i(\theta, s)}{\hat{R}} \right] \leq 1. \quad (2.33)$$

Because of the incentive compatibility constraint, this simplifies to  $I^i(s) \leq 1$ , where  $I^i(s)$  is the constant present value of the consumption bundles offered by the banks. The Inada conditions ensure that this constraint holds with equality, and this, together with (2.27) and (2.28), lead us to the equilibrium consumption bundle in (2.32a)-(2.32c). Notice that such amounts are not state-contingent, but are constant across types and exactly equal to the initial endowments. Intuitively, this is so because the incentive compatibility constraint states that, as a consequence of the unobservability of the trades, the banks should offer a consumption bundle whose present value is constant across types when evaluated at the *market interest rate*. However, the fact that the equilibrium interest rate

on the hidden assets is equal to the return on the long technology implies that the banks must offer a contract whose present value is constant across types when evaluated at the *banking return*, too. In other words, at the equilibrium prices, the objective of providing incentives to truth-telling (which pushes the banks to offer the same present value of consumption to both types) collides with the insurance motivation (which instead pushes the banks to offer more to the impatient depositors than to the patient ones), and the banks are not able to offer the efficient amount of within-sector risk sharing.<sup>7</sup>

Despite the indeterminacy of each bank's asset portfolio, we can use the clearing conditions in the hidden bond market (2.29) and in the interbank market to characterize the total amount of liquidity held by the banks in the whole economy in equilibrium as:

$$\begin{aligned} \sum_i X^i &= \sum_i [\pi^i(0, s)w_1^i(0, s) + \pi^i(1, s)w_1^i(1, s) + Z^i(s)] \\ &= \sum_i \pi^i(0, s) \left[ w_1^i(0, s) + \frac{w_2^i(0, s)}{\hat{R}} \right] = \Pi(0). \end{aligned} \quad (2.34)$$

This last result allows me to compare the decentralized outcome with the social planner solution of section 2.3.5. To this end, I introduce an index of relative liquidity  $\mathcal{L}$  as the ratio between the total amount of short assets and the total amount of long assets. As far as the planner is concerned, such a measure takes the value:

$$\mathcal{L}^P \equiv \frac{X^P}{Y^P} = \frac{\Pi(0)\mathcal{I}^P}{\Pi(1)\frac{R^P\mathcal{T}^P}{\hat{R}}} = \frac{\Pi(0)}{\Pi(1)} \frac{\hat{R}}{R^P}, \quad (2.35)$$

while in the banking equilibrium it is:

$$\mathcal{L}^B \equiv \frac{\sum_i X^i}{\sum_i Y^i} = \frac{\Pi(0)}{\Pi(1)}. \quad (2.36)$$

---

<sup>7</sup>The total welfare turns out to be equivalent to the one that the agents would get if no banks were in place, and is a well-known result in the literature on hidden savings (see Ales and Maziero, 2010), that has been used as a way to rationalize the co-existence of direct access and intermediated access to markets (Jacklin, 1987).

Clearly, the latter is less than  $\mathcal{L}^P$  because I proved that  $R^P < \hat{R}$ . Put differently, the banking system is always more illiquid than it should be from an efficiency perspective. This result depends on the fact that, in a perfectly competitive environment, there must be no arbitrage opportunities between the hidden market and the official banking system. This pushes the interest rate on the hidden bonds above its efficient level and, in turn, incentivizes the banks to invest relatively more in long-term securities and relatively less in safe liquid ones in order to ensure truth-telling.

Nevertheless, the main lesson of this section is that the inefficiency of the bank investment strategies are not enough to explain why they might be in distress. Negatively correlated shocks, and the availability of interbank markets where the banks can hedge against them, are in that sense crucial. When allowed to trade among themselves across sectors, the banks might be illiquid, but never bankrupt: there will always be enough demand and supply of bonds in the market, so the banks are always able to smooth consumption across states of the world.

### 2.4.2 Optimal Regulation

How can we affect the illiquidity of financial system and decentralize the efficient allocation? The current environment is helpful to provide an answer to this question, because the inefficiency of the equilibrium is endogenous and can be clearly identified by comparing the banking equilibrium to the solution to the planner's problem. Hence, we can think of some regulatory intervention to affect it at its very source.

As mentioned above, the banking equilibrium is inefficient because the interest rates in the asset markets are too high. The obvious consequence of such an observation would then be to directly regulate markets, for example through the imposition of taxes. Unfortunately, this is impossible in theory because trades are observable to neither the banks nor the regulators. Moreover, that might also be impossible in reality: financial transactions (for example in the stock markets) are difficult to

track, and even if governments regulate some securities, capital might fly away to the “shadow banking system”, or financial innovation would ensure that new unregulated instruments would be issued exactly to avoid such limitations. Therefore, what I propose here is an indirect approach: regulate markets by regulating banks.

Specifically, the regulatory intervention such that banks autonomously implement the constrained efficient allocation is a sector-specific minimum liquidity requirement imposed on their initial portfolios:

$$X^i \geq F^i. \quad (2.37)$$

The justification of such a rule is the following. In the newly regulated equilibrium, the interest rates in the asset market will be lower than those in the unregulated equilibrium. This means that the short asset would be dominated by the long asset, and no bank would hold liquidity at all. This cannot be an equilibrium, since clearing in the hidden market would be violated: impatient consumers would like to borrow, but no one would lend to them. Thus, the only way the banking system can support an equilibrium where the hidden interest rate is lower than the return on the long-term asset is via the introduction of a minimum liquidity requirement, so that banks are forced to hold enough resources to finance early consumption. By picking the right limit, the regulator can then manipulate the asset prices *indirectly* and the bank portfolios *directly*, and let them implement the efficient allocation.

Assume that the interbank markets are open and well-functioning. The banking problem in (2.20) is modified with the additional constraint in (2.37), and we can prove the following:

**Proposition 2.** *The minimum liquidity requirement:*

$$F^i = \sum_{k=1}^S \nu(k) \pi^i(0, k) \mathcal{I}^P, \quad (2.38)$$

where  $\mathcal{I}^P$  comes from the solution to the planner’s problem, implements

*the planner's solution.*

*Proof.* In Appendix C. ■

This is the multi-sectoral version of the optimal regulatory intervention proposed by Farhi et al. (2009). The optimal minimum liquidity requirement is a weighted average of all the sector-specific expenses that banks face at date 1 if impatient depositors are entitled to receive the efficient amount of consumption ( $\pi^i(0, s)\mathcal{I}^P$ ), weighted by a factor  $\nu(s)$ , i.e. the *economy-wide* probability of each state to be realized.

This result is interesting because it provides a theoretical rationale for the so-called “Liquidity Coverage Ratio”, which is a key part of the liquidity regulation proposed by the Basel Committee on Banking Supervision (2010).<sup>8</sup> Moreover, the theoretical minimum liquidity requirement features two of the main characteristics of the rules in the “Basel III Accord”, as (i) it dampens the cyclicity of budget requirements, by creating an ex-ante uncontingent rule, and (ii) promotes forward-looking provisions, by weighing all possible future states of the economy with common and sector-specific factors. In addition to those, a global regulatory standard is also supposed to affect systemic risk, and more generally tame moral hazard in the financial system. The conclusion here is that we have a further reason to introduce requirements on banks: to affect asset markets. This is an interesting yet novel way of rationalizing financial regulation.

## 2.5 Banking Equilibrium with Systemic Risk

To study the role of markets and liquidity shocks for the emergence of default as an equilibrium phenomenon, in this section I relax the hypothesis of no systemic risk, and analyze the case where the liquidity shocks affecting the banks are instead positively correlated. This means

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<sup>8</sup>The Liquidity Coverage Ratio is the ratio between total liquid assets and the estimated net cash outflow of each bank, and it is supposed to be larger than 1 at any point in time.

that, while the hidden market for the depositors is still active, interbank markets do not clear, because all the banks accessing the market want to either borrow or lend. As a consequence, default and storage are now the only instruments that the banks can use to transfer resources across states of the world and ensure that the incentive compatibility constraint is satisfied.

To be more specific, recall that, if no hidden trades are possible, the banks would be able to offer an equilibrium contract contingent on the realization of the aggregate state of the world (i.e. on the available per capita liquidity), and never store or default ex post (Allen and Gale, 2004). The reason why this is not possible in the presence of hidden trades is the following. In the competitive equilibrium, because of the no-arbitrage condition that is necessary to clear the market, it still must be the case that the interest rate on the hidden market  $R(s)$  is equal to the marginal rate of transformation  $\hat{R}$ . Assume that the banks fix  $w_2^i(0, s) = w_1^i(1, s) = 0$  for every  $i$  and  $s$ , that is, they deliver the incentive-compatible allocation that prevents the agents from trading. Then, the incentive compatibility constraint requires the ratio  $w_2^i(1, s)/w_1^i(0, s)$  to be constant and equal to  $\hat{R}$ , too. The banks need storage and default to ensure ex post that this is the case in every state of the world.

### 2.5.1 Competitive Equilibrium

The objective function of the banks is the same as before, and the problem formally reads the same as the one in (2.20), with the exception of  $Z^i(s) = 0$  in every sector  $i$  and state  $s$ . I rearrange the budget constraints in (2.21)-(2.22b) and make use of the incentive compatibility constraint to derive:

$$w_1^i(0, s) = 1 - \left(1 - \frac{1}{\hat{R}}\right) M^i(s) - (1 - r)D^i(s). \quad (2.39)$$

The total present value of the bank incentive-compatible expenditure must be equal to the per capita deposits, minus the deadweight losses



from either storage or default.<sup>9</sup> The first come from the missing investments in the long-term asset, and the second from the liquidation technology. The amounts stored and liquidated must be non-negative by definition, hence the banks either store liquidity, if the actual liquidity need is lower than the amount of short assets in portfolio, or default, if the actual liquidity need is higher than the amount of short assets in portfolio.

Then, the banking problem boils down to choosing the amount of initial liquidity  $X^i$ , and the early consumption  $w_1^i(0, s)$  (the late consumption is fixed by the incentive compatibility constraint to  $w_2^i(1, s) = \hat{R}w_1^i(0, s)$ ), which is equivalent to choosing the amounts of either storage or default in each state of the world:

$$\max_{X^i, w_1^i(0, s)} \sum_s \nu(s) [\pi^i(0, s)u(w_1^i(0, s)) + \beta\pi^i(1, s)u(\hat{R}w_1^i(0, s))], \quad (2.40)$$

subject to (2.39) and to:

$$D^i(s) = \frac{\pi^i(0, s) - X^i}{\pi^i(0, s) + r\pi^i(1, s)}, \quad (2.41)$$

$$M^i(s) = \hat{R} \frac{X^i - \pi^i(0, s)}{\pi^i(0, s) + \hat{R}\pi^i(1, s)}, \quad (2.42)$$

where the last two expressions come from rearranging the bank budget constraints, and must hold for any state  $s$ . To characterize the equilibrium, I plug (2.41) and (2.42) into (2.39), and take the first-order condition to find:

**Proposition 3.** *In the banking equilibrium with systemic risk, the amount of liquidity chosen by the banks is the solution to:*

$$\sum_s \lambda(s) \left[ \frac{1 - r}{\pi^i(0, s) + r\pi^i(1, s)} - \frac{1 - \frac{1}{\hat{R}}}{\frac{1}{\hat{R}}\pi^i(0, s) + \pi^i(1, s)} \right] = 0, \quad (2.43)$$

---

<sup>9</sup>The left hand side of (2.39) comes from  $w_1^i(0, s) [\pi^i(0, s) + \pi^i(1, s)\frac{\hat{R}}{R}] = w_1^i(0, s)$ .

where

$$\lambda(s) = \nu(s) [\pi^i(0, s) u'(w_1^i(0, s)) + \beta \pi^i(1, s) \hat{R} u'(\hat{R} w_1^i(0, s))]. \quad (2.44)$$

The representative bank chooses the amount of liquidity to hold in its portfolio so as to equalize a weighted average of the expected deadweight losses of default and storage in every state of the world, using as weights the marginal utilities of consumption in every state. The fact that the deadweight losses from storage and default are asymmetric implies that the expression in (2.43) is highly non-linear, and an analytical solution does not exist. Thus, in what follows I will show its numerical characterization.

### 2.5.2 Numerical Solution

Recall that the degree of relative risk aversion of the felicity function  $u(c)$  is larger than or equal to 1 by assumption. Hence, I choose a logarithmic function that, incidentally, is also equal to the original formulation in Diamond and Dybvig (1983). I assume that there are two possible states of the world: with probability  $\gamma$  the fraction of (or the probability of being) impatient depositors is 70 per cent, and I label this state “crisis”; with probability  $1 - \gamma$  the fraction of (or the probability of being) impatient depositors is instead 30 per cent, and I label this state “no crisis”.<sup>10</sup>

I find three parameters in the data: I back up the return on the long asset  $\hat{R}$  from the average prime rate imposed by the U.S. chartered commercial banks on their short-term loans to business, from Q2-2007 to Q4-2009.<sup>11</sup> For the same time period, I also choose the recovery rate  $r$  of the liquidation technology to be .45, equal to the mean recovery rate on bank loans according to Moody’s (2009),<sup>12</sup> and the intertemporal discount factor  $\beta$  from the average market yield on 1-year U.S. Trea-

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<sup>10</sup>These values are chosen only for expositional convenience, and changing them would not qualitatively affect the features of the equilibrium in any way.

<sup>11</sup>Source: *Board of Governors of the Federal Reserve System*.

<sup>12</sup>This number is not far from the structural estimate proposed by Chen (2010).

Table 2.2: Calibrated values of the parameters of the model

Parameter	Parameter Name	Value
$\hat{R}$	Long asset yield	1.05
$\beta$	Discount factor	0.9852
$r$	Recovery rate	0.45

sury bonds.<sup>13</sup> Notice that the calibrated deadweight losses from storage ( $1 - 1/\hat{R} = .0476$ ) turn out to be more than ten times lower than the calibrated deadweight losses from liquidation ( $1 - r = .55$ ).<sup>14</sup>

In figure 2.3, I plot the banking equilibrium for a given probability of the crisis state  $\gamma$ . There exists a relevant area of the state space where the banks choose an interior solution: the equilibrium amount of liquidity is such that the expected marginal benefit of having one more unit of it (in terms of avoiding liquidation in case of bankruptcy) is equal to its expected marginal costs (in terms of storage if it turns out to be excessive). In this area, the amount of initial liquidity is an increasing function of the probability of the crisis state  $\gamma$ . Given that the deadweight losses from default are considerably larger than those from storage, the transition between the two corner solutions is steep and happens for relatively low values of  $\gamma$ .

For extreme values of the probability of the crisis state, the banks instead choose some equally extreme portfolio strategies: if the probability of the crisis state is sufficiently low, they invest the least possible value in liquidity, and then use the default technology if a crisis is actually realized (the top middle panel of figure 2.3). In contrast, when the probability of the crisis state is sufficiently high, the banks “fly to liquidity”. Such an acute form of precautionary liquidity savings implies that the banks never default ex post, but store liquidity if no crisis happens at date 1 (the bottom middle panel of figure 2.3).

<sup>13</sup>Source: *Board of Governors of the Federal Reserve System*. The average yield is  $\rho = 1.5$  per cent, and  $\beta = 1/(1 + \rho)$ .

<sup>14</sup>I characterize the numerical solution of the problem using nonlinear programming techniques in Matlab. The code is available upon request.

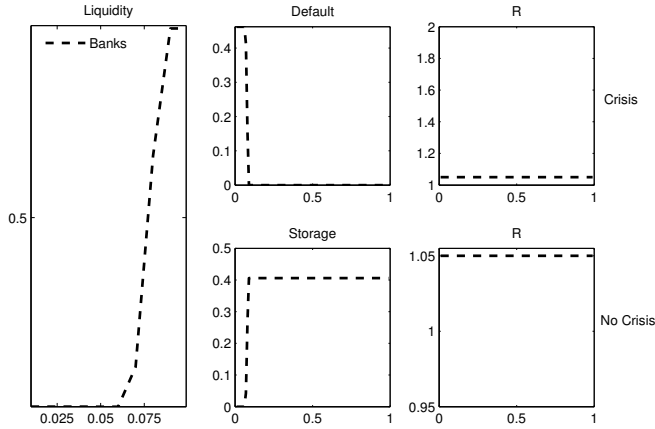


Figure 2.3: Banking equilibrium with systemic risk, for different probabilities of the crisis state  $\gamma$  (on the x-axis).

### 2.5.3 Policy Experiment

To check whether the model is a good representation of the reality, I study whether it is able to replicate some features of the U.S. economy that are not targeted in the calibration. In particular, I focus my attention on the implied probability of a financial crisis. To this end, I assume that  $\pi^i(0, 1) = .99$  in the crisis state (happening with probability  $\gamma$ ), and  $\pi^i(0, 2) = .01$  in the no-crisis state (happening with probability  $1 - \gamma$ ), so as to include all the values observed in the data. Then, I take the liquidity ratios of the U.S. chartered commercial banks, plotted in figure 2.1 at quarterly frequencies for the period from Q2-2007 to Q4-2009. I plug them into the model and back up the probability of the crisis state  $\gamma$  consistent with the theory. Then, following Veronesi and Zingales (2010), I calculate the probability of a crisis implied by a credit default swap index of U.S. banks, and compare the two. I report the results in table 2.3.<sup>15</sup>

<sup>15</sup>I use the quarterly averages of the “North American Banks 5-year CDS Index” (source: Datastream). I assume that the recovery rate in case of default is  $REC = 40$  per cent, and that the instantaneous default intensity is constant until maturity. I back this up from the no-arbitrage pricing formula of the credit default swap  $\mathcal{P}_t =$

Table 2.3: Fit of the Calibrated Model

	Data	Baseline Calibration	Alternative Calibration
Avg Pr(crisis) (%)	3.73	3.87	7.54
Std Pr(crisis) (%)	1.3588	0.1196	0.1523
Correlation with data	1	0.8154	0.8046

The model almost perfectly matches the average probability of a crisis according to the data (3.73 per cent versus 3.87 per cent). In contrast, it only accounts for about 9 per cent of the total volatility, but that is expected given the model lacks any dynamic features. Moreover, the calibrated series of probabilities exhibits the same increasing trend of the data, even if at a lower magnitude. This is confirmed by the fact that the two series are highly and positively correlated (0.8154).

To check the robustness of these results, I also repeat the analysis using an alternative calibration drawn from He and Xiong (2012).<sup>16</sup> In this case, the model overestimates the probability of a financial crisis, and gets slightly closer to actual volatility. The fact that the correlation is still high suggests that the structure of the theory works qualitatively well in replicating the data.

These results allow me to use the calibrated model to run a policy experiment. In particular, I want to study whether the minimum liquidity requirement that decentralizes the socially optimal allocation when interbank markets are available improves welfare also when the banks cannot exchange resources among themselves. This is an important question because, in section 2.4, I showed that such a regulation is actually equivalent to the “Liquidity Coverage Ratio” imposed as part of the Basel III Accord. Therefore, we can check if the regulation in times of no systemic risk is also good in times of systemic risk.

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$CDS_t/(1 - REC)$  and calculate the probability of default as  $q_t = 1 - e^{\mathcal{P}t}$ .

<sup>16</sup>In their dynamic model of debt runs, He and Xiong choose the return on bank assets to be equal to 1.07 (the average mortgage rate between 2005 and 2008) and a recovery rate of 0.55.

To answer this question, I numerically solve the problem in (2.40) with the additional constraint:

$$X^i \geq \gamma\pi^i(0, 1)w_1^i(0, 1) + (1 - \gamma)\pi^i(0, 2)w_1^i(0, 2), \quad (2.45)$$

which states that the amount of liquidity must be at least as large as the bank expected cash outflow, and is equivalent to the optimal regulation that I characterized in section 2.4.

The result that comes out is that, in equilibrium, the liquidity coverage ratio is binding only for very low values of the probability of the crisis state  $\gamma$ , because the banks choose high liquidity to avoid default when the probability is high. This has two consequences in terms of the expected welfare gains generated by the policy intervention.<sup>17</sup> First, the fact that the minimum liquidity requirement is not binding for high values of  $\gamma$  implies that its effect on welfare is negligible. Second, and more importantly, when the probability of the crisis state is low, the minimum liquidity requirement obliges the banks to be more liquid. This lowers the employment of the default technology if the crisis state is realized, but increases storage if the no-crisis state is realized (which happens with higher probability). Thus, the expected welfare gains are actually negative, and around -.01 per cent in the calibration.

### 2.5.4 Planner's Solution

This last result points out that the liquidity coverage ratio is not a sufficient policy intervention when the presence of systemic risk forbids the banks from trading in the interbank markets. Thus, the public authorities should further tailor liquidity regulation to those cases, in order

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<sup>17</sup>The values reported here are the the welfare gains in permanent consumption equivalent, that are equal to the weighted average of the utility gains in the two states of the world:

$$\kappa = \frac{\gamma[\pi^i(0, 1) + \beta\pi^i(1, 1)] \log\left(\frac{w_1^R(0,1)}{w_1^i(0,1)}\right) + (1 - \gamma)[\pi^i(0, 2) + \beta\pi^i(1, 2)] \log\left(\frac{w_1^R(0,2)}{w_1^i(0,2)}\right)}{\gamma[\pi^i(0, 1) + \beta\pi^i(1, 1)] + (1 - \gamma)[\pi^i(0, 2) + \beta\pi^i(1, 2)]}.$$

to decentralize the constrained efficient allocation. To show this, here I characterize the planner's problem:

$$\max_{\substack{\{X^i, Y^i, \mathcal{I}^i(s), \\ R(s), D^i(s), M^i(s)\}}} \sum_s \nu(s) [\pi^i(0, s)u(\mathcal{I}^i(s)) + \beta\pi^i(1, s)u(R(s)\mathcal{I}^i(s))], \quad (2.46)$$

subject to the feasibility of the initial portfolio allocation:

$$X^i + Y^i \leq 1, \quad (2.47)$$

and the ex post budget constraints:

$$X^i + rD^i(s) \geq \pi^i(0, s)\mathcal{I}^i(s) + M^i(s), \quad (2.48a)$$

$$\hat{R}(Y^i - D^i(s)) + M^i(s) \geq \pi^i(1, s)R(s)\mathcal{I}^i(s), \quad (2.48b)$$

which must hold in any possible state of the world  $s = 1, \dots, S$ .

In an environment where the banks cannot trade across sectors, a social planner is forced to yield to the very same limitation, and needs to use storage and default to cover the resource imbalances due to the systemic risk, and ensure that the incentive compatibility constraint is satisfied. However, there is one key difference between the planner and the banks: as showed in the previous section, the planner can choose the interest rate on the hidden bond  $R(s)$ . In other words, the planner solves the very same problem of the representative bank (maximizes the same objective function, subject to the same budget constraints and incentive compatibility constraint), but with one more instrument. Thus, the total welfare that she can provide is bigger than or equal to the one that the banks can provide.

I report in figure 2.4 the constrained efficient allocation (solid line), together with the competitive banking equilibrium (dashed line). The rationale for these results is the following. Assume that the probability of the crisis state  $\gamma$  is sufficiently low. On one side, the banks choose low liquidity ex ante (the left panel of figure 2.4), because they are afraid of the deadweight losses from storage if a crisis is not realized ex post. On

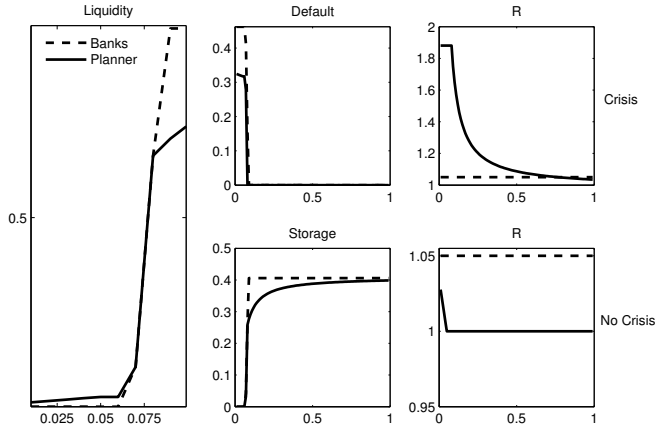


Figure 2.4: Banking equilibrium and planner solution with systemic risk for different probabilities of the crisis state  $\gamma$  (on the x-axis).

the other side, the planner does not exclusively rebalance the budget constraints (2.48a)-(2.48b) by storing liquidity ex post in the no-crisis state, but also by lowering the interest rate  $R^P(s)$  below its competitive value (the bottom right panel of figure 2.4). In this way, the early consumption increases (i.e., the impatient agents borrow at a lower rate) and the late consumption decreases (i.e., the patient agents lend at a lower rate). This means that, at date 0, the planner is free to choose a higher level of liquidity than the banks. Similarly, when the probability of the crisis state  $\gamma$  is sufficiently high, the banks engage in precautionary liquidity savings, because they are afraid of the deadweight losses from default in the crisis state. Conversely, the planner, in the crisis state, rebalances the budget constraints (2.48a)-(2.48b) by increasing the interest rate  $R^P(s)$  above its value in competitive equilibrium (the top right panel of figure 2.4). In this way, she lowers the early consumption (i.e., the impatient agents borrow at a higher rate) and increases the late consumption (i.e., the patient agents lend at a higher rate). Hence, the planner is free to choose an amount of liquidity lower than the banks when the probability of the crisis state is sufficiently high.



In other words, the planner uses the interest rate on the hidden bonds as an alternative to storage and default. Therefore, the first-order conditions of the problem pin down an upper and a lower bound for  $R^P(s)$  that, with a logarithmic felicity function, read:

$$1 \leq R^P(s) \leq \beta \frac{\hat{R}}{r}. \quad (2.49)$$

On one side,  $R^P(s)$  cannot be lower than 1 (the return from the storage technology) otherwise the depositors would just withdraw and store the resources themselves. On the other side, when instead  $R^P(s)$  is equal to the upper bound, the planner, in periods of crisis, is indifferent between covering liquidity imbalances via the interest rate channel or via the default technology. In between the bounds, where the planner uses neither storage nor the default procedure,  $R^P(s)$  is a decreasing function of the initial amount of liquidity  $X^P$ :

$$R^P(s) = \frac{w_2^P(1, s)}{w_1^P(0, s)} = \hat{R} \frac{1 - X^P \Pi(1, s)}{X^P \Pi(0, s)}. \quad (2.50)$$

Therefore, since the initial liquidity is increasing in the probability of the crisis state  $\gamma$ , the equilibrium interest rate  $R^P(s)$  is also decreasing in it. The numerical characterization of the planner's solution show exactly this behavior. On one side, when the probability of the crisis state is sufficiently low, the planner does not find convenient to further increase the interest rate in the crisis state (the top right panel of figure 2.4), and rebalances her budget constraints (2.48a)-(2.48b) by using the default technology (the middle top panel of figure 2.4). On the other side, when the probability of the crisis state is instead sufficiently high, the planner does not further lower the interest rate in the no-crisis state (the bottom right panel of figure 2.4), but uses the storage technology (the middle bottom panel of figure 2.4).

Although being just an extension of the result of section 2.3, the characterization of the constrained efficient allocation in the presence of systemic risk is the key result of the paper for two reasons. First, be-

cause it disproves the constrained efficiency of bankruptcy. Allen and Gale (2004) show that default emerges in the equilibrium of a Diamond-Dybvig model with aggregate shocks when the banks are *exogenously* constrained from offering a state-contingent contract to their customers, because default, in a sense, adds state-contingency when there is none. Moreover, since, in their framework, the constraint on the banking contract is completely exogenous, the planner is subject to it in the very same way as the banks, and therefore cannot improve the outcome of the decentralized equilibrium: the competitive equilibrium with default is constrained efficient. Here, instead, the banks are *endogenously* constrained from offering a state-contingent contract because of the presence of hidden trades, but the planner can generate higher welfare by imposing a state-contingent wedge between the marginal rate of transformation and the interest rate on the hidden bond. This leads me to the second source of interest in this result: since a feasible allocation that Pareto-dominates the competitive equilibrium exists, then there is space for a regulatory intervention to implement the constrained efficient allocation in a decentralized environment.

The analysis of this section suggests that, in the presence of systemic risk, the optimal regulation of liquidity should depend on the probability of the crisis state. When such a probability is sufficiently low, the banks are cumulating an inefficiently low amount of liquidity, which means that they are indeed “illiquid”. Thus, a *minimum* liquidity requirement is necessary to force them to increase their cushion of safe liquid assets and avoid default. When instead the probability of a crisis is sufficiently high, the banks are afraid of the deadweight losses of default, and choose an inefficiently safe strategy, which means that they are actually “hoarding” liquidity. Such a behavior should then be counteracted with the introduction of a *maximum* liquidity requirement. Therefore, this result provides the rationale for a regulatory intervention in the form of *countercyclical* liquidity requirements.

## 2.6 Concluding Remarks

Financial markets play a key role in linking illiquidity and distress in the financial system. In a stylized model of financial intermediation, I find that default emerges in equilibrium neither as a consequence of systemic risk alone, nor as a consequence of illiquidity, but only when these two phenomena show up simultaneously. Moreover, in contrast to the previous literature, default is not constrained efficient, and there is the space for a public authority to improve the outcome of the decentralized economy with a regulatory intervention. However, the optimal policy must be targeted to the aggregate state of the economy: while, in the absence of systemic risk, minimum liquidity requirements, similar to those imposed as part of the Basel III Accord, are the right type of intervention, in the presence of systemic risk we need minimum or maximum liquidity requirements depending on the whether the objective is to fight illiquidity or hoarding. Thus, my result provides a rationale for the introduction of countercyclical liquidity requirements.

More generally, the lesson that we can draw from this exercise is that economists and policy makers need not only study how illiquidity emerges and how to solve it *ex ante* with macroprudential regulations, but also how the investors (both banks and agents) interact among themselves in the financial markets. In the present environment, the interbank markets are a stabilizing force, while the asset markets are a distortion to the economy. However, it is not difficult to argue that, in reality, these roles can switch: the interbank markets can become a channel of contagion, and the asset markets can operate as substitutes for unavailable wholesale funding. I analyze some of these issues in a companion paper (Panetti, 2013). Similarly, it might be interesting to characterize environments where the individual access to the asset markets is limited, either because of some exogenous trading costs, like in Diamond (1997), or because of limited commitment, as in Antinolfi and Prasad (2008). These assumptions would affect the interest rate on the hidden bond and, in turn, the whole equilibrium, possibly in some crucial way. I leave these

issues to future research.

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## A Why Only Bonds in the Asset Markets?

For this proof, I follow Golosov and Tsyvinski (2007). Remember that, when borrowing and lending in the market, the individual types are still private information. In order to complete the set of traded securities, we may then add claims paying 1 unit of consumption conditional on reporting type  $\theta$  in state  $s$ . Define the price of such securities as  $Q(\theta, s)$ . I can prove the following:

**Lemma 3.**  $Q(\theta, s) \geq \frac{1}{R(s)}$  for every type  $\theta \in \{0, 1\}$  and  $s = 1, \dots, S$ .

**Proof.**  $1/R(s)$  is the price of a risk-free bond delivering one unit of consumption in the following period for each unit invested. I prove the lemma by contradiction. Assume that  $Q(\theta, s) < \frac{1}{R(s)}$  for some  $\theta$  and  $s$ . That would give rise to arbitrage opportunities: agents would issue an infinite amount of uncontingent bonds, buy the same amount of those state-contingent securities, then report exactly type  $\theta$  in state  $s$ , and enjoy infinite profits. That cannot be an equilibrium. ■

Given that  $Q(\theta, s) \geq \frac{1}{R(s)}$ , no type-contingent claim will be traded: the agents will never exchange securities which yield one unit of consumption if a specific type is reported, when they have the opportunity to trade a cheaper bond which yields one unit of consumption whatever type is reported.

## B Planner Problem without Hidden Trades

The social planner chooses the optimal contract and the efficient portfolio allocation in order to maximize the total ex-ante welfare of the economy. In doing so, she is subject to the constraint that the portfolio allocation

must provide enough resources to pay consumption in both periods to any agent of any type. In addition, the agents still have private information about their individual types. Then, I can apply the Revelation Principle and restrict the social planner problem to truth-telling mechanisms where every agent correctly reports her true type. Formally, the planner's problem is:

$$\max_{X,Y,\{w_t^i(\theta,s)\}_{s=1,\dots,S}^{\substack{\theta \in \{0,1\} \\ i=1,\dots,n \\ t=1,2}}} \sum_i \sum_s \nu(s) \sum_\theta \pi^i(\theta,s) U(C^i(\theta,s),\theta), \quad (2.51)$$

subject to:

$$X + Y \leq n, \quad (2.52)$$

and:

$$\sum_i \sum_\theta \pi^i(\theta,s) w_1^i(\theta,s) \leq X, \quad (2.53a)$$

$$\sum_i \sum_\theta \pi^i(\theta,s) w_2^i(\theta,s) \leq \hat{R}Y, \quad (2.53b)$$

for each  $s = 1, \dots, S$ , and:

$$U(C^i(0,s),0) \geq U(C^i(1,s),0), \quad (2.54a)$$

$$U(C^i(1,s),1) \geq U(C^i(0,s),1), \quad (2.54b)$$

for each  $i = 1, \dots, n$  and  $s = 1, \dots, S$ .<sup>18</sup> I report the solution to this problem in the next lemma, which fully characterizes the equilibrium:

**Lemma 4.** *The planner chooses the optimal allocation such that in every state  $s = 1, \dots, S$ , and for every  $i, j = 1, \dots, n$ :*

$$w_1^i(1,s) = w_2^i(0,s) = 0, \quad (2.55a)$$

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<sup>18</sup>As in the body of the paper, here I do not take into account the existence of the “run equilibrium”.

$$\frac{u'(w_1^i(0, s))}{u'(w_1^j(0, s))} = 1 = \frac{u'(w_2^i(1, s))}{u'(w_2^j(1, s))}, \quad (2.55b)$$

$$\beta \hat{R} u'(w_2^i(1, s)) = u'(w_1^i(0, s)), \quad (2.55c)$$

and:

$$\sum_i \left[ \pi^i(0, s) w_1^i(0, s) + \pi^i(1, s) \frac{w_2^i(1, s)}{\hat{R}} \right] = n. \quad (2.56)$$

The constrained efficient allocation is equivalent to the unconstrained optimum.

**Proof.** Guess (2.54a) and (2.54b) are slack. Re-write (2.52), (2.53a) and (2.53b) as:

$$\sum_i \sum_{\theta} \pi^i(\theta, s) \left[ w_1^i(\theta, s) + \frac{w_2^i(\theta, s)}{\hat{R}} \right] \leq n, \quad \forall s = 1, \dots, S. \quad (2.57)$$

Assign multipliers  $\lambda(s)$  to each constraint in (2.57). Clearly,  $w_1^i(1, s)$  and  $w_2^i(0, s)$  are optimally set to zero, since they would be only costs for the planner and provide no utility to the agents. The first-order conditions with respect to  $w_1^i(0, s)$  and  $w_2^i(1, s)$  read:

$$u'(w_1^i(0, s)) = \lambda(s), \quad (2.58a)$$

$$\beta u'(w_2^i(1, s)) = \lambda(s) \frac{1}{\hat{R}}, \quad (2.58b)$$

for each  $s = 1, \dots, S$ . Then we easily derive (2.55b). The Inada conditions ensures that the multiplier  $\lambda(s)$  is strictly positive, hence the intertemporal resource constraint (2.57) holds with equality, and a simplification leads to (2.56).

Finally, I need to verify that the incentive compatibility constraints are actually slack. The expressions in (2.54a) and (2.54b) now become:<sup>19</sup>

$$u(w_1^i(0, s)) \geq u(w_1^i(1, s)), \quad (2.59a)$$

---

<sup>19</sup>The third equation prevents the patient agents from pretending to be impatient, withdrawing at date 1, and storing until date 2.



$$u(w_2^i(1, s)) \geq u(w_2^i(0, s)), \quad (2.59b)$$

$$u(w_2^i(1, s)) \geq u(w_1^i(0, s)). \quad (2.59c)$$

The first two expressions are clearly satisfied, because  $w_1^i(1, s) = w_2^i(0, s) = 0$  and  $u(w)$  is an increasing function. The proof that the third expression holds with a strict inequality comes from the concavity of  $u(w)$  and the Euler equation, as:

$$\frac{u'(w_1^i(0, s))}{u'(w_2^i(1, s))} = \beta \hat{R} > 1, \quad (2.60)$$

where the last inequality holds by assumption. ■

## C Proofs

**Proof of lemma 2.** Attach the multiplier  $\lambda(s)$  to the resource constraint. The first-order conditions are:

$$\begin{aligned} \mathcal{I}^i(s) : \quad & \nu(s)[\pi^i(0, s)u'(\mathcal{I}^i(s)) + \beta R(s)\pi^i(1, s)u'(R(s)\mathcal{I}^i(s))] = \\ & = \lambda(s) \left[ \pi^i(0, s) + \pi^i(1, s) \frac{R(s)}{\hat{R}} \right], \end{aligned} \quad (2.61a)$$

$$R(s) : \quad \nu(s)\beta \sum_i \pi^i(1, s)u'(R(s)\mathcal{I}^i(s))\mathcal{I}^i(s) = \frac{\lambda(s)}{\hat{R}} \sum_i \pi^i(1, s)\mathcal{I}^i(s). \quad (2.61b)$$

Multiply both sides of (2.61a) by  $\mathcal{I}^i(s)$  and sum across  $i$ . Then, use (2.61b) to simplify and derive:

$$\lambda(s) = \frac{\nu(s) \sum_i \pi^i(0, s)u'(\mathcal{I}^i(s))\mathcal{I}^i(s)}{\sum_i \pi^i(0, s)\mathcal{I}^i(s)}. \quad (2.62)$$

Use (2.62) back into (2.61b) to derive the following condition:

$$\frac{\sum_i \pi^i(1, s)\mathcal{I}^i(s)}{\sum_i \pi^i(0, s)\mathcal{I}^i(s)} = \frac{\beta \hat{R} \sum_i \pi^i(1, s)u'(R(s)\mathcal{I}^i(s))\mathcal{I}^i(s)}{\sum_i \pi^i(0, s)u'(\mathcal{I}^i(s))\mathcal{I}^i(s)}. \quad (2.63)$$

The unconstrained optimum in (2.55b) is the solution to the constrained efficient problem. To see that, plug it into (2.63) and check that it is satisfied. The resources are also exhausted. From the Euler equation notice that:

$$\hat{R} > \beta \hat{R} = \frac{u'(\mathcal{I}^P)}{u'(R^P \mathcal{I}^P)} \geq R^P, \quad (2.64)$$

where we used the fact that  $\beta < 1$  and the hypothesis on relative risk aversion.<sup>20</sup> Moreover, rewrite the Euler equation as:

$$f(R) = \frac{u'(\mathcal{I}^P)}{u'(R \mathcal{I}^P)} - \beta \hat{R}. \quad (2.65)$$

Then,  $f(1) = 1 - \beta \hat{R} < 1$  together with the fact that  $f(R)$  is increasing gives the result that  $R^P > 1$ .  $\blacksquare$

**Proof of proposition 1.** Attach multipliers  $\lambda^i$ ,  $\xi^i(s)$  and  $\chi^i(s)$  to the constraints (2.21), (2.22a) and (2.22b), respectively. Split the constraints (2.22c) and (2.22d) into two parts, and assign the multipliers  $\zeta_D^i(s)$  and  $\zeta_M^i(s)$  to the non-negativity constraints of  $D^i(s)$  and  $M^i(s)$ , and the multipliers  $\eta_D^i(s)$  and  $\eta_M^i(s)$  to the upper bounds. The first-order conditions of the program then read:

$$w_1^i(0, s) : \quad \nu(s) \pi^i(0, s) u' \left( w_1^i(0, s) + \frac{w_2^i(0, s)}{\hat{R}} \right) = \pi^i(0, s) \xi^i(s), \quad (2.66a)$$

$$Z^i(s) : \quad \xi^i(s) = \tilde{R}(s) \chi^i(s) - \eta_M^i(s), \quad (2.66b)$$

$$X^i : \quad \lambda^i = \xi^i(s) + \eta_M^i(s), \quad (2.66c)$$

$$Y^i : \quad \lambda^i = \hat{R} \chi^i(s) + \eta_D^i(s), \quad (2.66d)$$

$$D^i(s) : \quad r \xi^i(s) + \zeta_D^i(s) + r \eta_M^i(s) = \hat{R} \chi^i(s) + \eta_D^i(s), \quad (2.66e)$$

$$M^i(s) : \quad \xi^i(s) + \eta_M^i(s) = \chi^i(s) + \zeta_M^i(s). \quad (2.66f)$$

<sup>20</sup>The assumption about relative risk aversion is crucial to show this result. Rewrite  $-\frac{u''(c)c}{u'(c)} \geq 1$  as  $-\frac{u''(c)}{u'(c)} \geq \frac{1}{c}$ . This in turn means that  $-(\log[u'(c)])' \geq (\log[c])'$ . Integrate between  $z_1$  and  $z_2 > z_1$  so as to obtain  $\log[u'(z_1)] - \log[u'(z_2)] \geq \log[z_2] - \log[z_1]$ . Once taken the exponent, the last expression gives  $\frac{u'(z_1)}{u'(z_2)} \geq \frac{z_2}{z_1}$ . If  $z_1 > z_2$ , the inequality is reversed.

The fact that the felicity function  $u(c)$  is increasing, together with the Inada conditions, the equations (2.66a), (2.66c), (2.66d) and the non-negativity of the multipliers  $\eta_D^i(s)$  and  $\eta_M^i(s)$  give that  $\lambda^i > 0$ . Equations (2.66c), (2.66d) and (2.66e) in equilibrium give  $\zeta_D^i(s) = (1 - r)\lambda^i > 0$ , hence  $D^i(s) = 0$  for any state  $s$  and sector  $i$  and  $\eta_D^i(s) = 0$  by complementary slackness. Similarly, the equations (2.66c), (2.66d) and (2.66f) give  $\zeta_M^i(s) = (1 - 1/\hat{R})\lambda^i > 0$ , hence  $M^i(s) = 0$  and  $\eta_M^i(s) = 0$ . As a consequence, both budget constraints at date 1 and 2 are binding, because  $\xi^i(s)$  and  $\chi^i(s)$  are strictly positive. Rewrite the problem of the representative bank in sector  $i$  making use of the incentive compatibility constraint:

$$\max_{I^i(s)} \sum_s \nu(s) [\pi^i(0, s)u(I^i(s)) + \beta\pi^i(1, s)u(\hat{R}I^i(s))], \quad (2.67)$$

subject to  $I^i(s) \leq 1$ , where  $I^i(s)$  is the incentive-compatible present value of the banking contract. Attach the multiplier  $\mu(s)$  to the constraint. The first-order condition reads:

$$\nu(s)\pi^i(0, s)u'(I^i(s)) + \beta\hat{R}\pi^i(1, s)u'(\hat{R}I^i(s)) = \mu(s), \quad (2.68)$$

which gives that  $\mu(s) > 0$  because of the increasing felicity function and of the Inada conditions. This means that  $I^i(s) = 1$ , and (2.27)-(2.28) give the equilibrium final consumption bundles. Finally, notice that the market clearing condition on the hidden asset market can be written as:

$$\sum_i \pi^i(0, s) \frac{w_2^i(0, s)}{\hat{R}} = \sum_i \pi^i(1, s)w_1^i(1, s). \quad (2.69)$$

Consolidate across sectors the budget constraint, and make use of this last expression and the market clearing condition in the interbank market to derive:

$$\sum_i X^i = \sum_i [\pi^i(0, s)w_1^i(0, s) + \pi^i(1, s)w_1^i(1, s) + Z^i(s)] =$$

$$= \sum_i \pi^i(0, s) \left[ w_1^i(0, s) + \frac{w_2^i(0, s)}{\hat{R}} \right] = \Pi(0), \quad (2.70)$$

and by feasibility  $\sum_i Y^i = \Pi(1)$ . ■

**Proof of proposition 2.** I impose  $D^i(s) = M^i(s) = 0$ , and solve the date-0 banking problem:

$$\begin{aligned} \max \sum_s \nu(s) & \left[ \pi^i(0, s) u \left( w_1^i(0, s) + \frac{w_2^i(0, s)}{R(s)} \right) + \right. \\ & \left. + \beta \pi^i(1, s) u(R(s)w_1^i(1, s) + w_2^i(1, s)) \right], \end{aligned} \quad (2.71)$$

subject to:

$$X^i + Y^i = 1, \quad (2.72a)$$

$$X^i = \sum_{\theta} \pi^i(\theta, s) w_1^i(\theta, s) + Z^i(s), \quad (2.72b)$$

$$\hat{R}Y^i + \tilde{R}(s)Z^i(s) = \sum_{\theta} \pi^i(\theta, s) w_2^i(\theta, s), \quad (2.72c)$$

$$X^i \geq F^i, \quad (2.72d)$$

and the incentive compatibility constraint in (2.10). Use (2.72a)-(2.72c) to derive the intertemporal resource constraint:

$$\sum_{\theta} \pi^i(\theta, s) \left[ w_1^i(\theta, s) + \frac{w_2^i(\theta, s)}{\hat{R}} \right] + \left( 1 - \frac{\tilde{R}(s)}{\hat{R}} \right) Z^i(s) = 1. \quad (2.73)$$

Similarly, the minimum liquidity requirement in (2.72d) becomes:

$$\sum_{\theta} \pi^i(\theta, s) w_1^i(\theta, s) + Z^i(s) \geq F^i. \quad (2.74)$$

Apply the following change of variables:

$$\mathbf{I}^i(s) = w_1^i(0, s) + \frac{w_2^i(0, s)}{R(s)}, \quad (2.75)$$

$$\mathbf{H}^i(s) = \sum_{\theta} \pi^i(\theta, s) w_2^i(\theta, s). \quad (2.76)$$

First, I express the objective function in terms of  $\mathbf{I}^i(s)$ :

$$\max_s \sum \nu(s) [\pi^i(0, s) u(\mathbf{I}^i(s)) + \beta \pi^i(1, s) u(R(s) \mathbf{I}^i(s))]. \quad (2.77)$$

Second, I rewrite the constraints of the program in terms of  $\mathbf{I}^i(s)$  and  $\mathbf{H}^i(s)$ . The liquidity requirement in (2.74) becomes:

$$\begin{aligned} & \pi^i(0, s) w_1^i(0, s) + \pi^i(1, s) w_1^i(1, s) + w_1^i(0, s) - w_1^i(0, s) + Z^i(s) = \\ & = w_1^i(0, s) + \pi^i(1, s) (w_1^i(1, s) - w_1^i(0, s)) + Z^i(s) = \\ & = w_1^i(0, s) + \pi^i(1, s) \frac{w_2^i(0, s) - w_2^i(1, s)}{R(s)} + Z^i(s) = \\ & = \left( w_1^i(0, s) + \frac{w_2^i(0, s)}{R(s)} \right) - \frac{\pi^i(0, s) w_2^i(0, s) + \pi^i(1, s) w_2^i(1, s)}{R(s)} + Z^i(s) = \\ & = \mathbf{I}^i(s) - \frac{\mathbf{H}^i(s)}{R(s)} + Z^i(s) \geq F^i. \end{aligned} \quad (2.78)$$

Similarly, the intertemporal budget constraint now reads:

$$\mathbf{I}^i(s) - \mathbf{H}^i(s) \left( \frac{1}{R(s)} - \frac{1}{\hat{R}} \right) + \left( 1 - \frac{\tilde{R}(s)}{\hat{R}} \right) Z^i(s) = 1. \quad (2.79)$$

The problem is to choose  $\{\mathbf{I}^i(s), \mathbf{H}^i(s), Z^i(s)\}$  to maximize the objective function in (2.77), subject to (2.78) and (2.79). Attach the multipliers  $\eta^i$  and  $\xi^i$  to (2.78) and (2.79), respectively. Then, the first-order conditions are:

$$\mathbf{I}^i(s) : \quad \xi^i - \eta^i = \nu(s) [\pi^i(0, s) u'(\mathbf{I}^i(s)) + \beta R(s) \pi^i(1, s) u'(R(s) \mathbf{I}^i(s))], \quad (2.80a)$$

$$\mathbf{H}^i(s) : \quad \frac{\eta^i}{R(s)} = \xi^i \left[ \frac{1}{R(s)} - \frac{1}{\hat{R}} \right], \quad (2.80b)$$

$$Z^i(s) : \quad \eta^i = \xi^i \left( 1 - \frac{\tilde{R}(s)}{\hat{R}} \right). \quad (2.80c)$$

Plug the constrained efficient allocation into the program:

$$\mathbf{I}^i(s) = \mathcal{I}^P, \quad (2.81a)$$

$$\mathbf{H}^i(s) = \pi^i(1, s) R^P \mathcal{I}^P, \quad (2.81b)$$

$$R(s) = R^P. \quad (2.81c)$$

I need to prove that, at the constrained efficient allocation, the multipliers are positive, the FOCs are satisfied and the markets clear for some positive prices. Plug (2.80a) into (2.80b), and use the Euler equation to find:

$$\xi^i \frac{R^P}{\hat{R}} = \nu(s) u'(I^P) \left[ \pi^i(0, s) + \pi^i(1, s) \frac{R^P}{\hat{R}} \right], \quad (2.82)$$

and notice that the RHS is positive, thus also  $\xi^i > 0$ . The multiplier  $\eta^i$  is positive by (2.80b), since  $\xi^i$  is positive and  $R^P < \hat{R}$ . Therefore, the minimum liquidity requirement is a binding constraint. Since we are decentralizing the efficient allocation, it must then be the case that  $\sum_i F^i = \Pi(0) \mathcal{I}^P$ . The proposed minimum liquidity requirement in (2.38) satisfies this requirement, as:

$$\sum_i F^i = \sum_i \sum_k \nu(k) \pi^i(0, k) \mathcal{I}^P = \mathcal{I}^P \sum_k \nu(k) \sum_i \pi^i(0, k) = \Pi(0) \mathcal{I}^P. \quad (2.83)$$

In equilibrium, the amount of bonds traded in the interbank markets is:

$$Z^i(s) = \left[ \sum_k \nu(k) \pi^i(0, k) - \pi^i(0, s) \right] \mathcal{I}^P, \quad (2.84)$$

thus  $\sum_i Z^i(s) = 0$ . From (2.80b) and (2.80c),  $\tilde{R}(s) = R^P$  in each state. ■

## Chapter 3

# Financial Liberalization with Hidden Trades\*

### 3.1 Introduction

Both the theory and the practice of economics tell us that financial integration is good: it allows a better diversification of risk, increases competition, spreads the returns from the comparative advantages and enhances economies of scale. Nevertheless, as highlighted by the IMF (Abiad et al., 2008), after the peaks of the nineties, financial integration around the world has come to a halt, both in developing and developed countries. The resistances, especially at the national level, against a banking union in the EU only constitute the last example of the difficulties that the process of financial integration has recently encountered. The aim of the present work is to offer a possible explanation to this phenomenon.

The story that I have in mind is one where financial integration affects the equilibrium prices of all those market-based unregulated channels for the circulation of liquidity that have developed as a consequence of

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financial liberalization and capital mobility, thus creating winners and losers from integration, and hindering further expansions.

To formalize this intuition, I develop a model of financial intermediation, where financial intermediaries (or, more commonly, banks) provide insurance to their customers against the realization of a private idiosyncratic shock, which affects their liquidity needs and makes them either patient or impatient to consume (as in Diamond and Dybvig, 1983). For this purpose, the banks collect deposits, invest in a long-term asset and in a storage technology (which is equivalent to liquidity), and sign a contract with their customers that states how much they are allowed to withdraw in the future, depending on the realization of their idiosyncratic liquidity needs.

I extend this framework in two directions. First, I assume that the world is divided into two countries, labeled Home (H) and Foreign (F), that have different investment technologies: Foreign has a higher yield on the long-term asset than Home. This means that Home has a comparative advantage in the storage technology, as the opportunity costs of holding liquidity versus the long-term asset is lower than in Foreign, and Foreign has a comparative advantage in the long-term asset. This difference can stem from different regulatory environments, or different production technologies that are available in the two countries, and is introduced to rationalize the need for financial integration.

As a second extension, I instead introduce the possibility for bank depositors to trade in a hidden market. That is, the agents can borrow and lend among themselves without being observed by their banks, by issuing or buying a bond whose return is determined in equilibrium (and is, in all effects, equivalent to the interest rate of the economy). The unobservability of these trades is a standard way of introducing the concept of “non-exclusivity” of the financial contracts, and is a plausible assumption for two main reasons: first, because it is difficult to imagine that a bank can preclude its customers from contacting other intermediaries, or make its contracts contingent on that; second, because, in this way, I introduce in the model all those institutions, markets and instruments



that financial liberalization and capital mobility have made available to the individual investors to bypass the traditional banking system in an anonymous way, and that have been generally labeled “new financial intermediaries” or, with a somewhat negative connotation, “shadow banking system”.

In the present environment, the non-exclusivity implies that the terms of the banking contract, by the Revelation Principle, must satisfy an incentive compatibility constraint: the present value of the consumption bundle that each depositor is entitled to receive by her bank (evaluated at the equilibrium interest rate on the hidden bond) must be independent of the realization of the individual idiosyncratic shock, so that no agent has incentives to misreport her liquidity need. This means that, in a competitive equilibrium, the presence of the hidden markets imposes a burden on the banks, which see their choice sets curbed by such a constraint (which always binds). I will distinguish four different cases, depending on whether the banking systems and the hidden markets of the two countries are integrated or not, and characterize the competitive equilibrium with hidden trades in all of them.

My first result shows that, when the banking systems of the two countries are not integrated, cross-country borrowing and lending among the depositors, despite being unobservable, do increase welfare with respect to complete autarky: this is because the banks cannot observe the behavior of their customers, but know that they can exchange resources across countries. Thus, they specialize in the asset in which they hold the comparative advantage (the storage technology for Home, and the long-term asset for Foreign) and let the depositors retrade and enjoy the gains from “hidden” financial integration.

More interestingly, I show that the availability of hidden trading opportunities halts the process of integration in the banking system. The intuition for this result is the following: in order to coordinate, the two countries need to both agree that integration is welfare-improving with respect to autarky. On one side, when the two banking systems are in autarky, but the agents are allowed to trade internationally, the banks

in both countries specialize their portfolios in the asset in which they hold a comparative advantage. Then, demand and supply pin down the equilibrium interest rate in the hidden market, which must lie between the two country-specific returns on the long-term assets, for the market to clear. On the other side, in the equilibrium where the two banking systems are also integrated, all banks can invest in the long-term asset of Foreign (as it yields a higher return), and the equilibrium interest rate in the hidden market must equal this, because there must be no arbitrage opportunities between the official banking system and the hidden market. Thus, the move from financial autarky to integration, in the presence of already-integrated hidden markets, generates an increase in the interest rate, which has a different effect on the welfare of the two countries: Home, i.e. the country specializing in liquidity, is better off, because its intertemporal terms of trade have improved (they lend liquidity at a higher rate of return); Foreign, i.e. the country specializing in the long-term asset, is instead worse off, because its intertemporal terms of trade have worsened (they are borrowing liquidity at a higher rate of return). Put differently, financial integration is not welfare-improving for the whole economy, but creates a winner and a loser country, depending on their comparative advantages. The necessary agreement to coordinate financial integration breaks off.

In the second part of the paper, I analyze the constrained-efficiency of the competitive equilibrium. In that respect, the crucial assumption is that a social planner can collect the endowments of the agents in the economy, and choose the best allocation to maximize their welfare, but takes as given the level of integration of the banking systems and of the hidden markets, and must satisfy the incentive compatibility constraint as the banks do. In this environment, I show that, when cross-country hidden trades are forbidden, or when both the banking system and the hidden markets are perfectly integrated, the planner is able to improve the market allocation and offer a contract equivalent to the first best: she compresses the ex post income profiles of the agents, by cross-subsidizing the consumption of those in liquidity need, and ensures that the alloca-

tion is incentive-compatible by imposing a wedge between the return on the long-term asset and the return on the hidden bond.

In contrast, when the two official banking systems are not integrated, but international hidden trades are possible, the planner cannot improve the welfare of the agents above the level provided by the banks in the competitive equilibrium. In other words, the competitive equilibrium is constrained-efficient. Intuitively, this is because the planner, who cannot transfer the endowments of the economy from one country to the other, sets a contract such that the agents have incentives to retrade, and exploits the gains from hidden financial integration, as the banks do. This is an important result for two reasons: first, because it disproves the classical result of Jacklin (1987) and Allen and Gale (2004) who show that the possibility for agents to trade in the market distorts the efficiency of the banking equilibrium in Diamond-Dybvig environments; second, because, at all other levels of financial integration, the differences between the competitive banking equilibria and the corresponding constrained efficient allocations provide the rationale for the introduction of minimum liquidity requirements. However, when the two banking systems are separated, and cross-country hidden trades are allowed, there is no way through which the decentralized equilibrium can be improved by regulation.

The rest of the paper is organized as follows. In section 3.2, I summarize the literature related to the present work. In section 3.3, I describe the environment, and characterize the equilibrium in a closed economy. In section 3.4, I extend the analysis to the two-country case and analyze the interactions between the possibility of hidden trades and the process of financial liberalization. In section 3.5, I characterize the constrained efficient allocation of both the closed economy and the two-country case, which I use as terms of comparison to study optimal regulation in section 3.6. Finally, in section 3.7, I conclude the paper.

### 3.2 Related Literature

The present paper mainly contributes to the literature that studies the limits of financial integration. Starting from the observation of Obstfeld and Taylor (2004) that financial globalization is primarily confined to rich countries, Mishkin (2007) lists many different reasons why financial globalization has not spread in less developed countries, mostly connected to the presence of information asymmetries that the institutional framework is not able to eliminate. However, most of the literature explains that financial integration has not developed because it can have adverse consequences on global imbalances (Mendoza et al., 2009), or because it exacerbates the contagion of systemic risk (Fecht and Gruner, 2005; Fecht et al., 2012) and aggregate shocks (Allen and Gale, 2000; Castiglionesi et al., 2010). Here, I take a different stance, and instead show how financial integration can have negative welfare effects, even in the absence of shocks or contagion.

To this end, I take as a starting point the workhorse model for the positive and normative analysis of financial intermediation developed by Diamond and Dybvig (1983), where the existence of financial intermediation is fully-microfounded as a way of decentralizing the constrained efficient allocation of risk in an economy with private idiosyncratic liquidity shocks. Jacklin (1987) is the first to address the issue of how the possibility for agents to engage in market trades limits the efficiency of the banking equilibrium in these environments. More recently, Farhi et al. (2009) analyze the same concepts in a mechanism-design framework, and rationalize the imposition of minimum liquidity requirements as a way of implementing the constrained efficient outcome in decentralized environments. Here, I extend their work to a two-country environment with comparative advantages and, in contrast to their findings, I show that the presence of hidden markets does not always hinder the (constrained) efficiency of the competitive banking equilibrium.

More generally, the present work contributes to the literature on the interactions between non-exclusivity of financial contracts and risk shar-

ing. Bisin and Guaitoli (2004) study an environment where the banks sign non-exclusive contracts with their customers, who are subject to moral hazard due to the unobservability of their actions. Castiglionesi and Wagner (2013) instead analyze the efficiency of the market allocation in an environment where the banks mutually insure against the realization of some idiosyncratic shock as an outcome of bilateral (and non-exclusive) contracting.

### 3.3 A Closed Economy

To understand the basic features of the environment that I am going to extend in the next section, I here characterize the equilibrium of a closed economy. The basic structure of the environment is similar to the Farhi et al. (2009) version of the Diamond and Dybvig (1983) model of financial intermediation.

#### 3.3.1 Preferences and Technology

The economy lasts for three periods, labeled  $t = 0, 1, 2$ , and is populated by a unitary continuum of ex ante identical agents, who are born at date 0 with an equal endowment  $e = 1$ .

All agents in the economy are affected by some idiosyncratic uncertainty, which hits them in the form of a preference shock. Being ex-ante equal, in  $t = 1$  every agent draws a type  $\theta \in \{0, 1\}$  which is private information to herself:  $\pi > 0$  is the probability of being of type 0, and  $(1 - \pi)$  is the probability of being of type 1. The preference shocks are independent and identically distributed across agents so that, by the law of large numbers, the cross-sectional distribution of the types is equivalent to their probability distribution:  $\pi$  and  $(1 - \pi)$  are the fractions of agents who turn out to be of type 0 and type 1, respectively. The role of the individual types is to affect the point in time at which the agents enjoy consumption. This happens according to the utility function  $U(c_1, c_2, \theta) = (1 - \theta)u(c_1) + \beta\theta u(c_2)$ . Clearly, if  $\theta = 0$ , the agent is

willing to consume only at date 1, while if  $\theta = 1$  she will consume only at date 2. As is customary in this line of research, I then refer to type-0 and type-1 agents as “early” (or impatient) and “late” (or patient) consumers, respectively. The felicity function  $u(c)$  is assumed to be increasing, concave, and satisfying the Inada conditions. Moreover, the coefficient of relative risk aversion  $-u''(c)c/u'(c)$  is larger than or equal to 1.

Two assets are available in the economy, which can be used to hedge against the idiosyncratic uncertainty. In line with the literature, I call “short asset” a storage technology, yielding 1 unit of consumption at  $t + 1$  for each unit invested in  $t$ . The other asset, that I call “long”, instead delivers  $\hat{R} > 1$  (with  $\beta\hat{R} > 1$ ) units of consumption in  $t = 2$  for each unit invested in  $t = 0$ , and can be interpreted as the marginal rate of transformation of a production technology. The short asset is “liquid”, as it provides a way of moving resources from one period to the following. The long asset instead cannot be liquidated before maturity, so it is “illiquid”.<sup>1</sup>

The economy is also populated by a large number of banks, which operate in a perfectly competitive market with free entry. At date 0 (i.e. before the realization of the private idiosyncratic shock), the agents deposit their endowments in the banks, and sign a contract with them.<sup>2</sup> The contract states the amount of consumption goods that the customers are entitled to withdraw at date 1 and 2, depending on their types. I define the banking contract as  $C(\theta) = \{c_1(\theta), c_2(\theta)\}$ , and label  $X$  and  $Y$  the amounts of short and long assets that the banks hold at date 0, respectively. A banking contract is feasible if:

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<sup>1</sup>A general feature of the Diamond-Dybvig framework is the presence of a “liquidation technology”, which can be employed to throw away the long asset and create extra liquidity, often at a cost. In this paper, I rule this out for simplicity, as the banks would never find it convenient to use the liquidation technology to finance early consumption.

<sup>2</sup>In their original contribution, Diamond and Dybvig (1983) prove that the banking contract is strictly preferred to a market allocation, where each agent chooses her own portfolio of assets, and then trades the long asset at date 1, after the realization of the idiosyncratic shock.

$$\pi \left[ c_1(0) + \frac{c_2(0)}{\hat{R}} \right] + (1 - \pi) \left[ c_1(1) + \frac{c_2(1)}{\hat{R}} \right] \leq 1. \quad (3.1)$$

In the environment described so far, a social planner would solve:

$$\max_{\{c_1(\theta), c_2(\theta)\}_{\theta \in \{0,1\}}} \pi u(c_1(0)) + \beta(1 - \pi)u(c_2(1)), \quad (3.2)$$

subject to the feasibility constraint (3.1) and the incentive compatibility constraints:

$$c_1(0) \geq c_1(1), \quad (3.3a)$$

$$c_2(1) \geq c_2(0), \quad (3.3b)$$

$$c_2(1) \geq c_1(0). \quad (3.3c)$$

Remember that the realizations of the idiosyncratic types are private information. Then, by the Revelation Principle, we can focus on truth-telling mechanisms where each agent has incentives to truthfully report her liquidity need: a type-0 agent must have no incentives to report being a type-1 (equation (3.3a)), and a type-1 agent must have no incentives to report being a type-0 (equation (3.3b)), which also includes the possibility of pretending to be impatient, getting  $c_1(0)$ , and storing the early consumption for the following period (equation (3.3c)).

Diamond and Dybvig (1983) show that, at the optimum, the incentive compatibility constraints are all slack, and that the constrained efficient allocation is equivalent to the first best:

$$u'(c_1(0)) = \beta \hat{R} u'(c_2(1)), \quad (3.4a)$$

$$\pi c_1(0) + (1 - \pi) \frac{c_2(1)}{\hat{R}} = 1, \quad (3.4b)$$

$$c_1(1) = c_2(0) = 0. \quad (3.4c)$$

The planner chooses a feasible contract such that the marginal rate of substitution between the early and the late consumption is equal to the marginal rate of transformation of the production technology. Moreover,

the fact that the degree of relative risk aversion is larger than or equal to 1 implies that:<sup>3</sup>

$$\beta \hat{R} = \frac{u'(c_1(0))}{u'(c_2(1))} \geq \frac{c_2(1)}{c_1(0)}, \quad (3.5)$$

hence  $c_2(1) < \hat{R}c_1(0)$  since  $\beta < 1$ . Using this result in the feasibility constraint, we find that:

$$c_1(0) > \pi c_1(0) + (1 - \pi) \frac{c_2(1)}{\hat{R}} = 1, \quad (3.6)$$

and therefore  $c_2(1)/\hat{R} < 1$ . This result states that, in the first best, the planner offers optimal insurance against the idiosyncratic shock by cross-subsidizing the impatient agents. For this purpose, the planner compresses the distribution of the ex post income profile of the agents: those who turn out to be impatient receive more than their endowment at date 1, while those who turn out to be patient receive less than their environment (in present value) at date 2.

### 3.3.2 The Hidden Market

I extend this environment by allowing the agents to engage in hidden trades at  $t = 1$ , after the idiosyncratic shock has been revealed to them. I model this feature of the economy as unobservable exchanges, through which individual depositors can anonymously borrow and lend an amount  $b(\theta)$  of uncontingent bonds yielding a “hidden” interest rate  $R$ , to be determined in equilibrium. Notice two things. First, the fact that agents trade only uncontingent bonds is not an a priori restriction on the completeness of the market, but an endogenous feature of the environment, as I show in Appendix A. Second, the results proposed here hinge neither on the fact that the banks cannot access this market

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<sup>3</sup>The assumption about relative risk aversion is crucial for this result. Rewrite  $-\frac{u''(c)c}{u'(c)} \geq 1$  as  $-\frac{u''(c)}{u'(c)} \geq \frac{1}{c}$ . This, in turn, means that  $-(\log[u'(c)])' \geq (\log[c])'$ . Integrate between  $z_1$  and  $z_2 > z_1$  so as to obtain  $\log[u'(z_1)] - \log[u'(z_2)] \geq \log[z_2] - \log[z_1]$ . Once taken the exponential, the last expression gives  $\frac{u'(z_1)}{u'(z_2)} \geq \frac{z_2}{z_1}$ . If  $z_1 > z_2$ , the inequality is reversed.



themselves nor on the date when the market opens, but only on the fact that the depositors can borrow and lend without being observed, while the activities of the banks are perfectly observable.

I formalize the problem faced by the agents in the hidden market in the following way. The agents take their decisions to borrow or lend at date 1. In doing so, they take as given the banking contract  $C(\theta)$  that they signed with the representative bank in the previous period, the interest rate  $R$  (because they are price-takers), and the realization of their idiosyncratic types. Then, the problem in the hidden market reads:<sup>4</sup>

$$V(C(\theta), R, \theta) = \max_{x_1(\theta), x_2(\theta), \theta'(\theta), b(\theta)} U(x_1(\theta), x_2(\theta), \theta), \quad (3.7)$$

subject to:

$$x_1(\theta) = c_1(\theta'(\theta)) + b(\theta), \quad (3.8)$$

$$x_2(\theta) = c_2(\theta'(\theta)) - Rb(\theta). \quad (3.9)$$

Given the state variables, the agents decide which type  $\theta'(\theta)$  to report to the banking sector (which will affect the amount of resources available for trade), the final consumption bundle  $\{x_1(\theta), x_2(\theta)\}$  actually consumed in the two periods, and the amount  $b(\theta)$  (which can be positive or negative) to borrow or lend in the hidden market, so as to maximize their welfare, subject to the budget constraints.

The environment described so far is a complex game of asymmetric information between the banks and their depositors. However, by the Revelation Principle, we can concentrate on truth-telling mechanisms, where the agents have incentives to reveal their true individual types to the banks. The incentive compatibility constraint can then be defined in the following way:

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<sup>4</sup>To simplify the notation, I explicitly write the final consumption allocation, the reported types and the bond trades only as functions of the realization of the idiosyncratic types  $\theta$ , but formally they also depend on the contract  $C(\theta)$  and the equilibrium interest rate  $R$ .

**Definition 4.** A banking contract  $C(\theta)$  is incentive-compatible if:

$$V(C(\theta), R, \theta) \geq V(C(\theta'), R, \theta) \quad (3.10)$$

for any  $\theta, \theta' \in \{0, 1\}$  with  $\theta \neq \theta'$ .

The incentive compatibility constraint states that each agent should get a higher welfare by reporting her true type than by reporting the other one and retrade but, given the presence of only two types, this can be simplified. Rewrite the problem as:

$$V(C(\theta), R, \theta) = \max_{x_1(\theta), x_2(\theta), \theta'(\theta)} U(x_1(\theta), x_2(\theta), \theta), \quad (3.11)$$

$$s.t. \quad x_1(\theta) + \frac{x_2(\theta)}{R} = c_1(\theta'(\theta)) + \frac{c_2(\theta'(\theta))}{R}. \quad (3.12)$$

For type 0 and 1, the incentive compatibility reads, respectively:

$$V(C(0), R, 0) \geq V(C(1), R, 0), \quad (3.13)$$

$$V(C(1), R, 1) \geq V(C(0), R, 1), \quad (3.14)$$

which can be rewritten as:

$$u\left(c_1(0) + \frac{c_2(0)}{R}\right) \geq u\left(c_1(1) + \frac{c_2(1)}{R}\right), \quad (3.15)$$

$$u(Rc_1(1) + c_2(1)) \geq u(Rc_1(0) + c_2(0)), \quad (3.16)$$

because  $x_2(0) = x_1(1) = 0$ . Thus, it is easy to see that a banking contract  $C(\theta)$  is incentive-compatible if:

$$c_1(0) + \frac{c_2(0)}{R} = c_1(1) + \frac{c_2(1)}{R}. \quad (3.17)$$

Truth-telling requires the banking contract to entitle the depositors to the same present value of consumption, evaluated at the interest rate on the hidden bond, regardless of the realization of the idiosyncratic uncertainty.

### 3.3.3 The Banking Problem

In the following, I focus my attention on pure strategy symmetric equilibria, where the banks share the same investment strategy. Therefore, without loss of generality, I can restrict myself to the analysis of a representative bank. The problem of the representative bank, given the assumptions of perfect competition and free entry, is to maximize the expected welfare of its customers:

$$\max_{\{c_1(\theta), c_2(\theta)\}_{\theta \in \{0,1\}}} \pi V(C(0), R, 0) + \beta(1 - \pi)V(C(1), R, 1), \quad (3.18)$$

subject to the intertemporal budget constraint:

$$\pi \left( c_1(0) + \frac{c_2(0)}{\hat{R}} \right) + (1 - \pi) \left( c_1(1) + \frac{c_2(1)}{\hat{R}} \right) \leq 1, \quad (3.19)$$

and the incentive compatibility constraint (3.17). The definition of a competitive banking equilibrium is straightforward:

**Definition 5.** *Given an endowment  $e = 1$  for each agent and a probability distribution  $\pi$  for the idiosyncratic shock, a competitive banking equilibrium with hidden markets is a contract  $C(\theta) = \{c_1(\theta), c_2(\theta)\}$ , a final consumption allocation  $\{x_1(\theta), x_2(\theta)\}$ , an interest rate  $R$  and an amount of hidden bonds  $\{b(\theta)\}$  for every type  $\theta \in \{0, 1\}$ , such that:*

- *for a given interest rate and contract, the final consumption allocation solves the problem in the hidden market (3.7), for every type;*
- *the contract solves the banking problem (3.18);*
- *markets clear:*

$$\pi \left( c_1(0) + \frac{c_2(0)}{\hat{R}} \right) + (1 - \pi) \left( c_1(1) + \frac{c_2(1)}{\hat{R}} \right) = 1, \quad (3.20)$$

$$\pi b(0) + (1 - \pi)b(1) = 0. \quad (3.21)$$

### 3.3.4 Timing

Before proceeding, it is useful to summarize the timing of actions and events: at date 0, each agent deposits her endowment into the banks, hence the total deposits are equal to 1. The banks set up an incentive-compatible contract with their depositors, entitling them to an amount of real consumption at date 1 and 2, and decide the portfolio allocation between the short and the long asset. At  $t = 1$ , all uncertainty is resolved: each agent gets to know her private type and, according to the report that she makes to the bank, receives an amount  $c_1(\theta)$  of the consumption good. After the withdrawal, the agents engage in side trades in the hidden market. Finally, at  $t = 2$  the agents receive  $c_2(\theta)$ , and their return on the hidden investment.

### 3.3.5 Competitive Equilibrium

To characterize the equilibrium of this economy, I go by backward induction. In the hidden market, the equilibrium interest rate  $R$  must be equal to the marginal rate of transformation  $\hat{R}$ . The rationale for this result is the following: if  $R < \hat{R}$ , the long asset dominates the short asset, and the banks invest all their deposits in the first one only, and let the depositors trade in the hidden market; but the impatient agents would be willing to borrow, while nobody would be there to lend, thus the equilibrium return would go to infinity, which is a contradiction. Similar lines of reasoning rule out the possibility that  $R > \hat{R}$ : if that were the case, the short asset would dominate the long asset, and the banks would invest only in liquidity. Then, the patient agents would be willing to lend  $c_1(1)$  in the hidden market, but they would not find any borrower, hence the interest rate  $R$  would go to 1, which is once more a contradiction.

With this result in hand, I can characterize the problem in the hidden market. A type-0 agent takes as given the banking contract  $\{c_1(\theta), c_2(\theta)\}$  and the interest rate  $R = \hat{R}$ , and solves:

$$\max u(x_1(0)), \tag{3.22}$$

subject to the budget constraints:

$$x_1(0) = c_1(0) + b(0), \quad (3.23a)$$

$$x_2(0) = c_2(0) - \hat{R}b(0). \quad (3.23b)$$

Notice that I am implicitly saying that the banking contract is incentive-compatible, so every agent reports her correct type:  $\theta'(0) = 0$ , and  $\theta'(1) = 1$ . A type-0 agent chooses  $x_2(0) = 0$ , because she does not enjoy utility from consuming at date 2, so it must be the case that  $b(0) = c_2(0)/\hat{R}$ , and  $x_1(0) = c_1(0) + c_2(0)/\hat{R}$ . In a similar way, a type-1 agent solves:

$$\max \beta u(x_2(1)), \quad (3.24)$$

subject to the budget constraints:

$$x_1(1) = c_1(1) + b(1), \quad (3.25a)$$

$$x_2(1) = c_2(1) - \hat{R}b(1). \quad (3.25b)$$

Thus, she chooses  $x_1(1) = 0$ , so that  $b(1) = -c_1(1)$ , and  $x_2(1) = \hat{R}c_1(1) + c_2(1)$ . These results imply that the hidden market clears if the total supply of bonds from the  $\pi$  impatient agents is equal to the total demand of bonds from the  $(1 - \pi)$  patient agents, or:

$$\pi \frac{c_2(0)}{\hat{R}} = (1 - \pi)c_1(1). \quad (3.26)$$

The representative bank at date 0 takes into account what the depositors choose at date 1, and solves:

$$\max \pi u \left( c_1(0) + \frac{c_2(0)}{\hat{R}} \right) + \beta(1 - \pi)u(\hat{R}c_1(1) + c_2(1)), \quad (3.27)$$

subject to the intertemporal budget constraint (3.19) and the incentive compatibility constraint (3.17). Define the incentive-compatible present value of consumption as  $I$ . Using the incentive compatibility constraint in the objective function and in the budget constraint, the problem now

reads:

$$\max_I \pi u(I) + \beta(1 - \pi)u(\hat{R}I), \quad (3.28)$$

subject to  $I \leq 1$ . Attach the Lagrange multiplier  $\lambda$  to the budget constraint. The first-order condition with respect to  $I$  gives the equilibrium value of the Lagrange multiplier:

$$\lambda = \pi u'(I) + \beta \hat{R}(1 - \pi)u'(\hat{R}I), \quad (3.29)$$

which is strictly positive because the felicity function  $u(c)$  is increasing and satisfies the Inada conditions. Therefore, by complementary slackness, the budget constraint is binding, which implies:

$$c_1(0) + \frac{c_2(0)}{\hat{R}} = c_1(1) + \frac{c_2(1)}{\hat{R}} = 1. \quad (3.30)$$

The system of equations consisting of (3.26) and (3.30) characterizes the solution to the banking problem: the equilibrium contract is undetermined, since this is a system of three equations in four unknowns.<sup>5</sup> Nevertheless, the final consumption bundle is determined by the type-0 and type-1 problems in (3.22) and (3.24), respectively:

$$x_1(0) = c_1(0) + \frac{c_2(0)}{\hat{R}} = 1, \quad (3.31a)$$

$$x_2(1) = \hat{R}c_1(1) + c_2(1) = \hat{R}, \quad (3.31b)$$

$$x_2(0) = x_1(1) = 0. \quad (3.31c)$$

This last result, together with the market clearing condition (3.26) for the hidden market, allows me to further characterize the bank portfolio allocation between the short and long assets, since:

$$X = \pi c_1(0) + (1 - \pi)c_1(1) = \pi c_1(0) + \pi \frac{c_2(0)}{\hat{R}} = \pi, \quad (3.32)$$

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<sup>5</sup>The solution proposed, among the others, by Farhi et al. (2009), where  $c_1(1) = c_2(0) = 0$ ,  $c_1(0) = 1$  and  $c_2(1) = \hat{R}$ , is one of the many possible solutions. In particular, it is the “no-retrade” contract, where the depositors directly get the incentive-compatible outcome of the hidden trades from the banks.

and  $Y = 1 - X = 1 - \pi$ . I summarize the results in the following proposition:

**Proposition 4.** *The competitive banking equilibrium in a closed economy is characterized by the final consumption allocation:*

$$x_1(0) = 1, \quad x_2(1) = \hat{R}, \quad (3.33a)$$

$$x_2(0) = 0, \quad x_1(1) = 0; \quad (3.33b)$$

the return on the hidden bond  $R = \hat{R}$ , and the bond trading:

$$b(0) = \frac{c_2(0)}{R}, \quad (3.34)$$

$$b(1) = -c_1(1). \quad (3.35)$$

The banking contract must satisfy:

$$c_1(0) + \frac{c_2(0)}{\hat{R}} = c_1(1) + \frac{c_2(1)}{\hat{R}} = 1, \quad (3.36)$$

$$\pi \frac{c_2(0)}{\hat{R}} = (1 - \pi)c_1(1), \quad (3.37)$$

and is undetermined. The bank portfolio allocation is  $X = \pi$  and  $Y = 1 - \pi$ .

The intuition for this result is the following: in equilibrium, the banks must be ex ante indifferent between the “official” banking channel and the hidden market. Therefore, the interest rate on the hidden bond  $R$  is equal to the return on the long asset  $\hat{R}$ , and the bank asset portfolio is undetermined. Nevertheless, this result, together with the incentive compatibility constraint and the binding intertemporal budget constraint, obliges them to set up a contract such that the present value of the consumption bundle that each agent receives (evaluated at the marginal rate of transformation) is independent of the realization of the idiosyncratic type, and equal to the initial endowment. As a consequence, the share of deposits  $X$  invested in the short asset is exactly equal to the fraction of depositors  $\pi$  in liquidity need.

### 3.4 A Two-Country Economy

In order to study how the presence of hidden channels for the circulation of liquidity affects the process of financial liberalization, in this section I extend the previous environment to a two-country world.

The economy is divided into two countries of equal dimension, that I label Home (H) and Foreign (F). The agents in the two countries are all *ex ante* equal, in the sense that they all have the same endowment and face the same probability  $\pi$  of being an early consumer. However, the banks have access to two different sets of technologies to hedge against the idiosyncratic risk: the short assets in both countries yield 1 unit of consumption at  $t + 1$  for each unit invested in  $t$ , but the two long assets deliver a country-specific amount of consumption  $\hat{R}^i$  in  $t = 2$  for each unit invested in  $t = 0$ , with  $\hat{R}^F > \hat{R}^H > 1$ . A way of rationalizing this assumption is to think that the two countries face different regulatory environments, or have access to different production technologies. In this respect, we can interpret the returns on the long assets as the opportunity costs of holding liquidity, thus  $\hat{R}^F > \hat{R}^H$  means that Home has a comparative advantage in the liquid technology, while Foreign has a comparative advantage in the long asset.

In what follows, I compare four different environments, which reflect all possible combinations of the different levels of integration in the banking system (BS) and the hidden market (HM), that I take as exogenous: I allow the agents to trade either in a domestic or in an international hidden market and, similarly, the two banking systems to be integrated or not. The different levels of integration in the banking system reflect the ability of the banks in each country to invest in the technology of the other country.

Clearly, the case #1 (autarkic banking systems and domestic hidden markets) is the two-country version of the closed economy that I analyzed in the previous section. In the three remaining cases, instead, the two countries integrate, in the sense that the interest rates are equalized across countries. However, the channel through which this equalization



Table 3.1: The Different Levels of Market Integration

	Domestic HM	International HM
Autarkic BS	Case #1	Case #4
Integrated BS	Case #2	Case #3

is achieved matters in terms of welfare and, in turn, for the level of integration that the two countries are able to coordinate.

### 3.4.1 Case #2: Integrated BS and Domestic HM

In this environment, the two hidden bond markets are local, in the sense that the individual depositors cannot borrow and lend among themselves across the border, but only with other agents in the same country. However, the two banking systems are integrated, which means that, given my assumption that  $\hat{R}^H < \hat{R}^F$ , the representative bank in Home can also invest in the long asset of Foreign. The definition of the competitive banking equilibrium changes accordingly, and takes into account the different ways in which the markets must clear:

**Definition 6.** *Given an endowment  $e = 1$  for each agent and a probability distribution  $\pi$  for the idiosyncratic shock, a competitive banking equilibrium with integrated banking systems and domestic hidden markets is a contract  $C^i(\theta) = \{c_1^i(\theta), c_2^i(\theta)\}$ , a final consumption allocation  $\{x_1^i(\theta), x_2^i(\theta)\}$ , an interest rate  $R^i$  and an amount of hidden bonds  $b^i(\theta)$  for every type  $\theta \in \{0, 1\}$  and country  $i = H, F$ , such that:*

- for a given interest rate and contract, the final consumption allocation solves the problem in the hidden market (3.7), for every type in every country;
- the contract solves the banking problem (3.18), in every country;
- markets clear in every country:

$$\pi \left( c_1^i(0) + \frac{c_2^i(0)}{\hat{R}^i} \right) + (1 - \pi) \left( c_1^i(1) + \frac{c_2^i(1)}{\hat{R}^i} \right) = 1; \quad (3.38)$$

- the bond market clears in every country:

$$\pi b^i(0) + (1 - \pi)b^i(1) = 0. \quad (3.39)$$

Following the same logic that I exploited in the closed-economy case, I argue that, in equilibrium, the country-specific interest rate  $R^i$  must be equal, in both countries, to the marginal rate of transformation  $\hat{R}^F$  of the technology of Foreign, so that the representative banks are ex ante indifferent between investing in the short asset and in the long asset of that country.

This result makes the case #2 similar to the closed economy, with the only exception of the availability of the foreign technology for the Home country. In equilibrium, the present value of the consumption bundle that each type in each country receives, evaluated at the marginal rate of transformation, must be the same, and equal to the initial deposit. Moreover, the amount of resources invested in the liquid asset is again equal to the fraction of depositors who turn out to be impatient, or  $X^i = \pi$ . I summarize the equilibrium in the following proposition:

**Proposition 5.** *The competitive banking equilibrium with integrated banking systems and domestic hidden markets is characterized by the final consumption bundles:*

$$x_1^i(0) = 1, \quad x_2^i(1) = \hat{R}^F, \quad (3.40a)$$

$$x_2^i(0) = 0, \quad x_1^i(1) = 0; \quad (3.40b)$$

the interest rate on the hidden bonds  $R^i = \hat{R}^F$  and the bond trading:

$$b^i(0) = \frac{c_2^i(0)}{R^i}, \quad b^i(1) = -c_1^i(1), \quad (3.41)$$

in every country  $i = H, F$ . The banking contracts must satisfy:

$$c_1^i(0) + \frac{c_2^i(0)}{\hat{R}^F} = c_1^i(1) + \frac{c_2^i(1)}{\hat{R}^F} = 1, \quad (3.42)$$

$$\pi \frac{c_2^i(0)}{\hat{R}^F} = (1 - \pi)c_1^i(1), \quad (3.43)$$

in every country, and is undetermined. The bank portfolio allocations are  $X^i = \pi$  and  $Y^i = 1 - \pi$  in every country  $i = H, F$ .

### 3.4.2 Case #3: Integrated BS and International HM

In this third case, both the banking systems and the hidden bond markets of the two countries are integrated. This means that, as before, the banks in Home can invest in the high-yield technology of Foreign, while the depositors can also exchange resources across the border without being observed. Thus, the only change in the definition of the equilibrium from the previous case lies in the clearing condition in the bond market, which now reads:

$$\sum_{i=H,F} [\pi b^i(0) + (1 - \pi)b^i(1)] = 0. \quad (3.44)$$

Following the same reasoning as in the previous sections, in equilibrium the (unique) interest rate  $R$  on the hidden bond must be equal to the marginal rate of transformation of the integrated economy,  $\hat{R}^F$ . The problem in the hidden markets also yields the same results as before, so for a type-0 agent  $x_2^i(0) = 0$ ,  $b^i(0) = c_2^i(0)/R$ , and  $x_1^i(0) = c_1^i(0) + c_2^i(0)/\hat{R}^F$ , while for a type-1 agent  $x_1^i(1) = 0$ ,  $b^i(1) = -c_1^i(1)$ , and  $x_2^i(1) = \hat{R}^F c_1^i(1) + c_2^i(1)$ . This means that the final consumption bundle will be the same as in case #2, i.e. such that the present value that each type in each country receives, evaluated at the marginal rate of transformation, is the same, and equal to the initial deposit. However, the clearing condition in the bond market does not characterize the bank portfolio allocation in each country, but only the total amount of resources invested in liquidity in the whole economy. To see this, notice that (3.44) can be rewritten as:

$$(1 - \pi)c_1^H(1) + (1 - \pi)c_1^F(1) = \pi \frac{c_2^H(0)}{\hat{R}^F} + \pi \frac{c_2^H(0)}{\hat{R}^F}. \quad (3.45)$$

Thus, we can derive the equilibrium world amount of short assets as:

$$\begin{aligned} X^W &= \pi c_1^H(0) + \pi c_1^F(0) + (1 - \pi)c_1^H(1) + (1 - \pi)c_1^F(1) = \\ &= \pi \left[ c_1^H(0) + \frac{c_2^H(0)}{\hat{R}^F} \right] + \pi \left[ c_1^F(0) + \frac{c_2^F(0)}{\hat{R}^F} \right] = 2\pi. \end{aligned} \quad (3.46)$$

**Proposition 6.** *The competitive banking equilibrium with integrated banking systems and international hidden markets is characterized by the final consumption bundles:*

$$x_1^i(0) = 1, \quad x_2^i(1) = \hat{R}^F, \quad (3.47a)$$

$$x_2^i(0) = 0, \quad x_1^i(1) = 0; \quad (3.47b)$$

the interest rate on the hidden bond  $R = \hat{R}^F$ , and the bond trading:

$$b^i(0) = \frac{c_2^i(0)}{R^i}, \quad b^i(1) = -c_1^i(1). \quad (3.48)$$

The banking contracts must satisfy:

$$c_1^i(0) + \frac{c_2^i(0)}{\hat{R}^F} = c_1^i(1) + \frac{c_2^i(1)}{\hat{R}^F} = 1, \quad (3.49)$$

in every country, and the clearing condition in the hidden market:

$$(1 - \pi)c_1^H(1) + (1 - \pi)c_1^F(1) = \pi \frac{c_2^H(0)}{\hat{R}^F} + \pi \frac{c_2^F(0)}{\hat{R}^F}, \quad (3.50)$$

and are undetermined. The bank portfolio allocations in the two countries are also undetermined, but the total amount of short and long assets held in the world economy are  $X^W = 2\pi$  and  $Y^W = 2(1 - \pi)$ , respectively.

### 3.4.3 Case #4: Autarkic BS and International HM

The last case, where the banks can only invest in their own domestic technologies, but the depositors can borrow and lend among themselves in an international hidden market, deserves some deeper thoughts. The competitive banking equilibrium is defined as follows:

**Definition 7.** Given an endowment  $e = 1$  for each agent and a probability distribution  $\pi$  for the idiosyncratic shock, a competitive banking equilibrium with autarkic banking systems and international hidden markets is a contract  $C^i(\theta) = \{c_1^i(\theta), c_2^i(\theta)\}$ , a final consumption allocation  $\{x_1^i(\theta), x_2^i(\theta)\}$ , an interest rate on the hidden bond  $R$  and an amount of hidden bonds  $\{b^i(\theta)\}$  for every type  $\theta \in \{0, 1\}$  and country  $i = H, F$ , such that:

- for a given interest rate and contract, the final consumption allocation solves the problem in the hidden market (3.7), for every type in every country;
- the contract solves the banking problem (3.18), in every country;
- markets clear in every country  $i = H, F$ :

$$\pi \left( c_1^i(0) + \frac{c_2^i(0)}{\hat{R}^i} \right) + (1 - \pi) \left( c_1^i(1) + \frac{c_2^i(1)}{\hat{R}^i} \right) = 1; \quad (3.51)$$

- the bond market clears internationally:

$$\sum_{i=H,F} [\pi b^i(0) + (1 - \pi)b^i(1)] = 0. \quad (3.52)$$

Following the same logic that I exploited in the closed-economy case, I argue that the equilibrium interest rate on the hidden bond must lie between  $\hat{R}^H$  and  $\hat{R}^F$ . In fact, if  $R > \hat{R}^F$ , the short assets would dominate the long assets in both countries. Thus, the patient depositors in both countries would be willing to lend but, finding no borrowers on the hidden market, the equilibrium interest rate  $R$  would go to 1, which is a contradiction. Similarly, if  $R < \hat{R}^H$ , the long assets would dominate the short assets, and the impatient depositors would want to borrow in the hidden market, driving the equilibrium interest rate to infinity, which is again a contradiction. Thus, the only case left is  $\hat{R}^H \leq R \leq \hat{R}^F$ .

Once more, a type-0 agent in country  $i$  solves the problem in the hidden market in (3.22), so the solution yields  $x_2^i(0) = 0$ ,  $b^i(0) = c_2^i(0)/R$ , and  $x_1^i(0) = c_1^i(0) + c_2^i(0)/R$ . Similarly, for a type-1 agent in country  $i$ ,

we follow the problem in (3.24) and obtain  $x_1^i(1) = 0$ ,  $b^i(1) = -c_1^i(1)$ , and  $x_2^i(1) = Rc_1^i(1) + c_2^i(1)$ . The market clearing condition for the hidden bonds then reads:

$$\pi \frac{c_2^H(0)}{R} + \pi \frac{c_2^F(0)}{R} - (1 - \pi)c_1^H(1) - (1 - \pi)c_1^F(1) = 0. \quad (3.53)$$

The banks in each country solve the problem (3.27), subject to the budget constraint (3.19) and the incentive compatibility constraint (3.17). However, since  $\hat{R}^H \leq R \leq \hat{R}^F$ , the representative bank in Home only invests in the short asset, and the representative bank in Foreign only in the its local long asset:

$$X^H = Y^F = 1, \quad (3.54)$$

$$Y^H = X^F = 0. \quad (3.55)$$

This also means that we can simplify the expressions for the banking problems in the two countries, since:

$$c_2^H(0) = c_2^H(1) = 0, \quad (3.56)$$

$$c_1^F(0) = c_1^F(1) = 0. \quad (3.57)$$

The banking problem in Home becomes:

$$\max \pi u(c_1^H(0)) + \beta(1 - \pi)u(Rc_1^H(1)), \quad (3.58)$$

subject to:

$$\pi c_1^H(0) + (1 - \pi)c_1^H(1) \leq 1, \quad (3.59)$$

and the incentive compatibility constraint, which now simplifies to  $c_1^H(0) = c_1^H(1)$ . This transforms the bank budget constraint in  $c_1^H(0) \leq 1$ . From the first-order condition, it is easy to see that, as in the closed-economy case, the Lagrange multiplier on the budget constraint:

$$\lambda = \pi u'(c_1^H(0)) + \beta R(1 - \pi)u'(Rc_1^H(0)) \quad (3.60)$$

is strictly positive in equilibrium, because the felicity function  $u(c)$  is increasing and satisfies the Inada conditions. Hence, by complementary slackness, the budget constraint holds with equality, and we derive the equilibrium contract  $c_1^H(0) = c_1^H(1) = 1$ . In a similar way,  $c_1^F(0) = c_1^F(1) = 0$  modifies the banking problem in Foreign as:

$$\max \pi u\left(\frac{c_2^F(0)}{R}\right) + \beta(1 - \pi)u(c_2^F(1)), \quad (3.61)$$

subject to:

$$\pi \frac{c_2^F(0)}{\hat{R}^F} + (1 - \pi) \frac{c_2^F(1)}{\hat{R}^F} \leq 1, \quad (3.62)$$

and the incentive compatibility constraint  $c_2^F(0) = c_2^F(1)$ . The same lines of reasoning as before lead us to an equilibrium where the budget constraint holds with equality, so we find that  $c_2^F(0) = c_2^F(1) = \hat{R}^F$ .

Once we have pinned down the equilibrium banking contracts, the clearing condition in the bond market (3.53) gives the equilibrium interest rate  $R$  as:

$$R = \frac{\pi}{1 - \pi} \frac{c_2^F(0)}{c_1^H(1)} = \frac{\pi}{1 - \pi} \hat{R}^F, \quad (3.63)$$

which is an equilibrium if it lies between  $\hat{R}^H$  and  $\hat{R}^F$ . I summarize the results in the following proposition:

**Proposition 7.** *Assume that  $\frac{\hat{R}^H}{\hat{R}^F} < \frac{\pi}{1-\pi} < 1$ . The competitive banking equilibrium with autarkic banking systems and international hidden markets is characterized by the banking contracts:*

$$c_2^H(0) = c_2^H(1) = 0, \quad (3.64a)$$

$$c_1^H(0) = c_1^H(1) = 1, \quad (3.64b)$$

$$c_1^F(0) = c_1^F(1) = 0, \quad (3.64c)$$

$$c_2^F(0) = c_2^F(1) = \hat{R}^F; \quad (3.64d)$$

the interest rate on the hidden bond  $R = \frac{\pi}{1-\pi} \hat{R}^F$ ; the bond trading:

$$b^H(0) = b^F(1) = 0, \quad (3.65a)$$

$$b^H(1) = -1, \quad (3.65b)$$

$$b^F(0) = \frac{1 - \pi}{\pi}; \quad (3.65c)$$

and the final consumption bundles:

$$x_1^H(0) = 1, \quad x_2^H(1) = R, \quad (3.66a)$$

$$x_1^F(0) = \frac{1 - \pi}{\pi}, \quad x_2^F(1) = \hat{R}^F. \quad (3.66b)$$

The bank portfolio allocations are:

$$X^H = Y^F = 1, \quad (3.67)$$

$$Y^H = X^F = 0. \quad (3.68)$$

The intuition for this result is the following. At the equilibrium interest rate, the banks in both countries, which cannot make direct contact with each other, set up a contract such that their depositors enjoy the gains from “hidden” financial integration. The banks in Foreign, which hold a comparative advantage in the long asset, invest their entire endowment in it, and let their impatient depositors borrow liquidity in the hidden market by issuing a total amount of bonds equal to  $\pi \hat{R}^F / R$ , which is a decreasing function of the interest rate  $R$ . Conversely, the banks in Home, which hold a comparative advantage in the short asset, invest their entire endowment in it, and let their patient depositors lend a total amount of liquidity equal to  $(1 - \pi)$  in the hidden market, which is completely inelastic to changes in the interest rate  $R$ .<sup>6</sup> In that way,

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<sup>6</sup>The assumption on the probability distribution of the idiosyncratic shock is necessary to obtain an interior solution. The results become more complex if we assume that  $\pi/(1 - \pi)$  is outside the assumed bounds. If  $\pi/(1 - \pi) \geq 1$ , the interest rate hits its upper bound, or  $R = \hat{R}^F > \hat{R}^H$ : the banks in Home still invest their entire endowment in the short asset, but the banks in Foreign are indifferent between the short and the long asset, and need to adjust their portfolio allocation for the hidden market to clear. In particular, the banks in Foreign need to invest more in the short asset, and ensure that such an amount is, in turn, lent in the hidden market. They achieve this by offering early consumption only to the patient depositors. Thus, differently from the basic case,  $c_1^F(1) > 0$  and  $Y^F < 1$ . Similarly, if  $\pi/(1 - \pi) \leq \hat{R}^H / \hat{R}^F$ , the interest rate hits its lower bound, or  $R = \hat{R}^H < \hat{R}^F$ : the banks in Foreign still



the hidden market, in contrast to what happens in the closed economy, is not just a constraint on the portfolio allocation of the banks, but a channel that they can exploit in the absence of an integrated banking system. These considerations are going to be key for the analysis of policy coordination and of the efficiency of the banking equilibrium.

### 3.4.4 Hidden Trades and Policy Coordination

I summarize the final consumption allocations  $\{x_1^i(0), x_2^i(1)\}$  of the four different equilibria in table 3.2, and use them to analyze how the presence of hidden channels for the circulation of liquidity affects the process of financial liberalization in the whole economy.

Assume that the two countries coordinate the level of integration that they are willing to implement, based on the expected welfare gains that they can achieve from the policy change. Therefore, with a slight change of notation, I say that the level of integration  $j = 1, 2, 3, 4$  (corresponding to the four cases analyzed above) is preferred over another level  $j'$  if no country is worse off with  $j$  than with  $j'$ , or:

$$\pi u(x_1^i(0, j)) + \beta(1 - \pi)u(x_2^i(1, j)) \geq \pi u(x_1^i(0, j')) + \beta(1 - \pi)u(x_2^i(1, j')), \quad (3.69)$$

for every country  $i = H, F$ .

When the hidden trades are completely forbidden, financial liberalization only pertains to the banking system, and it is easy to argue that is always dominant with respect to autarky: the welfare in Foreign is unaffected, while Home is better off, as its banks can access the high-yield technology of the other country.

In the presence of hidden trades, the governments of the two countries do not have more information than the banks, and are not able to

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invest their entire endowment in the long asset, but the banks in Home are indifferent between the short and the long asset, and need to adjust their portfolio allocation for the hidden market to clear. In particular, the banks in Home need to invest more in the long asset, and ensure that such an amount is, in turn, used to issue bonds in the hidden market. They achieve this by offering late consumption only to the impatient depositors, thus  $c_2^H(0) > 0$  and  $X^H < 1$ .

Table 3.2: Competitive Banking Equilibria at Different Levels of Market Integration

	Domestic HM	International HM
Autarkic BS	$x_1^i(0) = 1, x_2^i(1) = \hat{R}^i,$ $R^i = \hat{R}^i.$	$x_1^H(0) = 1, x_2^H(1) = R,$ $x_1^F(0) = \frac{1-\pi}{\pi}, x_2^F(1) = \hat{R}^F,$ $R = \frac{\pi}{1-\pi} \hat{R}^F.$
Integrated BS	$x_1^i(0) = 1, x_2^i(1) = \hat{R}^F,$ $R^i = \hat{R}^F.$	$x_1^i(0) = 1, x_2^i(1) = \hat{R}^F,$ $R = \hat{R}^F.$

observe the trades in the hidden markets. However, they can determine the level of cross-country integration by deciding who is allowed to trade internationally. Thus, the process of financial liberalization combines two distinct dimensions: the banking system, and the hidden market.

Assume that the two countries start in case #1: autarkic banking systems, and domestic hidden markets. A comprehensive process of financial liberalization, which includes both the integration of the banking systems and of the hidden markets, is equivalent to a move to case #3, and is always approved since:

$$\pi u(1) + \beta(1 - \pi)u(\hat{R}^i) \leq \pi u(1) + \beta(1 - \pi)u(\hat{R}^F) \quad (3.70)$$

for every  $i = H, F$ . This thorough integration allows the banks in Home to invest in the long-term foreign technology, so the patient agents in Home improve their welfare ex post, and all depositors improve their expected welfare ex ante. At the same time, the welfare of the agents in Foreign is unaffected, hence the final allocation in case #3 dominates that in case #1.

The move from case #1 to case #2 or #4 and then to case #3 instead represents a process of sequential liberalization, where either the

two banking systems or the two hidden markets are integrated before the others. It is easily seen that, while keeping the hidden markets local, the integration of the two banking systems (moving from case #1 to case #2) is, for the same reasons as for the move to case #3, welfare improving. The opening of the hidden market, while keeping the two banking systems separated (moving from case #1 to case #4), is also welfare improving for both Home and Foreign, as:

$$\text{H : } \pi u(1) + \beta(1 - \pi)u(\hat{R}^H) < \pi u(1) + \beta(1 - \pi)u\left(\frac{\pi}{1 - \pi}\hat{R}^F\right), \quad (3.71)$$

$$\text{F : } \pi u(1) + \beta(1 - \pi)u(\hat{R}^F) < \pi u\left(\frac{1 - \pi}{\pi}\right) + \beta(1 - \pi)u(\hat{R}^F). \quad (3.72)$$

The rationale for this result is the following. At the equilibrium interest rate, the banks specialize in the asset in which they hold the comparative advantage (Home's banks in the short asset, and Foreign's banks in the long asset), and let their customers trade unobservably. The patient agents in Home can lend liquidity in the hidden market at a higher rate than in autarky, since  $R \geq \hat{R}^H$ , and, at the same time, the impatient agents in Foreign can borrow liquidity at a lower rate, since  $R \leq \hat{R}^F$ . In other words, the hidden market operates as a channel through which the two countries can exploit their comparative advantages, and enjoy the gains from "hidden" financial integration, so it is always welfare-improving with respect to autarky.

The move from case #2 to case #3, i.e. the opening of the hidden market to cross-country trades in the presence of an already-integrated banking system, is welfare-neutral, as the equilibrium interest rate  $R$  is unaffected. More interesting is to see what happens at the integration of the two banking systems, when the hidden markets are already integrated (the move from case #4 to case #3):

$$\text{H : } \pi u(1) + \beta(1 - \pi)u\left(\frac{\pi}{1 - \pi}\hat{R}^F\right) < \pi u(1) + \beta(1 - \pi)u(\hat{R}^F), \quad (3.73)$$

$$F : \pi u \left( \frac{1 - \pi}{\pi} \right) + \beta(1 - \pi)u(\hat{R}^F) > \pi u(1) + \beta(1 - \pi)u(\hat{R}^F). \quad (3.74)$$

While, in case #4, the interest rate  $R$  that clears the market must lie between the two marginal rates of transformation  $\hat{R}^H$  and  $\hat{R}^F$ , when the two systems become integrated, the only possible equilibrium rate is that which makes the banks ex ante indifferent between the short asset and the long asset of Foreign, that is,  $R = \hat{R}^F$ . The increase in the equilibrium interest rate creates winners and losers from financial integration: the patient agents in Home (who are the lenders of case #4) are better off at integration, because their intertemporal terms of trade improve when moving to case #3; in contrast, the impatient agents in Foreign (who are the borrowers of case #4) are worse off, because they borrow at a higher rate. This means that Home is in favor of integration, and Foreign is not. Thus, the necessary mutual agreement to implement the policy reform is broken. In other words, in an environment with hidden trades, the countries can only coordinate a partial level of financial integration.

### 3.5 Planner Problem with Hidden Trades

In this section, I characterize the solution to the social planner problem in the presence of hidden trades. This is a necessary step to analyze whether there is space for a regulatory intervention by the government to improve the allocation of the decentralized environment. As in the previous section, in order to highlight the main features of the equilibrium, I first solve the problem in the closed economy, and then extend the results to the two-country world.

#### 3.5.1 Closed Economy

In a closed economy, the planner chooses an allocation that maximizes the ex ante welfare of the agents:

$$\pi U(c_1(0), c_2(0), 0) + \beta(1 - \pi)U(c_1(1), c_2(1), 1), \quad (3.75)$$

subject to the feasibility constraint (3.1). Moreover, by the Revelation Principle, the planner imposes a “no-retrade constraint”, i.e. the contract must be such that the utility that each type receives must be larger than or equal to the one they would get by retrading, in order to induce truth-telling:

$$U(c_1(\theta), c_2(\theta), \theta) \geq V(C(\theta), R, \theta), \quad (3.76)$$

for every  $\theta \in \{0, 1\}$ .

Farhi et al. (2009) show that this problem is equivalent to one where the planner chooses a present value of consumption  $\mathcal{I}$  that is equal for all types (so that the incentive compatibility constraint is satisfied and no agent retrades) and the interest rate  $R$  on the hidden bond. Intuitively, this is because the planner is not constrained by the no-arbitrage condition between the banking system and the hidden market. Thus, she does not take the return on the hidden bond as given, but is able to pick the optimal one by manipulating the allocation of the aggregate available resources between date 1 and date 2.

Technically, the objective function of the planner:

$$\pi u(\mathcal{I}) + \beta(1 - \pi)u(R\mathcal{I}), \quad (3.77)$$

where  $\mathcal{I} = c_1(\theta) + \frac{c_2(\theta)}{R}$ , turns out to be similar to the one of the bank in (3.28), but with the key difference that the interest rate  $R$  is now a choice variable. The definition of the equilibrium is the following:

**Definition 8.** *Given an endowment  $e = 1$  for each agent and a probability distribution  $\pi$  for the idiosyncratic shock, a constrained efficient allocation is a present value of consumption  $\mathcal{I}$  and an interest rate  $R$  on the hidden bond that solve:*

$$\max_{\mathcal{I}, R} \pi u(\mathcal{I}) + \beta(1 - \pi)u(R\mathcal{I}), \quad (3.78)$$

*subject to the resource constraint:*

$$\pi\mathcal{I} + (1 - \pi)\frac{R\mathcal{I}}{\hat{R}} \leq 1. \quad (3.79)$$

The first-order conditions of the program (3.78) with respect to  $\mathcal{I}$  and  $R$  read:

$$\pi u'(\mathcal{I}) + \beta(1 - \pi)Ru'(R\mathcal{I}) = \lambda \left[ \pi + (1 - \pi)\frac{R}{\hat{R}} \right], \quad (3.80)$$

$$\beta\mathcal{I}(1 - \pi)u'(R\mathcal{I}) = \lambda(1 - \pi)\frac{\mathcal{I}}{\hat{R}}, \quad (3.81)$$

where  $\lambda$  is the Lagrange multiplier attached to the resource constraint (3.79). Using (3.81) to simplify (3.80), we find that  $\lambda = u'(\mathcal{I})$ , which is strictly positive because the felicity function  $u(c)$  is increasing and satisfies the Inada conditions. Thus, by complementary slackness, the resource constraint holds with equality, and the constrained efficient allocation is characterized in the following proposition:

**Proposition 8.** *The constrained efficient allocation in a closed economy is characterized by the system of equations:*

$$u'(\mathcal{I}^*) = \beta\hat{R}u'(R^*\mathcal{I}^*), \quad (3.82)$$

$$\pi\mathcal{I}^* + (1 - \pi)\frac{R^*\mathcal{I}^*}{\hat{R}} = 1. \quad (3.83)$$

*The constrained-efficient equilibrium interest rate on the hidden bonds  $R^*$  is always strictly lower than  $\hat{R}$ .*

The expression in (3.82) states that, in equilibrium, the planner chooses a contract satisfying an Euler equation, that is, the planner offers a contract equivalent to the one that she would offer in the absence of information asymmetries (i.e. the first best), where the marginal rate of substitution between early and late consumption is equal to the marginal rate of transformation  $\hat{R}$ .

From the equilibrium condition (3.82), I can derive the upper bound

for the efficient interest rate  $R^*$ , as:

$$\hat{R} > \beta \hat{R} = \frac{u'(\mathcal{I}^*)}{u'(R^* \mathcal{I}^*)} \geq R^*, \quad (3.84)$$

where the first inequality comes from  $\beta$  being less than 1, and the second is a consequence of the fact that the coefficient of relative risk aversion is larger than or equal to 1.<sup>7</sup> This result states that, in order to make the first best incentive-compatible, the planner imposes a wedge between the marginal rate of transformation  $\hat{R}$  and the interest rate on the hidden bond  $R^*$ . This is because, as already mentioned in section 3.3, in the first best the planner compresses the ex post income profile of the agents to cross-subsidize the impatient ones, that is,  $\mathcal{I}^* > 1$  and  $R^* \mathcal{I}^* < \hat{R}$ . However, in the presence of hidden trades, this would not be incentive-compatible, because the patient agents would rather misreport their types to get the higher early consumption  $\mathcal{I}^*$  and retrade. The planner ensures that this is not accomplished by reducing the equilibrium interest rate below the marginal rate of transformation.

### 3.5.2 Two-Country Economy

I now extend the concepts on the behavior of the planner in a closed economy to the two-country economy of section 3.4. The planner maximizes the sum of the expected utilities of the two countries:

$$\sum_{i=H,F} [\pi U(c_1^i(0), c_2^i(0), 0) + \beta(1 - \pi)U(c_1^i(1), c_2^i(1), 1)], \quad (3.85)$$

subject to the resource constraints and the no-retrading constraint. However, she takes as given the exogenous institutional environment, which might constrain her from accessing the technologies of the two countries. In other words, when the two banking systems are autarkic (cases #1 and #4), the planner can only invest the endowment of each country in the available domestic technologies, and when they are integrated (cases

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<sup>7</sup>See note 3.

#2 and #3) she can instead make the long-term investment in the long asset of Foreign in both countries.

In the case where the banking systems are autarkic and the hidden markets domestic (case #1), the constrained efficient allocation in both countries is, as in the corresponding competitive equilibrium, the same as in the closed economy, and comes as the solution to the system of equations:

$$u'(\mathcal{I}^{i*}) = \beta \hat{R}^i u'(R^{i*} \mathcal{I}^{i*}), \quad (3.86)$$

$$\pi \mathcal{I}^{i*} + (1 - \pi) \frac{R^{i*} \mathcal{I}^{i*}}{\hat{R}^i} = 1, \quad (3.87)$$

which must hold for every country  $i = H, F$ . The Euler equation (3.86) and the resource constraint (3.87) characterize the country-specific present values of consumption  $\mathcal{I}^i$  and interest rates in the hidden markets  $R^{i*}$ . As in the closed economy, the equilibrium allocation is equivalent to the first best, *conditional on the institutional environment*: the planner provides an allocation of resources equivalent to the one with no information asymmetries, i.e. such that the marginal rate of substitution between early and late consumption is equal to the marginal rate of transformation  $\hat{R}^i$ . This means that, in order to provide insurance against the probability of being impatient, the planner compresses the ex post income profiles of the agents by cross-subsidizing early consumption, so  $\mathcal{I}^i > 1$  and  $R^{i*} \mathcal{I}^{i*} < \hat{R}^i$  in both countries. Then, in order to make this allocation incentive-compatible, the planner imposes a country-specific wedge between the interest rate  $R^i$  and the marginal rate of transformation  $\hat{R}^i$ , so that no one has incentives to access the hidden market and retrade. For example, with a CRRA felicity function of the form  $u(c) = c^{1-\sigma}/(1-\sigma)$ , the Euler equation (3.86) gives  $R^{i*} = (\beta \hat{R}^i)^{\frac{1}{\sigma}} < \hat{R}^i$ , and  $R^{H*} < R^{F*}$  since  $\hat{R}^H < \hat{R}^F$ .

In the case of integrated banking systems and domestic hidden markets (case #2), the planner can use the high-yield technology of Foreign in both countries, but must set up a contract such that the agents have



no incentives to retrade in their domestic hidden markets. The definition of the equilibrium is the following:

**Definition 9.** *Given an endowment  $e = 1$  for each agent and a probability distribution  $\pi$  for the idiosyncratic shock, a constrained efficient allocation with integrated banking systems and domestic hidden markets is a present value of consumption  $\mathcal{I}^i$  and an interest rate on the hidden bond  $R^i$  for each country  $i = H, F$  that solve:*

$$\max_{\mathcal{I}^i, R^i} \sum_{i=H,F} [\pi u(\mathcal{I}^i) + \beta(1 - \pi)u(R^i \mathcal{I}^i)], \quad (3.88)$$

subject to the resource constraints:

$$\pi \mathcal{I}^i + (1 - \pi) \frac{R^i \mathcal{I}^i}{\hat{R}^F} \leq 1, \quad (3.89)$$

for every  $i = H, F$ , where  $\mathcal{I}^i = c_1^i(\theta) + c_2^i(\theta)/R^i$ .

When instead both the banking systems and the hidden markets of the two countries are integrated (case #3), the definition of the planner's problem is different from the previous case only because the planner has to solve for the unique interest rate  $R$  that rules out retrading in the international hidden market. More formally, the planner solves:

$$\max_{\mathcal{I}^i, R} \sum_{i=H,F} [\pi u(\mathcal{I}^i) + \beta(1 - \pi)u(R \mathcal{I}^i)], \quad (3.90)$$

subject to the resource constraints:

$$\pi \mathcal{I}^i + (1 - \pi) \frac{R \mathcal{I}^i}{\hat{R}^F} \leq 1, \quad (3.91)$$

which must hold for every country  $i = H, F$ .

Essentially, the difference between these two problems lies in the fact that, when the hidden markets are domestic (case #2), the planner can fix a country-specific wedge between the interest rate in the hidden market  $R^{i*}$  and the marginal rate of transformation  $\hat{R}^F$  while, when the

hidden markets are integrated (case #3), there can only be one wedge, to ensure that market clearing is satisfied. However, since the two countries are exactly symmetric (with respect to the distribution of the initial endowment and of the idiosyncratic shock) and have access to the same technologies (because of the exogenous level of integration in the banking system), there is no reason why the two equilibria should be different. Hence, the constrained efficient interest rates in case #2,  $R^{H**}$  and  $R^{F**}$ , are actually the same, and equal to the constrained efficient interest rate  $R^{**}$  of case #3. Thus, the solution to both case #2 and #3 comes from the system of equations:

$$u'(\mathcal{I}^{**}) = \beta \hat{R}^F u'(R^{**} \mathcal{I}^{**}), \quad (3.92)$$

$$\pi \mathcal{I}^{**} + (1 - \pi) \frac{R^{**} \mathcal{I}^{**}}{\hat{R}^F} = 1, \quad (3.93)$$

which must hold for every country  $i = H, F$ .

A completely different result comes from the planner's problem when the two banking systems are autarkic, but Home and Foreign share an international hidden market (case #4). Here, the institutional environment forbids the planner to use the high-yield long asset of Foreign for the long-term investment in Home. Thus, while in the other three cases the planner, as in the closed economy, chooses an allocation such that no agent has incentives to retrade, here she is going to exploit the hidden market to achieve the gains from hidden financial integration. For the sake of clarity, here I rewrite the problem in case #4. The planner solves:

$$\max \sum_{i=H,F} \left[ \pi u \left( c_1^i(0) + \frac{c_2^i(0)}{R} \right) + \beta(1 - \pi) u(Rc_1^i(1) + c_2^i(1)) \right], \quad (3.94)$$

subject to the country-specific resource constraint:

$$\pi \left( c_1^i(0) + \frac{c_2^i(0)}{\hat{R}^i} \right) + (1 - \pi) \left( c_1^i(1) + \frac{c_2^i(1)}{\hat{R}^i} \right) \leq 1, \quad (3.95)$$

which must hold for both countries  $i = H, F$ , and the incentive compat-

ibility constraint (3.17).

Remember that, in cases #1 to #3, the clearing condition in the hidden market is satisfied because the planner is able to provide the first-best allocation, and therefore no agent retrades because no one can improve the proposed allocation. Here, as in the corresponding competitive equilibrium, the planner instead sets up a contract such that the agents do retrade in the hidden market. This means that, for the hidden market to clear, the unique equilibrium interest rate  $R^{***}$  must be the one at which the hidden demand and supply of liquidity are equalized. Thus, the same lines of reasoning as in section 3.4 leads me to argue that the constrained-efficient interest rate  $R^{***}$  must lie between the two marginal rates of transformation  $\hat{R}^H$  and  $\hat{R}^F$ : values lower than  $\hat{R}^H$  or higher than  $\hat{R}^F$  would push the planner to invest the endowments of both countries either completely in the long assets or completely in the short assets, which would preclude the market clearing.

As a consequence, the planner invests all endowment of Home in the short asset, and lets the patient agents lend liquidity in the hidden market, and all endowment of Foreign in the long asset, and lets the impatient agents borrow liquidity in the hidden market:

$$c_2^{H***}(0) = c_2^{H***}(1) = 0, \quad (3.96a)$$

$$c_1^{F***}(0) = c_1^{F***}(1) = 0. \quad (3.96b)$$

This, together with the incentive compatibility constraint in (3.17), also implies that:

$$c_1^H(0) = c_1^H(1), \quad (3.97a)$$

$$c_2^F(0) = c_2^F(1). \quad (3.97b)$$

Thus, I can simplify the planner's problem in case #4 as:

$$\max_{c_1^H(0), c_2^F(0)} \pi \left[ u(c_1^H(0)) + u\left(\frac{c_2^F(0)}{R}\right) \right] + \beta(1 - \pi) [u(Rc_1^H(0)) + u(c_2^F(0))], \quad (3.98)$$

subject to:

$$c_1^H(0) \leq 1, \quad (3.99a)$$

$$c_2^F(0) \leq \hat{R}^F. \quad (3.99b)$$

The first-order conditions of the program give strictly positive Lagrange multipliers on the two budget constraints, because the felicity function  $u(c)$  is increasing and satisfies the Inada conditions. Thus, by complementary slackness, the budget constraints hold with equality and, in equilibrium, the planner chooses  $c_1^{H***}(0) = c_1^{H***}(1) = 1$  and  $c_2^{F***}(0) = c_2^{H***}(0) = \hat{R}^F$ , exactly as the banks do in the competitive equilibrium. Hence, we can state the following:

**Proposition 9.** *The competitive banking equilibrium with autarkic banking systems and international hidden markets (case #4) is constrained efficient.*

The intuition for this result is the following. At all other levels of financial integration, the hidden trades represent a burden on the competitive equilibrium: in fact, were they forbidden, the banks would be able to offer the same constrained-efficient allocation provided by the planner. In contrast, here the hidden trades are necessary, because they are the only available channel for integrating the two countries. The planner picks an interest rate on the hidden bond that lies between the two marginal rates of transformation, because that is the only unique interest rate that clears the hidden market for positive trades. As a consequence, the specialization of the banks of each country in the asset in which they hold a comparative advantage (the banks in Home in the short asset, and the banks in Foreign in the long asset) is a constrained efficient portfolio strategy: there exists no other feasible allocation that, at the equilibrium interest rate  $R^{***}$ , satisfies the incentive compatibility constraint and yields a higher welfare than the competitive banking equilibrium.

This is a critical result for two connected reasons: first, because it

disproves the classic result of Jacklin (1987) and Allen and Gale (2004), who showed that the possibility for the agents of trading in the market distorts the efficiency of the banking equilibrium in Diamond-Dybvig environments; second, because, in all the other three cases, the differences between the competitive banking equilibria and the corresponding constrained efficient allocations provide the rationale for the introduction of some kind of government intervention to decentralize the constrained efficient outcome. However, when the two banking systems are separated and cross-country hidden trades are allowed, there is no way through which the government can improve the outcome of the decentralized environment.

## 3.6 Optimal Regulation

The complete characterization of the planner solution, for the different levels of financial integration, allows me to compare the constrained efficient allocations of section 3.5 to those offered by the banks in the competitive equilibria of section 3.4. This comparison will highlight the available space for a regulatory intervention, to improve the decentralized outcomes, and provide the lead to what is the right regulation that we should impose on the system, depending on the level of integration in the banking systems and in the hidden markets. As in the previous sections, I start with the analysis of the closed economy, and then move to the two-country environment.

### 3.6.1 Closed Economy

From the comparison between the constrained efficient allocation and the decentralized solution, it is evident that the difference between the two is essentially due to the equilibrium interest rates  $R$  and  $R^*$ , as the first must be equal to the marginal rate of transformation  $\hat{R}$ , while the second is instead lower. As I said above, this is a consequence of the fact that, in the decentralized environment, the only possible equilibrium that

clears the hidden market is the one where there are no arbitrage opportunities, i.e. the banks and the agents are ex ante indifferent between the investment in the banking system and the hidden market. In turn, the equality of returns pushes the banks to skew their asset portfolios towards the long asset, in order to ensure incentive compatibility, and this rules out the efficient cross-subsidization of the impatient depositors that the planner provides.

The obvious consequence of this observation would then be to directly regulate markets, for example through the imposition of taxes, so as to affect the equilibrium interest rate  $R$ . However, this is impossible, because trades are observable to neither the intermediaries nor the regulators. Therefore, what I propose here is a regulatory intervention such that the banks autonomously implement the constrained efficient allocation, which takes the form of a minimum liquidity requirement:

$$X \geq M. \tag{3.100}$$

The rationale of such a rule is the following. In the newly regulated equilibrium, the interest rate is going to be lower than the marginal rate of transformation. This means that the short asset is going to be dominated by the long asset, and no intermediary will hold liquidity. However, this cannot be an equilibrium, since clearing in the hidden market would be violated: the impatient consumers would like to borrow, but no one would lend to them. Thus, the only way in which the banking system can sustain a competitive banking equilibrium where the interest rate is lower than the return on the long asset is via the introduction of a minimum liquidity requirement, so that the banks are forced to hold enough resources to finance early consumption. In other words, by picking the right requirement, the regulator manipulates the bank portfolios *directly*, and the interest rate *indirectly*, by reshuffling the resources across time in an efficient way.

More formally, I extend the problem in (3.27) with the imposition of the constraint in (3.100). To solve this problem, I apply the following

change of variables:

$$\mathbf{I} = c_1(0) + \frac{c_2(0)}{R}, \quad (3.101)$$

$$\mathbf{H} = \pi c_2(0) + (1 - \pi)c_2(1), \quad (3.102)$$

where  $\mathbf{I}$  is the present value of the consumption bundle that an impatient depositor gets from the contract (that, by incentive compatibility, must be equal to the present value that a patient depositor gets), and  $\mathbf{H}$  is the total amount of consumption good that the bank has to pay at  $t = 2$ . The minimum liquidity requirement can be expressed in the following way:

$$\begin{aligned} X &= \pi c_1(0) + (1 - \pi)c_1(1) = \\ &= c_1(0) + (1 - \pi)(c_1(1) - c_1(0)) = \\ &= c_1(0) + (1 - \pi)\frac{c_2(0) - c_2(1)}{R} = \\ &= \left( c_1(0) + \frac{c_2(0)}{R} \right) - \frac{\pi c_2(0) + (1 - \pi)c_2(1)}{R} = \\ &= \mathbf{I} - \frac{\mathbf{H}}{R} \geq F, \end{aligned} \quad (3.103)$$

where I used the incentive compatibility constraint in the third step. In a similar way, I rewrite the intertemporal budget constraint as:

$$\mathbf{I} - \mathbf{H} \left[ \frac{1}{R} - \frac{1}{\hat{R}} \right] = 1. \quad (3.104)$$

Therefore, the banking problem now reads:

$$\max_{\mathbf{I}, \mathbf{H}} \pi u(\mathbf{I}) + \beta(1 - \pi)u(R\mathbf{I}), \quad (3.105)$$

subject to (3.103) and (3.104). I attach the multipliers  $\mu$  and  $\lambda$  to (3.103) and (3.104), respectively, so that the first-order conditions of the program are:

$$\mathbf{I}: \quad \pi u'(\mathbf{I}) + \beta R(1 - \pi)u'(R\mathbf{I}) = \lambda - \mu, \quad (3.106a)$$

$$\mathbf{H}: \quad \frac{\mu}{R} = \lambda \left[ \frac{1}{R} - \frac{1}{\hat{R}} \right], \quad (3.106b)$$

which can be put together in:

$$\pi u'(\mathbf{I}) + \beta R(1 - \pi)u'(R\mathbf{I}) = \lambda \frac{R}{\hat{R}}. \quad (3.107)$$

For some positive multipliers  $\mu$  and  $\lambda$ , the constrained efficient allocation satisfies the optimality conditions: we can see this by substituting the interest rate  $R$ , the present value  $\mathbf{I}$  and the amount of late consumption  $\mathbf{H}$  with the corresponding values in the constrained efficient allocation  $R^* < \hat{R}$ ,  $\mathcal{I}^*$  and  $\mathcal{H}^* = (1 - \pi)R^*\mathcal{I}^*$ . Hence, the minimum liquidity requirement in equilibrium holds with equality, and implements the planner solution as the outcome of the decentralized environment.

**Proposition 10.** *The minimum liquidity requirement:*

$$M = \pi\mathcal{I}^*, \quad (3.108)$$

where  $\mathcal{I}^*$  comes from the solution to the planner problem, implements the planner solution in the competitive banking equilibrium.

Two things are worth noticing. First, since in the regulated equilibrium  $R^* < \hat{R}$ , no agent has incentives to retrade in the hidden market, the market clearing condition of the definition 5 is satisfied. Second, since  $\mathcal{I}^* > 1$  as showed in section 3.3, the minimum liquidity requirement  $M$  is larger than  $\pi$ : the optimal regulation pushes the banks to hold more liquidity than in the unregulated equilibrium. Intuitively, this works because the minimum liquidity requirement reallocates the aggregate resources of the economy from date 2 to date 1, thus lowering the interest rate.



### 3.6.2 Two-Country Economy

The lesson that we learn from the closed-economy case is that, despite the fact that the origin of the inefficiency of the competitive banking equilibrium lies in the pricing system in the hidden market, we can solve the resulting misallocation of resources by instead imposing the right minimum liquidity requirement on the banking system. The aim of this section is to replicate the analysis in the two-country case, and characterize the optimal regulatory intervention as a function of the different levels of integration in the banking systems and the hidden markets.

The optimal regulation when the banking systems of the two countries are autarkic and each country has a domestic hidden market (case #1) is a replica of that in a closed economy: in each country, the equilibrium interest rate  $R^i = \hat{R}^i$  is above its efficient level  $R^{i*}$ , and a country-specific minimum liquidity requirement of the form  $M^i = \pi \mathcal{I}^{i*}$  decentralizes the constrained efficient allocation by raising the amount of short assets that the banks hold in portfolio. Two things are worth-noticing: first, the heterogeneity of the optimal regulation across countries is not a consequence of different levels of idiosyncratic risk, but of different investment technologies. Second, for a standard CRRA felicity function, the minimum liquidity requirement is looser (i.e., lower) in the country that holds a comparative advantage in liquidity (in this case, Home) than in the other. To see this, notice that the efficient amount of early consumption  $\mathcal{I}^{i*}$  that the regulated banks provide is a decreasing function of the country-specific ratio  $R^i / \hat{R}^i$  between the interest rate and the marginal rate of transformation. From the Euler equation (3.86):

$$\frac{R^i}{\hat{R}^i} = \beta^{\frac{1}{\sigma}} \hat{R}^{i \frac{1}{\sigma} - 1}. \quad (3.109)$$

Since the coefficient of relative risk aversion  $\sigma$  is larger than or equal to 1 by assumption, we have that  $R^H / \hat{R}^H \geq R^F / \hat{R}^F$ , because  $\hat{R}^H < \hat{R}^F$ . Therefore  $\mathcal{I}^{H*} \leq \mathcal{I}^{F*}$ , and  $M^H \leq M^F$ .

In a similar way, when the banking systems are integrated (cases #2

and #3), and the banks in Home gain access to the long asset of Foreign, the interest rates on the hidden bonds  $R^i = \hat{R}^F$  are above their economy-wide efficient levels, notwithstanding if the hidden markets are integrated or not. Therefore, the optimal regulation is an economy-wide minimum liquidity requirement  $M = \pi \mathcal{L}^{**}$ . This means that a process of financial liberalization that moves from the complete separation of the two countries to an integrated banking system (from case #1 to case #2 or #3) should also be accompanied by a regulatory change: an increase in the minimum liquidity requirement of the country that gains the most from integration, i.e. whose intertemporal terms of trade have improved (in this case, Home). However, there is a key difference between case #2 and case #3. In case #2 (integrated banking systems and domestic hidden markets), the market clearing conditions on the local hidden markets allow us to completely characterize the equilibrium share of initial wealth invested in the short asset by the banks in each country (see proposition 5). Hence, the imposition of the minimum liquidity requirements increases the equilibrium amount of short assets in both countries and, as a consequence, lowers the interest rates. Conversely, in case #3 (integrated banking systems and international hidden markets), we are only able to characterize the equilibrium total amount of short assets held by the banking system in the whole economy (see proposition 6). Therefore, the imposition of the minimum liquidity requirements increases the *economy-wide* amount of short assets held by the banking system, but we cannot specify whether the amount of short assets held by the banks in each country increases or not.

Finally, we are left with the last, and most interesting, result of section 3.5: the competitive banking equilibrium with autarkic banking systems and international hidden markets (case #4) is constrained efficient. This means that there exists no other feasible allocation that satisfies the incentive compatibility constraint and dominates the market outcome and, therefore, no government intervention can be imposed without negatively altering the competitive equilibrium. As a consequence, a process of financial liberalization that opens the hidden markets to international

Table 3.3: Optimal Regulation at Different Levels of Market Integration

	Domestic HM	International HM
Autarkic BS	$M^H = \pi \mathcal{I}^{H*}$ $M^F = \pi \mathcal{I}^{F*}$	No Regulation
Integrated BS	$M^H = \pi \mathcal{I}^{**}$ $M^F = \pi \mathcal{I}^{**}$	$M^H = \pi \mathcal{I}^{**}$ $M^F = \pi \mathcal{I}^{**}$

trades, while keeping the two banking systems separate (a move from case #1 to case #4) – which we saw is the maximum level of coordination that Home and Foreign can achieve – should be accompanied by the elimination of the country-specific minimum liquidity requirements that the two countries need in financial autarky. If that were not the case, the equilibrium portfolio strategy of the banks in Home would not change (at the equilibrium interest rate, they would still invest all their endowment in the short asset and the minimum liquidity requirement would be slack), but the banks in Foreign would be forced to invest an inefficient amount of deposits in the short asset, thus lowering the interest rate below its constrained efficient level.

### 3.7 Concluding Remarks

In the present work, I propose a mechanism to rationalize the observation that the process of financial integration around the world has come to a halt in the last 10-15 years: financial integration affects the equilibrium prices of all those market-based unregulated channels for the circulation of liquidity that have developed as a consequence of financial liberalization and capital mobility, thus creating winners and losers from integration and hindering further expansions. To formalize this idea, I construct a two-country model of banking, where the banks have ac-

cess to country-specific investment technologies, and the depositors can borrow and lend among themselves in a hidden market.

The main lesson that we learn from this exercise is that the order in which the markets are integrated is of importance for how deep the integration process can go. This also means that further waves of financial liberalization might come at a lower pace, and eventually among countries that are economically and financially homogeneous. Moreover, it is not clear whether a tighter international connection among countries can lead to a deeper financial integration than that achievable through coordination: in the present environment, for example, a political union (i.e. a supranational authority maximizing the sum of the total welfare of the two countries) would prefer a complete integration of the financial systems of the two countries (case #3) to a system where only the hidden markets are integrated (case #4) only if the expected welfare gains of the patient agents in Home are higher than the expected welfare losses of the impatient agents in Foreign (which is not always true here).

Finally, the analysis of the constrained efficiency of the different competitive equilibria suggests that financial regulation should adapt to the level of integration of the international financial system and, in general, become stricter for those countries that gain more from integration. However, regulation is not always necessary: there exist environments where the presence of unregulated trading opportunities does not limit the constrained efficiency of the competitive equilibrium, and therefore does not justify the introduction of minimum liquidity requirements.

The environment developed in the present work is a source of further interest because of the possible extensions that we can make from it: in particular, it would be interesting to study the robustness of the results to financial crises, in the form of bank runs or unexpected spikes in the probability of the idiosyncratic shock, and how the resilience of the system changes with the level of financial integration in the banking system (as in Allen and Gale, 2000), as well as in the hidden market. I leave these issues for future research.

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## A Why Only Bonds in the Hidden Market?

Remember that, when borrowing and lending, the individual types are still private information. In order to complete the set of traded securities, we may then add claims paying 1 unit of the consumption good conditional on reporting type  $\theta$ . Define the price of those securities as  $Q(\theta)$ . The price of a risk-free bond delivering one unit of consumption in the following period for each unit invested today is  $1/R$ . I can prove the following:

**Lemma 5.**  $Q(\theta) \geq \frac{1}{R}$  for every type  $\theta \in \{0, 1\}$ .

**Proof.** I prove the lemma by contradiction. Assume that  $Q(\theta') < \frac{1}{R}$  for some  $\theta'$ . That would give rise to arbitrage opportunities: agents would buy an infinite number of securities, sell uncontingent bonds of the same amount, then report exactly type  $\theta'$ , and enjoy infinite utility. That cannot be an equilibrium. ■

Given that  $Q(\theta) \geq \frac{1}{R}$ , no type-contingent claims will be traded: the agents will never exchange securities which yield one unit of consumption if a specific type is reported, when they have the opportunity to trade a cheaper bond which yields one unit of consumption whatever type is reported.





## Chapter 4

# Bank Liquidity, Stock Market Participation, and Economic Growth\*

### 4.1 Introduction

The financial crisis that hit the U.S. economy in 2007-2009 has pulled the attention of academia and policymakers back to the issue of the liquidity of the financial system. With the present work, we want to contribute to this debate, and provide a framework to think about this topic.

In figure 4.1, we plot a measure of the relative liquidity of the U.S. financial system: liquid assets of financial businesses, as a percentage of their total liabilities. The graph shows a well-known fact: in the last 60 years, the U.S. financial institutions have moved their portfolios away from safe liquid assets and towards riskier investments. This phenomenon

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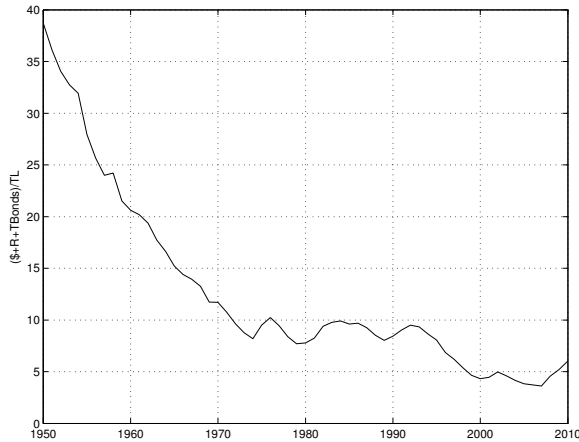


Figure 4.1: Liquid assets of the U.S. financial businesses as a percentage of total liabilities. Liquid assets are defined as the sum of vault cash, reserves and Treasury securities. Source: Flow of Funds Accounts of the United States.

has not exclusively hit the U.S.: for example, a similar measure, produced by the Bank of England for the United Kingdom, exhibits a qualitatively identical pattern (see figure 4.3).

The aim of the present work is to reconcile this stylized fact with the extensive literature studying the transformations in the “financial architecture” - i.e., the mix of financial intermediaries (or, more commonly, banks) and markets - of many developing and developed economies. Berger et al. (1995) argue that the U.S. banking system has evolved from a position of “protected monopsony”, where the banks were the only institutions allowed to collect and invest the savings of the households, into a market-oriented system, where new institutions, generally labeled as “new financial intermediaries”, have developed an offer of banking services without being regulated as proper banks. Examples of new financial intermediaries include hedge funds, money market mutual funds, and investment banks, to name just a few. More generally, the growth of these instruments and institutions, which took the name of “disintermediation”

of the financial system, has manifested itself through an increasing diversification of household portfolios. Guiso et al. (2002) show that, in the last twenty years, the U.S., as well as many other countries in the world, have experienced a dramatic increase in the proportion of direct and indirect stockholding by individual investors.

To jointly take into account these considerations, we build upon the idea, suggested by Berger et al., that market factors and innovation are the fundamental explanations for the loss of the bank monopsony power that we observed historically. In other words, we study a complex financial system where banks and markets<sup>1</sup> compete in offering insurance against some idiosyncratic shocks and fruitful investment opportunities to households. The mechanism that we have in mind is one where, at low levels of economic development, the presence of fixed entry costs prevents the agents from accessing the market, and pushes them to contact the banks whose portfolio is relatively skewed towards liquid assets. However, after a certain threshold, the agents are rich enough to access the markets, where the relative liquidity is lower, so the relative liquidity of the whole financial system (banks *and* markets) drops because of this increasing market participation.

More formally, we embed a theory of financial intermediation and markets into a general equilibrium growth model. The agents in the economy are hit by an idiosyncratic shock that makes them “impatient” to consume, as in Diamond and Dybvig (1983). The banks offer insurance against these shocks via a banking contract: they collect deposits, and invest in liquidity and capital on behalf of their customers. In this environment, it is a well-known result that the banks cross-subsidize those customers who turn out to be impatient, by offering them an amount of liquid consumption that is higher than the amount that they deposited and, to finance such an arrangement, invest relatively more in liquidity than in capital. It is also well-known that, if the agents independently accessed the market and invested in liquidity and capital, they would

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<sup>1</sup>Here we use “markets” as a shortcut that includes the broader concept of new financial intermediaries.

choose a lower amount of liquidity, and get less cross-subsidization. Thus, the banking equilibrium would always be preferred to the market allocation.

To break up this dominance, we tweak the environment in two directions. First, we assume that the banks pay an iceberg-type cost on the return to their capital investment. This cost can emerge from regulation, which limits the way in which the banks invest their capital, or from a technological constraint. Moreover, by only imposing it on the banks, we replicate the preferential tax treatment enjoyed by the capital gains with respect to the interests from deposits which is typical of many developing and developed countries (including the U.S.). Second, the agents who invest directly in the market must pay a fixed entry cost. This can be seen as a transaction cost or an institutional impediment that prevents the agents from accessing the market, and it is a tool that has been extensively used in finance (Vissing-Jorgensen, 2003; Guiso et al., 2008) and in macroeconomics (Acemoglu and Zilibotti, 1997; Townsend and Ueda, 2006), while also having some strong empirical support (Guiso et al., 2002).

The interplay between the bank iceberg cost and the fixed entry cost constitutes the cornerstone of our analysis. We assume that the agents engage in a discrete investment decision, by choosing between a bank account and a direct investment in the market, and show how the competitive pressure from this alternative investment opportunity affects the bank asset portfolio and, in turn, the overall relative liquidity of the financial system.

Technically, we solve a banking problem, augmented by imposing a participation constraint: the banking contract must be such that the depositors are, in expectation, at least as well off as they would be by trading in the market. We show that, depending on whether this constraint is binding or not, we will have very different results. In a pure banking equilibrium, the banks provide higher liquidity than what agents would get in the market. Moreover, with CRRA utility, the bank liquidity ratio is decreasing in the transition towards its steady state, and is constant

in the long run, because deposits (i.e. the liabilities of the bank balance sheets) on one side, and liquidity and capital (i.e. the assets of the bank balance sheets) on the other must grow at the same rate.

In the constrained problem, the liquidity ratio of the whole financial system instead exhibits a non-increasing trend. The reason is that, in equilibrium, the banks always offer the unconstrained contract, regardless of whether the participation constraint binds or not. Thus, at low levels of economic development, that is, as long as the income of the agents is below a threshold which is a function of the fixed entry costs and the iceberg-type costs for banks, the participation constraint is slack: the expected welfare of the agents is higher with the banking arrangement than in the market, as the banks offer cross-subsidization and high liquidity, like in the unconstrained problem. However, above the threshold, the banks are not able to offer a contract that enforces participation. In other words, the banking equilibrium collapses, and the agents optimally choose to directly access the market, where the relative liquidity is lower.

In the second part of the paper, we validate our theoretical prediction that the liquidity ratio in the financial system drops because of the increasing participation of the individual investors to market trades. To this end, we take an unbalanced panel of bank liquid reserves, constructed by the World Bank for around 100 different countries for the period 1970-2010, and proxy the availability of external investment channels with an index of securities market policy, provided by the IMF, that increases as regulatory changes are imposed to advance the development of markets. Our results show that a one-unit increase in this index leads to a drop in the liquidity ratio of between 13 and 22 percentage points. Moreover, we prove that this effect is stable when controlling for other types of financial liberalizations, and highly nonlinear: moving the index from 0 to 2 would lead to a drop in the bank liquidity ratio of between 20 and 25 per cent, while moving it from 0 to 3 would lead to a drop of between 30 and 37 per cent. The introduction of very mild reforms (i.e. moving the index from 0 to 1) instead has an insignificant (or only

slightly positive) effect.

The rest of the paper is organized as follows. In sections 4.2 and 4.3, we first summarize the literature related to our work and the empirical evidence, respectively. In section 4.4, we describe the economic environment of our model, and in section 4.5 we characterize its equilibrium. In section 4.6, we show the results of our econometric analysis. Finally, section 4.7 concludes the paper.

## 4.2 Related Literature

This paper contributes to several lines of research. First, it connects the literature on market participation to the literature studying the evolution of the roles of banks and financial markets, the so-called “financial architecture”, which has the work of Gurley and Shaw (1955) as its cornerstone. More recently, Song and Thakor (2010), relying on an extensive empirical literature, study a mechanism according to which the interaction between banks and markets is not only based on competition, but also on complementarity and co-evolution of the two. The work of Demirguc-Kunt et al. (2012) is only the last example of a series of papers<sup>2</sup> that finds that, as a country develops, the size of both banks and securities markets increases. The authors also find that the correlation between economic growth and the development of securities markets increases over time, thus reinforcing the view - that we share here - that the market plays an increasingly important role in affecting the real economy.

Despite the extension of the empirical analysis, not many authors have focused on explaining the mechanisms underlying the evolution of the financial architecture and its influence on the banking system, Boyd and Smith (1998) and Deidda and Fattouh (2008) being two notable exceptions. They both study environments where asymmetric information about the profitability of an investment opportunity pushes for some costly state verification. Boyd and Smith (1998) use this assumption to

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<sup>2</sup>See Levine (2005) for a survey.

analyze the evolution of the debt and the equity markets, while Deidda and Fattouh (2008) point their attention to the interactions between banks, which gather information, and disclosure laws in the stock markets. Our work differs from theirs because we do not explain the coexistence of banks and markets with the need for monitoring, but instead focus on the willingness of the individual investors to insure themselves against idiosyncratic shocks, as in Diamond and Dybvig (1983). Our work is inspired by some dynamic models of banking used in different set-ups in the literature (Bencivenga and Smith, 1991; Qi, 1994; Allen and Gale, 1997; Ennis and Keister, 2003), which are here extended to consider market participation.

Finally, the present paper contributes to the analysis of the connections between finance and growth. The macroeconomic literature on this topic starts from the seminal work of Greenwood and Jovanovic (1990) and focuses on the role of increasing individual participation in the financial system as a mechanism for enhancing risk diversification (Acemoglu and Zilibotti, 1997), and to affect income inequalities (Townsend and Ueda, 2006). All these authors share the idea of modeling the financial system as a “black box”, while we provide a characterization of an environment where both banks and markets are explicitly microfounded.

### 4.3 Empirical Evidence

In this section, we provide some empirical evidence showing that a decreasing liquidity ratio in the financial system is a general feature of the process of economic growth. In figure 4.1, we plot a measure of relative liquidity of U.S. financial businesses: liquid assets as a percentage of total liabilities. Following a common practice in the literature, we define liquid assets as the sum of vault cash, excess and required reserves, and Treasury bonds.<sup>3</sup> The series exhibits a significant downward trend:

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<sup>3</sup>According to the IMF, such a measure “provides an indication of the liquidity available to meet expected and unexpected demands for cash. The level of liquidity indicates the ability of the deposit-taking sector to withstand shocks to their balance

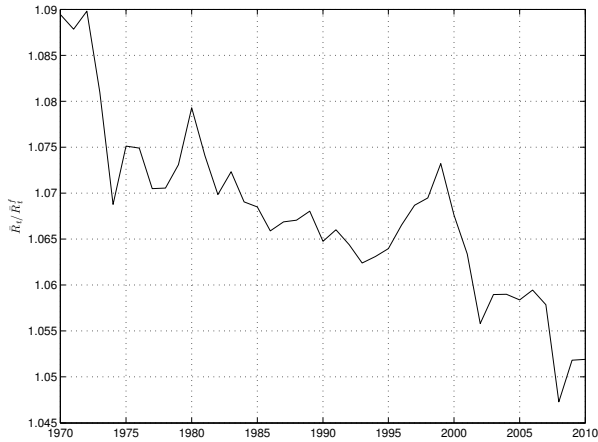


Figure 4.2: Relative price of liquidity with respect to market prices. The relative price of liquidity is calculated as the ratio between the compounded returns (base date: 1940) on the S&P500 and on a 10-year U.S. Treasury bond. Source: Aswath Damodaran, available at: <http://pages.stern.nyu.edu/~adamodar/>.

it started at around 40 per cent in the 1950s, and fell to a level below 5 per cent in the 2000s. The average growth rate in the period (in log terms) is -3.34 per cent while, even after the steep decline of the period 1950-1970, relative liquidity has decreased at an average rate of -2.40 per cent. These observations are robust to an alternative specification of the liquidity ratio that is also used in the literature: if we substitute total financial assets at the denominator, we find a pattern that is qualitatively identical to the original one.

It can be argued that the downward trend in the liquidity ratio is a consequence of an underlying downward trend in the relative price of liquidity because, in the data, both assets and liabilities (i.e., the numerator and the denominator of the ratio) are evaluated at market prices. In order to rule out this argument, we proxy the relative price of liquidity with the inverse of the compounded return on a ten-year U.S. Treasury bond, relative to the return on the S&P500. From figure 4.2, it is evident that the series has decreased in the period 1970-2010. This

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sheet”.



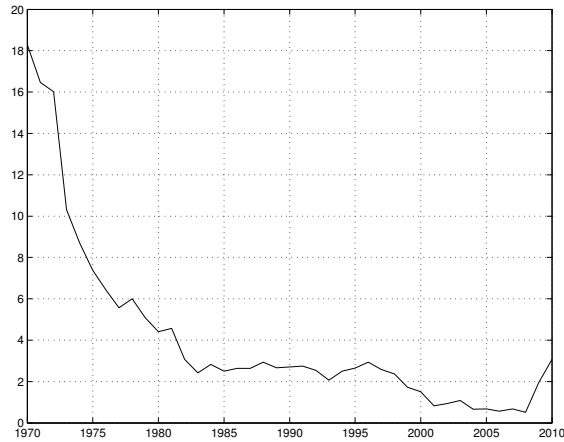


Figure 4.3: Sterling liquid assets relative to total asset holdings of the UK banking sector. Source: Bank of England.

pattern was expected, given that it reflects the fall of the equity risk premium, which is a well-known phenomenon and has been extensively analyzed in the past (Jagannathan et al., 2000; Lettau et al., 2008). What is interesting to notice here is that the fall in the relative price of liquidity has been quantitatively negligible: its average growth rate is just  $-0.06$  per cent. This allows us to safely rule out any considerations regarding prices, and focus on the behavior of economic agents in the following sections.

Finally, as mentioned earlier, the decreasing liquidity in the financial system is not a phenomenon that exclusively involves the United States. Bordeleau and Graham (2010) report evidence of a similar pattern in the Canadian banking system. In figure 4.3, we instead plot a measure of relative liquidity, calculated by the Bank of England for the United Kingdom, and show that this series exhibits a negative average growth rate ( $-6.64$  per cent), with a sharp decline in the 1970's, and a continuing downward trend in the following years. There also exists some empirical evidence at a cross-sectional level. In a sample of 100 countries in the period 1970-2010, low-income countries do, on average, have an amount of bank liquid reserves (as a percentage of total assets) of around 26 per

Table 4.1: Bank Liquid Reserves to Bank Assets Ratio (%)

	1970	1990	2010	Average 1970-2010
Low-income countries	30.95	32.97	33.18	26.30
Middle-income countries	14.90	18.95	23.38	19.96
High-income countries	5.37	4.96	6.54	6.76

Source: World Bank and IMF

cent, versus 20 per cent for middle-income countries, and 6.8 per cent for high-income countries. This pattern is consistent in every year of our sample, as shown in table 4.1.

## 4.4 The Model

### 4.4.1 Preferences, Endowments and Technology

Time is infinite and discrete. The economy is populated by two-period-living overlapping generations of agents. At each point in time, a new cohort is born, represented by a unitary continuum of ex ante identical agents, each endowed with one unit of labor when born, and zero units in the second period of their lifetime.

All agents in the economy are affected by some idiosyncratic uncertainty, which hits them in the form of a preference shock. At the end of the first period of their lives, every newborn agent publicly draws a type  $\theta \in \{0, 1\}$ , where  $\pi > 0$  is the probability of being of type 0.<sup>4</sup> The preference shocks are independent and identically distributed so that, by the law of large numbers, the cross-sectional distribution of the types is equivalent to their probability distribution:  $\pi$  is the fraction of agents which turns out to be of type 0, and the fraction of agents which is of type 1 is  $(1 - \pi)$ . The role of the individual types is to affect the point in time at which the agents enjoy consumption. This happens according

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<sup>4</sup>By assuming that the preference shocks are publicly revealed, we implicitly rule out bank run equilibria.

to the utility function:

$$U(c_t^t, c_{t+1}^t, \theta) = (1 - \theta)u(c_t^t) + \theta u(c_{t+1}^t), \quad (4.1)$$

where the superscript indicates the birth date, and the subscript the period in which the s consume. Clearly, if  $\theta = 0$ , the agent is willing to consume only in the first period of her life, and if  $\theta = 1$  she will consume only in the second one. As is customary in this line of research, we then refer to type-0 and type-1 agents as “early” (or impatient) and “late” (or patient) consumers, respectively. The felicity function  $u(c)$  is increasing, twice continuously differentiable, strictly concave, and satisfies the Inada conditions. Moreover, the coefficient of relative risk aversion  $-u''(c)c/u'(c)$  is larger than or equal to 1.

In order to finance the consumption bundle in  $t$  and  $t + 1$ , two different technologies are available. The first is employed by a perfectly competitive firm, and is represented by a neoclassical production function  $Y_t = Rf(K_t, A_tL_t)$ , with constant returns to scale,  $f' > 0$  and  $f'' < 0$ .  $R$  is a scale parameter, whose role will soon be clear, when we talk about the banking problem. Labor, inelastically provided by the newborn cohort at each point in time, is augmented by an exogenous technological process  $A_t$ , and yields the salary  $w_t = RA_t f_2(K_t, A_tL_t)$ . Capital instead needs “time to build”: the amount invested in  $t - 1$  matures only in  $t$ , yields a return  $r_t = Rf_1(K_t, A_tL_t)$ , and then fully depreciates. Importantly, we rule out intergenerational transfers, i.e. there exists no mechanism to transfer the return on capital received by the current old cohort to the current impatient s. This hypothesis, together with time to build, ensures that the capital will only be held ex post by the patient s. Therefore, there exists a role for a storage technology, that we call “liquidity”, to finance the consumption of those who turn out to be impatient: it yields one unit of the consumption good for each unit invested at the beginning of the period.

#### 4.4.2 Investment Opportunities

The preference structure and the available technologies imply that the  $s$  in this economy must make a non-trivial investment decision: once they receive their salaries, they must decide their holdings of liquidity and capital, before knowing if they will turn out to be patient or impatient (because the idiosyncratic shock is revealed at the end of period  $t$ ). For this purpose, there are two investment channels that the agents can exploit: they can directly trade in the market, or sign a deposit contract with a bank. This investment decision is discrete (i.e. the  $s$  either deposit their salary in the bank or invest it in the market), and is denoted by the dummy variable  $\phi_t$ , which takes the value of 1 if the  $s$  invest in the market, or 0 if they make a deposit in the bank.

When the  $s$  invest in the market, they take their own investment decisions after the payment of a fixed cost  $\xi$ . The problem in the market then reads:

$$V^M(w_t, r_{t+1}, p_t) = \max_{\{x_t^t, x_{t+1}^t, z_t^M, k_{t+1}^M\}} \pi u(x_t^t) + (1 - \pi)u(x_{t+1}^t), \quad (4.2)$$

subject to:

$$z_t^M + k_{t+1}^M = w_t - \xi, \quad (4.3a)$$

$$z_t^M + p_t k_{t+1}^M = x_t^t, \quad (4.3b)$$

$$r_{t+1} \left( k_{t+1}^M + \frac{z_t^M}{p_t} \right) = x_{t+1}^t. \quad (4.3c)$$

The agents choose how much to consume in  $t$  and  $t + 1$  ( $x_t^t$  and  $x_{t+1}^t$ , respectively) and the amounts of liquidity ( $z_t^M$ ) and capital ( $k_{t+1}^M$ ) to maximize their expected welfare, subject to the budget constraints. At the beginning of period  $t$ , they work and get a salary  $w_t$ , pay the fixed entry cost  $\xi$ , and invest what remains in liquidity and capital (equation (4.3a)). Then, at the end of period  $t$ , they all get to know their individual types, and a secondary market opens, where they can exchange liquidity and capital at price  $p_t$ . This means that the consumption of the impatient

s at the end of period  $t$  (equation (4.3b)) is equal to the liquidity held in portfolio ( $z_t^M$ ), plus the proceeds that they earn from selling their holdings of capital ( $p_t k_{t+1}^M$ ). Similarly, the consumption of the patient s at  $t+1$  (equation (4.3c)) is equal to the return on the capital invested in the previous period ( $r_{t+1} k_{t+1}^M$ ), plus the return on the amount of capital bought in the secondary market ( $r_{t+1} z_t^M / p_t$ ). The s are price-takers, so the total welfare  $V^M$  that they enjoy from directly trading in the market is a function of the salary  $w_t$ , the return to capital  $r_{t+1}$ , and the price  $p_t$  in the secondary market, which are determined in equilibrium.

The second channel that the agents can employ to make their investments is the banking system. That is, each newborn cohort can form a coalition, called “bank”, that collects the salaries of its members and invests in liquidity and capital on their behalf. For this bank portfolio problem to be interesting, we need some further assumptions. The banks pay an iceberg cost  $\tau$  on the return to the invested capital  $r_t$ . The parameter  $R$  must be such that  $(1 - \tau)r_t > 1$ : if that were not the case, the banks would invest all their capital in the storage technology, and roll it over to the following period to finance late consumption. Moreover, we assume that there exists a technology through which the banks can liquidate their capital investment before its maturity, but its return is lower than unity: in this way, the banks are forced to hold liquidity to finance early consumption. Importantly, we also assume that the banks, as coalitions of s belonging to the same cohort, live for two periods only. In fact, Qi (1994) shows that an infinitely-lived bank would operate as a social planner: it would only invest in capital, since it yields a higher return than liquidity, and use it to finance the consumption of both patient and impatient s, thus allowing intergenerational transfers. We rule this possibility out, exactly because we are interested in the bank portfolio choice and its evolution. Finally, we assume free entry in the banking sector, so that profits in equilibrium are zero, and characterize a pure-strategy symmetric equilibrium so that, without loss of generality, we can focus our attention on the behavior of a representative bank solving the dual problem:

$$\max_{\{c_t^t, c_{t+1}^t, z_t^B, k_{t+1}^B\}} \pi u(c_t^t) + (1 - \pi)u(c_{t+1}^t), \quad (4.4)$$

subject to the budget constraints:

$$z_t^B + k_{t+1}^B = w_t, \quad (4.5a)$$

$$z_t^B = \pi c_t^t, \quad (4.5b)$$

$$(1 - \tau)r_{t+1}k_{t+1}^B = (1 - \pi)c_{t+1}^t, \quad (4.5c)$$

and to the participation constraint:

$$\pi u(c_t^t) + (1 - \pi)u(c_{t+1}^t) \geq V^M(w_t, r_{t+1}, p_t). \quad (4.6)$$

The representative bank exploits the law of large numbers to choose how to optimally invest the total deposits in liquidity and capital (equation (4.5a)), so as to maximize the expected welfare of its customers. The liquidity  $z_t^B$  is employed to pay an amount of early consumption  $c_t^t$  to  $\pi$  impatient depositors (equation (4.5b)) and the return to the capital investment  $(1 - \tau)r_{t+1}k_{t+1}^B$  is employed to pay the late consumption  $c_{t+1}^t$  to  $(1 - \pi)$  patient depositors (equation (4.5c)).<sup>5</sup> Finally, the banks are in competition with what the depositors can achieve in the market, so the contract  $\{c_t^t, c_{t+1}^t\}$  must be such that the s are at least as well off as they would be if they choose the alternative investment option. This is ensured by imposing the participation constraint in (4.6).<sup>6</sup>

With these descriptions in hand, we are ready to define the object of our analysis, which we call “constrained banking equilibrium”:

**Definition 10.** *Given an initial value  $K_0$ , a constrained banking equilibrium is a price vector  $\{r_t, w_t, p_t\}$ , a bank portfolio strategy  $\{z_t^B, k_{t+1}^B\}$  and a deposit contract  $\{c_t^t, c_{t+1}^t\}$ , an individual portfolio strategy  $\{z_t^M, k_{t+1}^M\}$*

<sup>5</sup>The fact that the realizations of the idiosyncratic types are public information implies that we do not need to impose an incentive compatibility constraint. Incidentally, we could choose the scale parameter  $R$  to be high enough to ensure that  $c_{t+1}^t \geq c_t^t$ , so that our results would not change even if the types were private.

<sup>6</sup>This is similar in spirit to the “disintermediation constraint” of Allen and Gale (1997).

and a consumption allocation  $\{x_t^t, x_{t+1}^t\}$ , a market participation choice  $\phi_t \in \{0, 1\}$ , and production inputs  $\{K_t, L_t\}$  for every  $t = 0, 1, \dots$  such that:

- For given prices, the deposit contract and the bank portfolio strategy solve the banking problem in (4.4);
- For given prices, the consumption allocation and the individual portfolio strategy solve the problem in the market in (4.2);
- For given prices, the production inputs maximize firm profits;
- Markets clear:

$$K_t = (1 - \phi_t)k_t^B + \phi_t k_t^M, \quad (4.7)$$

$$L_t = 1. \quad (4.8)$$

The important thing to notice is that, given that the individual investment choice is discrete, the total capital in the economy comes either in the form of bank credit or in the form of equity. Moreover, labor supply is inelastic, so in equilibrium total labor is fixed, and equal to 1.

### 4.4.3 Timing

To conclude this section, we sum up the timing of actions. In each period  $t$ , (i) production takes place, with the capital cumulated by the patient  $s$  born at  $t - 1$  (which characterizes the state of the economy) and the labor provided by the newborn cohort; (ii) the patient  $s$  from period  $t - 1$  consume the return on capital  $r_t$ , and the young  $s$  receive the salary  $w_t$ ; (iii) the representative bank chooses the deposit contract for the newborn generation, stating the amount of consumption goods that they will receive at the end of period  $t$  and at  $t + 1$ ; (iv) the types are publicly revealed; (v) the secondary market for capital opens; (vi) the impatient  $s$  consume.

#### 4.4.4 Unconstrained Banking Equilibrium

As a benchmark to the main problem, we start our analysis with the characterization of the unconstrained banking equilibrium. That is, we solve the problem in (4.4) only subject to the budget constraints (4.5a)-(4.5c): the representative bank collects the wages, and invests them in liquidity and capital on behalf of their customers, so as to have the right amount of consumption good at  $t$  and  $t + 1$  that maximizes their welfare. We label  $V_U^B$  the utility function from this problem. From the date- $t$  budget constraint, it is easily seen that in the long run it must be the case that liquidity, capital, and the salary (and, as a consequence, production) must grow at the same rate, thus the following holds:

**Lemma 6.** *In the unconstrained banking equilibrium, the liquidity ratio  $\mathcal{L}_t \equiv \frac{z_t^B}{w_t}$  is constant in the long run.*

We plug the budget constraints into the objective function and solve:

$$\max_{k_{t+1}} \pi u \left( \frac{w_t - k_{t+1}}{\pi} \right) + (1 - \pi) u \left( \frac{(1 - \tau)r_{t+1}k_{t+1}}{1 - \pi} \right). \quad (4.9)$$

The equilibrium of this environment is characterized by the budget constraints of the bank and by the Euler equation:

$$u'(c_t^t) = (1 - \tau)r_{t+1}u'(c_{t+1}^t). \quad (4.10)$$

In equilibrium, the representative bank chooses an allocation such that the marginal rate of substitution between early and late consumption  $u'(c_t^t)/u'(c_{t+1}^t)$  is equal to the marginal rate of transformation  $(1 - \tau)r_{t+1}$ . Since the market clearing condition implies that  $K_t = k_t^B$  (i.e. we only have intermediated capital), this Euler equation is an implicit difference equation that characterizes the evolution of the total capital in the economy.

With a logarithmic felicity function, we can use the budget constraints and the Euler equation to derive a closed-form solution to the



equilibrium deposit contract:

$$c_t^t = w_t, \quad (4.11)$$

$$c_{t+1}^t = (1 - \tau)r_{t+1}w_t. \quad (4.12)$$

Those depositors who turn out to be impatient receive exactly the amount that they deposited, and those who instead turn out to be patient receive an amount of consumption equal to what they would receive if they invested all their deposits in capital. This also implies that the liquidity ratio  $\mathcal{L}_t \equiv z_t^B/w_t$  is constant at every point in time, and equal to  $\pi$ . This is a consequence of the fact that the income and substitution effects cancel out, thus any change in the return from capital does not affect the relative allocation of the initial portfolio.

With the degree of relative risk aversion being larger than 1, we instead cannot find a closed-form solution to the equilibrium contract. However, two well-known results emerge, as shown in a numerical example in figure 4.4.<sup>7</sup> First, the income effect dominates the substitution effect, meaning that, as the economy grows and capital increases, the return on capital  $r_t$  drops and the bank rebalances its portfolio by relatively increasing its investment in capital. That is, the liquidity ratio decreases in the transition towards the steady state.

The second result instead states that the liquidity ratio  $\mathcal{L}_t$  is strictly larger than  $\pi$  at any point in time (both in the transition and in the steady state). To see this, assume that  $\mathcal{L}_t \leq \pi$ . By the budget constraints in (4.5a)-(4.5c), this implies that  $c_t^t \leq w_t$  and  $c_{t+1}^t \geq (1 - \tau)r_{t+1}w_t$ . Then, by the Euler equation in (4.10):

$$(1 - \tau)r_{t+1} = \frac{u'(c_t^t)}{u'(c_{t+1}^t)} > \frac{c_{t+1}^t}{c_t^t} \geq (1 - \tau)r_{t+1}, \quad (4.13)$$

where the strict inequality comes from the degree of relative risk aversion

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<sup>7</sup>We assume that the felicity function is CRRA, with the degree of relative risk aversion  $\sigma = 4$  and  $\pi = .28$ . The production function is  $Y_t = K_t^\alpha (A_t L_t)^{1-\alpha}$ , with  $\alpha = .45$ . The exogenous technological trend is  $A_t = R(1 + \gamma)^t$ , with  $R = 2.3626$  and  $\gamma = .02$ . The tax rate is  $\tau = .05$ .

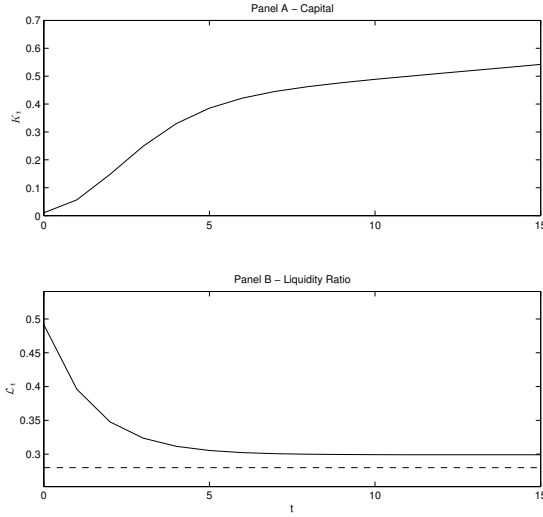


Figure 4.4: The evolution of the total capital and of the liquidity ratio in the unconstrained banking equilibrium.

being larger than 1, and is clearly a contradiction.<sup>8</sup> This result shows that the representative bank engages in the cross-subsidization of the impatient depositors in equilibrium: in order to provide insurance against the risk of being impatient (and not being able to enjoy the higher return guaranteed by the return to capital), the bank compresses the ex post income profile of its customers, and offers a contract where the amount of early consumption  $c_t^E$  is higher than the initial deposit  $w_t$ , and the late consumption is lower than the amount that the patient depositors would get if they invested all their deposits in capital.

<sup>8</sup>To see this, rewrite  $-\frac{u''(c)c}{u'(c)} > 1$  as  $-\frac{u''(c)}{u'(c)} > \frac{1}{c}$ . This is equivalent to  $-(\log[u'(c)])' > (\log[c])'$ . Integrate between  $z_1$  and  $z_2 > z_1$  so as to obtain  $\log[u'(z_1)] - \log[u'(z_2)] > \log[z_2] - \log[z_1]$ . Once taken the exponential, the last expression gives  $\frac{u'(z_1)}{u'(z_2)} > \frac{z_2}{z_1}$ . If  $z_1 > z_2$ , the inequality is reversed.

## 4.5 Constrained Banking Equilibrium

We now characterize the constrained banking equilibrium defined in the previous section, where the representative bank must satisfy the participation constraint. To this end, we need to start from the characterization of the solution to the problem in the market. In particular, we can prove the following:

**Lemma 7.** *In every constrained banking equilibrium,  $p_t = 1$ .*

The rationale for this result is simple. If  $p_t > 1$ , the investment in capital would be more remunerative than the investment in liquidity. Then, those agents who turn out to be impatient would like to sell their holdings of capital in the secondary market. However, there would be no buyer, and the price  $p_t$  would go to zero, leading to a contradiction. In a similar way, if  $p_t < 1$ , liquidity dominates capital. This means that the agents who turn out to be patient would like to use their holdings of liquidity to buy capital, but there would be no seller in the secondary market, and the price would go to infinity, once more leading to a contradiction. Intuitively, given that the  $s$  are all ex ante identical, the only possible equilibrium price is the one that makes them indifferent between holding liquidity and capital. This also means that the equilibrium asset portfolio of the agents in the market is undetermined. Yet, despite this indeterminacy, we can still use the budget constraints in (4.3a)-(4.3c) (with  $p_t = 1$ ) to find:

**Lemma 8.** *The solution to the problem of the agents trading in the market is:*

$$x_t^t = w_t - \xi, \quad (4.14)$$

$$x_{t+1}^t = r_{t+1}(w_t - \xi). \quad (4.15)$$

*The liquidity ratio in the market is:*

$$\mathcal{L}_t^M = \frac{\pi x_t^t}{w_t - \xi} = \pi. \quad (4.16)$$

It is important to notice that the liquidity ratio in the market  $\mathcal{L}_t^M$  is always lower than or equal to what the representative bank chooses in the unconstrained problem. This result means that the market allocation does not provide ex post the same level of cross-subsidization that the banks are able to offer in the unconstrained problem, and formally shows the origin of the inefficiency of the market solution: the price does not reflect the willingness of the agents to smooth consumption across time, as a consequence of the fact that the agents do not have access to a complete set of state-contingent claims.<sup>9</sup> In the literature on financial intermediation, these considerations provide a rationale for the emergence of a banking equilibrium, equivalent to our unconstrained equilibrium, which Pareto-dominates the market solution (Diamond and Dybvig, 1983). Here the presence of the bank iceberg-type cost and of the market entry cost instead allows us to rule out this dominance, because it makes the bank compete with an institution (i.e., the market) that, in all effects, employs a different technology.

With the characterization of the problem in the market at hand, we can now solve for the constrained banking equilibrium by plugging the budget constraints into the objective function and the participation constraint:

$$\max_{k_{t+1}} \pi u \left( \frac{w_t - k_{t+1}}{\pi} \right) + (1 - \pi) u \left( \frac{(1 - \tau)r_{t+1}k_{t+1}}{1 - \pi} \right), \quad (4.17)$$

subject to:

$$\pi u \left( \frac{w_t - k_{t+1}}{\pi} \right) + (1 - \pi) u \left( \frac{(1 - \tau)r_{t+1}k_{t+1}}{1 - \pi} \right) \geq V_M(w_t, r_{t+1}, p_t), \quad (4.18)$$

where:

$$V_M(w_t, r_{t+1}, p_t) = \pi u(w_t - \xi) + (1 - \pi) u(r_{t+1}(w_t - \xi)). \quad (4.19)$$

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<sup>9</sup>As highlighted by Wallace (1988), the restriction on the individual access to state-contingent claims naturally arises in every model where financial intermediation plays a role.

Attach the Lagrange multiplier  $\eta_t$  to (4.18). The first-order condition reads:

$$(1 + \eta_t) [u'(c_t^t) - (1 - \tau)r_{t+1}u'(c_{t+1}^t)] = 0. \quad (4.20)$$

Clearly, since the multiplier  $\eta_t$  must be non-negative, the only solution that satisfies the optimality condition is the unconstrained optimum:

$$u'(c_t^t) = (1 - \tau)r_{t+1}u'(c_{t+1}^t), \quad (4.21)$$

providing utility  $V_U^B$ . From here, two cases are possible: either (i)  $\eta_t = 0$  and  $V_U^B > V^M$ , or (ii)  $\eta_t > 0$  and  $V_U^B = V^M$ . This allows us to identify a threshold level of capital  $\hat{K}$  at which  $V_U^B = V^M$ , or:

$$\pi u(c_t^t(\hat{K})) + (1 - \pi)u(c_{t+1}^t(\hat{K})) = \pi u(x_t^t(\hat{K})) + (1 - \pi)u(x_{t+1}^t(\bar{K})), \quad (4.22)$$

that is, such that the  $s$  are indifferent between the bank channel and the market channel. With log-utility, we already know that  $c_t^t = w_t$  and  $c_{t+1}^t = (1 - \tau)r_{t+1}w_t$ , so we can express the threshold in terms of a salary level:

$$\bar{w} = \frac{\xi}{1 - (1 - \tau)^{1-\pi}}. \quad (4.23)$$

Thus, as long as  $w_t \leq \bar{w}$ , the constrained banking equilibrium exists, and is equivalent to the unconstrained optimum. As the economy grows, and  $w_t$  becomes larger than  $\bar{w}$ , the banks are not able to sustain an allocation that satisfies the participation constraint, thus no constrained banking equilibrium exists, and all agents choose the market channel. We summarize these findings in the following:

**Lemma 9.** *If  $K_t < \hat{K}$ , the constrained banking equilibrium is equivalent to the unconstrained equilibrium, and the market participation rate is  $\phi_t = 0$ . If  $K_t \geq \hat{K}$ , there exists no constrained banking equilibrium, and  $\phi_t = 1$ .*

We use this characterization of the equilibrium to derive the properties of the relative liquidity of the overall financial system in the constrained problem. At low levels of development, only the banks exist and,

as we showed in the characterization of the unconstrained problem, they choose an amount of relative liquidity that is higher than or equal to  $\pi$ , constant in the long run, and decreasing during the transition path if the degree of relative risk aversion is larger than 1. After the economy reaches the threshold  $\hat{K}$ , the banks cannot sustain the competition from the markets, and the relative liquidity of the financial system drops:

**Proposition 11.** *In the constrained banking equilibrium, the liquidity ratio of the financial system is  $\mathcal{L}_t > \pi$  if  $K_t < \hat{K}$ , and  $\mathcal{L}_t = \pi$  if  $K_t \geq \hat{K}$ .*

#### 4.5.1 A Numerical Example

To shed some more light on the constrained banking equilibrium, we conclude this section with a numerical example, where we show how the liquidity ratio in the financial system drops as the market participation rate increases. To this end, we choose the felicity function  $u(c)$  to be CRRA, with the degree of relative risk aversion  $\sigma = 4$ , and the probability of being an impatient consumer  $\pi = .28$ , as calibrated by Mattana and Panetti (2013).<sup>10</sup> The production function is Cobb-Douglas, with  $Y_t = RK_t^\alpha(A_tL_t)^{1-\alpha}$  and  $\alpha = .3$ . We follow Romer (1990) and model the exogenous technological trend  $A_t$  as a capital externality, that is,  $A_t = \bar{K}_t$ , where  $\bar{K}_t$  is the average capital in the whole economy. This implies the simplifying results that the economy is always in steady state, and that the equilibrium return on capital is constant and equal to  $r_t = \alpha R$ . We further pick  $\tau$  to be 5 per cent, and the scaling parameter  $R$  such that the interest rate (net of taxes) paid by the banks is equal to 1.3. Finally, we divide every newborn generation into three groups of dimension  $\mu^i$ , with  $\sum_i \mu^i = 1$ , that are heterogeneous with respect to the market entry costs  $\xi^i$ , with  $\xi^1 < \xi^2 < \xi^3$ . The agents form banking coalitions separately in each group, so that there are three represen-

<sup>10</sup>Mattana and Panetti (2013) derive  $\pi$  by calibrating a dynamic model of banking with infinitely-lived agents to the U.S. economy. The authors use the resource constraint and the liquidity constraint of the bank, and find that  $\pi = \frac{z_t/Y_t}{1-I_t/Y_t}$ , where  $I_t$  is gross total investment. In the data, liquid assets as a percentage of GDP are around .21, and the investment/GDP ratio is around .25. This yields the given value of  $\pi$ .

Table 4.2: Parameters of the Numerical Example

$\pi$	$\sigma$	$\alpha$	$R$	$\tau$	$\mu^1$	$\mu^2$	$\mu^3$	$\xi^1$	$\xi^2$	$\xi^3$
0.28	4	0.3	4.5614	0.05	0.3	0.4	0.3	0.5	10	200

tative banks in the economy, each facing a different incentive problem (depending on the market entry cost).<sup>11</sup> We summarize our choice of the parameters in table 4.2.

In figure 4.5, we plot the time series of the relative liquidity of the financial system (panel A), both in the unconstrained and the constrained optimum, and the market participation rates (panel B). The equilibrium salary is  $w_t = (1 - \alpha)RK_t$ , and the Euler equation in (4.10) gives the amount of future capital in the unconstrained problem as:

$$K_{t+1}^U = \frac{1}{1 + \frac{\pi}{1-\pi}[\alpha R(1-\tau)]^{1-\frac{1}{\sigma}}} w_t, \quad (4.24)$$

which is lower than  $(1 - \pi)w_t$  because  $\sigma > 1$  and  $\alpha R(1 - \tau) > 1$ . From here, we can solve for the constant liquidity ratio  $\mathcal{L}^U = 1 - (K_{t+1}^U/w_t) \approx .32$ , which is larger than the fraction of impatient depositors  $\pi$  and reflects the willingness of the banks to cross-subsidize them. In the constrained problem, in line with the prediction of lemma 9, the banks in the three groups cannot instead sustain the participation of their customers at three different points in time. Thus, the groups move away in sequence from the banking allocation to the market and, in accordance with proposition 11, the relative liquidity converges stepwise towards  $\pi$ .

In figure 4.6, we report the evolution of the real side of the economy. In panel A, we plot the time series of total capital, and in panel B the growth rate of the economy, again both in the unconstrained and constrained problems. Given the equilibrium salary and the optimal portfolio allocation in (4.24), it is easy to derive the steady-state (gross) growth

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<sup>11</sup>This assumption is not restrictive: a single representative bank for the whole economy would still discriminate between the three groups and offer them three group-specific contracts.

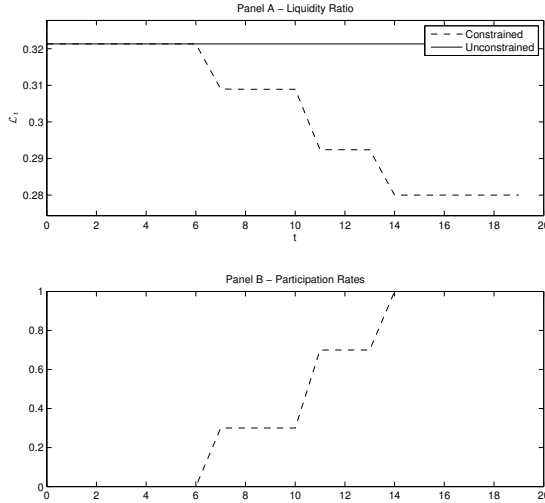


Figure 4.5: The evolution of the liquidity ratio and of the participation rates in the unconstrained and the constrained banking equilibrium.

rate in the unconstrained equilibrium as:

$$g^U \equiv \frac{K_{t+1}^U}{K_t} = \frac{(1 - \alpha)R}{1 + \frac{\pi}{1-\pi}[\alpha R(1 - \tau)]^{1-\frac{1}{\sigma}}}. \quad (4.25)$$

By market clearing, we instead have that the equilibrium capital in the constrained problem is:

$$\begin{aligned} K_{t+1}^C &= \sum_i \mu^i [\phi_t^i(1 - \pi)(w_t - \xi^i) + (1 - \phi_t^i)K_{t+1}^U] = \\ &= (1 - \alpha)RK_t \sum_i \mu^i \left[ \phi_t^i(1 - \pi) + \frac{1 - \phi_t^i}{1 + \frac{\pi}{1-\pi}[\alpha R(1 - \tau)]^{1-\frac{1}{\sigma}}} \right] + \\ &\quad - (1 - \pi) \sum_i \mu^i \phi_t^i \xi^i, \end{aligned} \quad (4.26)$$

where  $\phi_t^i$  is the market participation rate in group  $i$ . Thus, the growth



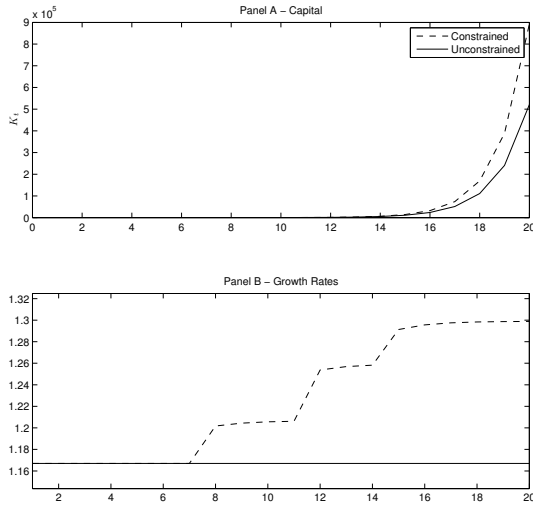


Figure 4.6: The evolution of the total capital and of the growth rate of the economy in the unconstrained and the constrained banking equilibrium.

rate is:

$$\begin{aligned}
 g^C = & (1 - \alpha)R \sum_i \mu^i \left[ \phi_t^i (1 - \pi) + \frac{1 - \phi_t^i}{1 + \frac{\pi}{1-\pi} [\alpha R (1 - \tau)]^{1-\frac{1}{\sigma}}} \right] + \\
 & - \frac{1 - \pi}{K_t} \sum_i \mu^i \phi_t^i \xi^i.
 \end{aligned} \tag{4.27}$$

The first term of this expression is higher than or equal to the unconstrained growth rate  $g^U$ , because it is a weighted average of two terms that are higher than  $g^U$  since we proved that:

$$\frac{1}{1 + \frac{\pi}{1-\pi} [\alpha R (1 - \tau)]^{1-\frac{1}{\sigma}}} < 1 - \pi. \tag{4.28}$$

The second term is an increasing and concave function of the level of capital  $K_t$ , with  $\sum_i \mu^i \phi_t^i \xi^i$  being a constant once the agents in group  $i$  abandon the banking scheme. Therefore, the panel B of figure 4.6 shows that the growth rate in the constrained problem increases stepwise, and

converges toward a higher steady-state than in the unconstrained optimum, leading to a higher level of capital.

## 4.6 Econometric Analysis

The main result of the previous sections highlights an explanation for the decreasing trend in the relative liquidity of the financial system that we observe in the data: as the economy develops, the agents abandon the banks, which provide high relative liquidity, for the market allocation, where the relative liquidity is lower. Thus, an interesting consequence of this mechanism is that, as the barriers to enter the market become lower, the competitive pressure on the banks should build up, thus pushing the liquidity ratio of the whole financial system further down:  $\frac{\partial \mathcal{L}_t}{\partial \xi} > 0$ .

The aim of this section is to return to the data, and test the validity of this theoretical prediction by estimating the following equation:

$$\log(liqratio_{it}) = \beta_0 + \beta_1 SMP_{it} + \beta_2 \log(RGDP_{it}) + \beta_3 X_{it} + \mu_t + \epsilon_{it}. \quad (4.29)$$

As a proxy for the relative liquidity of the financial system, we want to exploit the unbalanced panel of bank relative liquidity that we briefly analyzed in section 4.3. Our dependent variable *liqratio* is defined as the ratio of domestic currency holdings and deposits with the monetary authorities to claims on other governments, nonfinancial public enterprises, the private sector, and other banking institutions. As mentioned earlier, this is a commonly-used indicator of the liquidity available to the banks to meet expected and unexpected demands for cash.<sup>12</sup>

As the independent variable, we need a real-world equivalent of the exogenous fixed cost  $\xi$ , which we interpret as an intrinsic transaction cost or institutional impediment that affects the possibility of accessing the alternative market channel. To this end, we use the variable

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<sup>12</sup>A version of the Fisher test developed by Maddala and Wu (1999) (that we use here because it does not require a balanced panel) rejects the null hypothesis of non-stationarity of the series ( $\chi^2 = 203.22$ ) at a 1 per cent significance level. More details about the construction of the variable are available in Appendix A.

“Securities market policy” (*SMP*) that we draw from the database of financial reforms produced by the IMF (Abiad et al., 2008), an unbalanced panel that covers various regulatory changes affecting the financial system (credit controls, interest rate controls, entry barriers, state ownership, etc.) in around 90 countries for the period 1970-2010. *SMP* is an index summarizing all regulatory interventions that make the access to security markets easier.<sup>13</sup> The index takes the value of 0 if a securities market does not exist, and increases in discrete steps up to 3, as the system becomes fully liberalized. The prediction from our theory says that, as the access to the market becomes easier (i.e., the index of securities market policy increases) the liquidity ratio should decrease, which means that  $\beta_1 < 0$ .

We also add a series of controls to the analysis. First, since the theory predicts the liquidity ratio to decrease with economic development, we add the real GDP per capita as regressor. Second, since the process of financial liberalization in reality almost never affects only one part of the financial system, but generally comes as a wave of regulation and deregulation of various aspects of the system itself, we want to test whether the evolution of our securities market policy index does not reflect some broader regulatory change. Hence, we control for some other measures of financial liberalization: the indices of credit controls and banking sector supervision drawn from the same IMF database, and the Chinn-Ito measure of openness in capital account transactions (Chinn and Ito, 2008). Third, to take care of any other worldwide aggregate shock that might influence the bank liquidity ratio, we add time dummies. We control for all other country-specific characteristics (like the institutional environment, or country-specific shocks) that we do not explicitly include as regressors via fixed effects. However, we also report the estimates of a random effect model, and the  $\chi^2$  of the Hausman test, that never rejects

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<sup>13</sup>According to the authors, these include “[...] the auctioning of government securities, establishment of debt and equity markets, and policies to encourage development of these markets, such as tax incentives or developments of depository and settlement systems”.

the hypothesis that the difference in the coefficients is non-systematic. Finally, in all our specifications, the Fisher test rejects the hypothesis of the presence of unit roots in the residuals.

We report our results in table 4.3. The coefficient of the securities market policy index on the first row is significant and has the expected sign: a one-unit increase in the index leads to a drop in the bank liquidity ratio of around 22 percentage points. The inclusion of real GDP as a regressor affects neither the significance nor the magnitude of the coefficient in a notable way (columns 3 and 4). However, once we control for other forms of financial liberalization (columns 5 to 10), the coefficient falls slightly, while still being highly significant: at its lowest estimate, a one-unit increase in the SMP index leads to a drop in the liquidity ratio of around 13 percentage points.

In order to further analyze the non-linearities between securities market liberalization and the bank liquidity ratio, we split our indicator into four dummy variables, corresponding to the four values it takes in the data. Then, we study the nonlinear effects of financial liberalization both directly on the bank liquidity ratio and indirectly through the interaction of the dummies with real GDP.

The results are reported in table 4.4. Columns 1 to 4 show that the negative average effect found in the previous table kicks in only when an extensive process of securities market liberalization is implemented: moving the index from 0 to 2 would lead to a drop in the bank liquidity ratio of between 23 and 25 per cent, while moving it from 0 to 3 would lead to a drop of between 29 and 37 per cent. The introduction of very mild reforms (i.e. moving the index from 0 to 1) instead only has a slightly significant effect once we control for the level of real GDP, and tends to increase the bank liquidity ratio by roughly 16 per cent. These results are confirmed when we interact the dummies with real GDP (columns 5-6): moving the index from 0 to 2 would increase the negative effect of GDP on the liquidity ratio by around 3.3-3.7 percentage points, while moving it from 0 to 3 would increase the negative effect by more than 5 per cent. Moving from 0 to 1 would instead not have any effect that is

statistically different from zero.

## 4.7 Concluding Remarks

In the present work, we develop a theory of finance and growth to explain the decreasing trend in relative liquidity of many financial systems around the world as a consequence of the evolution of the architecture of the financial system, during the process of economic development. We characterize the equilibrium of a growth model where banks and markets compete for the provision of insurance services and investment opportunities to the households, and we showed that, after a certain threshold, the market allocation is preferred to the banking equilibrium, and the relative liquidity of the overall financial system drops, as the markets are not able to provide *ex post* the same cross-subsidization of the impatient depositors offered by the banks. We also find evidence of such a mechanism being in place in the real world: a one-unit increase in the index of securities market liberalization (that we take as a proxy for the market entry costs) leads to a drop in the relative liquidity of between 13 and 22 percentage points.

To conclude, we believe that our work is interesting because it allows us to have a first look at a class of models that can be used in the future to answer very different questions. In particular, this environment can be extended to formally model financial innovation, and in this way endogenize the bank technological/regulatory constraint  $\tau$ , or we can introduce search in the stock market, so as to endogenize the market entry cost  $\xi$ . We might also run a growth accounting exercise, to quantitatively evaluate the contribution of intermediaries and markets on the observed growth rate of GDP, or feed the model with high frequency shocks and study its business cycle properties. These last two extensions would require the abandonment of the current OLG structure, which is not well-suited for a quantitative analysis, in favor of a representative agents set-up. We leave all these considerations to future research.

Table 4.3: Bank Liquidity Ratio and Market Participation: Direct Effect

Dep. variable: <i>log(liqratio)</i>	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Securities Markets Policy (SMP)	-0.246*** (-3.543)	-0.252*** (-3.872)	-0.257*** (-3.722)	-0.221*** (-3.412)	-0.208*** (-3.471)	-0.181*** (-3.186)	-0.161*** (-2.703)	-0.138*** (-2.437)	-0.171*** (-2.813)	-0.150*** (-2.600)
(Log of) Real GDP			-0.638** (-2.498)	-0.364*** (-3.400)	-0.700*** (-3.271)	-0.463*** (-4.626)	-0.786*** (-3.727)	-0.475*** (-4.727)	-0.754*** (-3.512)	-0.455*** (-4.400)
Financial Openness					0.039 (1.402)	0.036 (1.342)	0.048* (1.750)	0.047* (1.761)	0.051* (1.841)	0.050* (1.881)
Credit Controls							-0.202*** (-5.024)	-0.197*** (-5.023)	-0.197*** (-4.830)	-0.191*** (-4.815)
Banking Supervision									-0.048 (-0.811)	-0.060 (-1.059)
Constant	-1.567*** (-7.482)	-1.802*** (-8.315)	3.546* (1.724)	1.188 (1.320)	4.089** (2.387)	1.922** (2.281)	4.714*** (2.794)	2.377*** (2.789)	4.602*** (2.586)	2.313*** (2.685)
Observations	739	739	737	737	716	716	716	716	716	716
Number of countries	45	45	45	45	45	45	45	45	45	45
Fisher $\chi^2$	111.55	112.34	125.23	129.23	107.45	109.19	102.85	107.44	107.59	113.30
Method	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE
Hausman $\chi^2$		5.06		0.47		9.49		0.93		11.77

t-statistics in parentheses. \*\*\* p&lt;0.01, \*\* p&lt;0.05, \* p&lt;0.1. Year effects included as controls.

Table 4.4: Bank Liquidity Ratio and Market Participation: Nonlinear and Interacted Effects

Dep. variable: $\log(\text{liquidity})$	(1)	(2)	(3)	(4)	(5)	(6)
SMP==1	0.140 (1.551)	0.132 (1.494)	0.134 (1.492)	0.148* (1.687)		
SMP==2	-0.276** (-2.099)	-0.293** (-2.326)	-0.263** (-2.016)	-0.231** (-1.836)		
SMP==3	-0.438*** (-2.262)	-0.457** (-2.498)	-0.420*** (-2.181)	-0.348** (-1.911)		
(Log of) Real GDP			-0.714*** (-3.276)	-0.434*** (-4.018)	-0.680*** (-3.129)	-0.405*** (-3.695)
(Log of) Real GDP * SMP==1					0.016 (1.413)	0.018 (1.583)
(Log of) Real GDP * SMP==2					-0.038** (-2.301)	-0.034** (-2.179)
(Log of) Real GDP * SMP==3					-0.056** (-2.452)	-0.050** (-2.311)
Constant	-1.692*** (-8.387)	-1.518*** (-6.138)	4.237** (2.327)	2.049*** (2.237)	3.933** (2.162)	1.839** (2.001)
Observations	716	716	716	716	716	716
Number of countries	45	45	45	45	45	45
Fisher $\chi^2$	134.59	135.39	133.09	137.40	134.53	138.50
Method	FE	RE	FE	RE	FE	RE
Hausman $\chi^2$		1.94		7.52		4.47

t-statistics in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Year effects, financial openness, credit controls and banking supervision included as controls.

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## A Data Appendix

- **Bank Supervision:** Index of banking sector supervision. It is the sum of three indices, normalized on a 0-3 scale. It includes: a dummy where 1 indicates when a country adopted a capital adequacy ratio based on the Basel standard; an index of independence of the banking supervisory agency, on a 0-2 scale; an index of effectiveness of banking supervision, on a 0-2 scale. Source: IMF (Abiad et al., 2008).
- **Credit Controls:** Index of credit controls and reserve requirements. It is the sum of three indices, normalized on a 0-3 scale. It includes: an index of restrictiveness of reserve requirements, on a 0-2 scale; a dummy where 1 indicates if mandatory credit allocations to certain sectors are eliminated or do not exist; a dummy where 1 indicates when the mandatory requirement of credit allocation at subsidized rates is eliminated or banks do not have to supply credits at subsidized rates. Source: IMF (Abiad et al., 2008).
- **Financial Openness:** The Chinn-Ito index of financial openness. It is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF Annual Report on Exchange Arrangements and Exchange Restrictions. The data are available for the period 1970 to 2010, for 182 countries. Source: Chinn and Ito (2008).
- **liqratio:** Bank liquid reserves to bank assets ratio (%). It is the ratio of domestic currency holdings and deposits with the monetary authorities to claims on other governments, nonfinancial public enterprises, the private sector, and other banking institutions. Data are available for the period 1947 to 2003, for 106 countries. Source: World Development Indicators, World Bank, and International Financial Statistics, IMF.
- **Real GDP:** PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices. Data are available for the period 1950 to 2009, for 189 countries. Source: Penn World Tables (Heston et al., 2011).

- **Securities Market Policy:** Index of securities market liberalization. It takes the value of 0 if a securities market does not exist; 1 when a securities market is starting to form with the introduction of auctioning of T-bills or the establishment of a security commission; 2 when further measures have been taken to develop securities markets (tax exemptions, introduction of median and long-term government bonds in order to build the benchmark of a yield curve, policies to develop corporate bond and equity markets, or the introduction of a primary dealer system to develop government security markets); 3 when further policy measures have been taken to develop derivative markets or to broaden the institutional investor base by deregulating portfolio investments and pension funds, or completing the full deregulation of stock exchanges. Source: IMF (Abiad et al., 2008).

# Sammanfattning

Denna avhandling består av tre uppsatser rörande de ekonomiska aspekterna av banker och marknader. Varje enskilt kapitel är självständigt, men de har alla ett tema och en metod som är gemensamma med de övriga kapitlen.

Det gemensamma temat är analysen av utvecklingen av den ”finansiella arkitekturen” – dvs blandningen av “finansiella intermediärer” (eller vanligare – banker) och marknader – i många utvecklings- och industrialiserade länder. Berger m.fl. (1995) hävdar exempelvis att banksystemet i USA har utvecklats från en ställning som en skyddad monopsonist där bankerna var de enda institutioner som hade rätt att samla in och investera hushållens besparingar, till ett marknadsorienterat system, där nya institutioner, allmänt kallade “nya finansiella intermediärer”, har utvecklat ett erbjudande om banktjänster utan att regleras som banker. Mer allmänt så har framväxten av dessa instrument och institutioner, vilka fick namnet “disintermediation” i det finansiella systemet, visat sig genom en ökande differentiering av hushållens portföljer. Guiso m.fl. (2002) visar att under de senaste tjugo åren har USA, såväl som många andra länder i världen, upplevt en dramatisk ökning i förhållandet mellan direkta och indirekta värdepappersinnehav för individuella investerare.

Metodologiskt är syftet med denna avhandling att studera hur banker och marknader interagerar sinsemellan ur ett teoretiskt perspektiv. I detta syfte tar det preliminära steget för att identifiera en strategi för att skapa en modell sin utgångspunkt i en mer grundläggande fråga: vad gör bankerna i ett modernt samhälle? I denna avhandling så intar jag en

ståndpunkt när det gäller vilken som är bankernas viktigaste roll och fokuserar på riskhantering: dvs, eftersom likviditet, betalningstjänster och tillgångsomvandling bidrar till detta, medan informationshantering och övervakning inte entydigt kännetecknar bankverksamheten, då många andra olika institutioner (t ex kreditvärderingsföretag, företag som tillhandahåller kreditvärdeshistorik osv) utför denna verksamhet utan att fungera som faktiska banker.

För att skapa en modell där bankerna är riskhanterare har jag inspirerats jag av Diamond och Dybvig (1983) uppsats. Deras modell har blivit ett standardramverk för att analysera de ekonomiska aspekterna av banksystemet eftersom den ger en tydlig och helt mikrobaserad logisk grund för dess existens, så som en mekanism för att decentralisera den effektiva allokeringen av likviditetsrisken. Inom denna teori fungerar bankerna som koalitioner av individer som förenar risker och gemensamt försäkrar sig mot en idiosynkratisk likviditetschock. I detta syfte så samlar bankerna insättningar och investerar dessa för kundernas räkning och tillhandahåller på så sätt en likviditetsomvandling.

Intresset för detta ramverk ligger också i det faktum att det utgör en lämplig modell för att besvara ett antal normativa frågor. Kapitel 2 och 3 använder i själva verket detta för att studera hur interaktionen mellan banker och marknader påverkar det sätt på vilket regeringen bör reglera det finansiella systemet. Detta är ett aktuellt ämne, speciellt då det efter finanskrisen 2007-2009 visade sig hur utvecklingen av det sk ”skugg-banksystemet” har utvidgat eftersläpningen mellan det finansiella systemet och de offentliga reglerarna och hur bristen på uppdaterad reglering kan leda till i det närmaste ödesdigra konsekvenser för samhället som helhet.

Viktigt är att jag i denna avhandling följer synsättet att det enda som berättigar en regeringsintervention i det finansiella systemet är när marknadsallokeringen inte uppfyller det s k Första Valfärdsteoremet. Med andra ord, införandet av alla former av finansiella regleringar är enbart berättigade när utfallet av den decentraliserade ekonomin inte är paretoeffektivt, till följd av förekomsten av någon form av marknadsmiss-

lyckande. Detta innebär att det preliminära steget i analysen av optimal reglering är en fullständig karaktärisering av jämvikten i ett samhällsplanerarproblem där samhällsplaneraren samlar alla resurser i samhället och fördelar dem bland agenterna, under samma friktioner och begränsningar som dem som bankerna utsätts för. I den meningen ser vi den optimala regleringen som en mekanism som utformats och ålagts av en extern myndighet för att upprätthålla en effektiv resursallokering, när koordinationen mellan *s k* atomistic agents i samhället är omöjlig.

I kapitel två, **En teori om bankillikviditet och ofullgjorda skyldigheter med orapporterad handel** (“A Theory of Bank Illiquidity and Default with Hidden Trades”), utforskar jag hur tillgången på handelsmöjligheter för såväl banker som individuella investerare påverkar sambandet mellan illikviditet och långivare som inte fullgör sina skyldigheter i det finansiella systemet. I detta syfte så utvecklar jag en Diamond-Dybvig modell av bankväsendet med idiosynkratiska och aggregerade störningar, där insättare kan handla med på en lånemarknad sinsemellan utan att observeras av sina banker. Det faktum att handeln inte kan observeras snedvrider resursallokeringen i den konkurrenskraftiga jämvikten, genom att göra räntan (förhållandet mellan framtida och nuvarande konsumtion) endogent icke slumpartad. Inom detta ramverk visar jag att när det föreligger icesystemiska aggregerade risker så händer det aldrig att bankerna inte fullgör sina skyldigheter och att banksystemet är illikvitt i den meningen att när det föreligger jämvikt så har det relativt mindre likvida tillgångar än vad samhällsplaneraren skulle ha. Det berättigar till en intervention från regeringens sida, i form av bankspecifika minimikrav på likviditet. När det istället föreligger en systemrisk så kan bankerna inte fullgöra sina skyldigheter enbart om sannolikheten för en framtida allvarlig störning är tillräckligt låg och en allvarlig störning faktiskt inträffar. Vidare kan banksystemet ha en för stor likviditet eller illikviditet, i den meningen att det har högre eller lägre likviditet än samhällsplaneraren, beroende på sannolikheten för en framtida allvarlig chock. Detta påkallar införandet av kontracykliska likviditetskrav.

I kapitel tre, **Finansiell liberalisering med orapporterad han-**

**del** ("Financial Liberalization with Hidden Trades"), ger jag en möjlig förklaring till varför den finansiella liberaliseringsprocessen, trots dess välkända betydelse, har stannat upp under de senaste tjugo åren (Abiad m.fl., 2008). I detta syfte så utvidgar jag Diamond-Dybvig modellen med orapporterad handel från det föregående kapitlet (men utan aggregerad osäkerhet) till en miljö med två länder med komparativa fördelar. I denna miljö visar jag att öppnandet av en internationell orapporterad marknad förbättrar båda ländernas välfärd vad gäller fullständig finansiell självständighet. I jämvikten med två separerade banksystem och en internationell orapporterad marknad specialiserar sig varje marknad i själva verket på den tillgång där den har en komparativ fördel, och låter agenterna bedriva handel osedda och åtnjuta vinsterna av "orapporterad" finansiell integration. Av större intresse är att jag även visar att två länder inte kan koordinera en djupare integrationsnivå eftersom flytten från ett enväldigt till ett integrerat banksystem, i närvaron av redan integrerade orapporterade marknader, genererar en ökning av jämviktsräntan vilket skapar länder som är vinnare och länder som är förlorare, beroende på deras komparativa fördelar. Jag analyserar även hur integrationsnivån i banksystemet och på de orapporterade marknaderna påverkar effektiviteten med vissa begränsningar i den konkurrenskraftiga bankjämvikten. I min huvudsakliga slutsats visar jag att när de två banksystemen inte är integrerade, men orapporterad handel är möjlig, kan planeraren inte förbättra agenternas välfärd ovanför den nivå som tillhandahålls av bankerna i en konkurrenskraftig jämvikt. Annorlunda uttryckt så är den konkurrenskraftiga jämvikten effektiv med vissa begränsningar. Det är ett intressant resultat eftersom på alla de andra nivåerna av finansiell integration så skapar skillnaderna mellan konkurrenskraftiga jämvikter och de motsvarande allokeringar som är effektiva med vissa begränsningar en logisk grund för att införa minimikrav för likviditet. När det två banksystemen är separerade, och orapporterad handel länder emellan är tillåten, så finns det emellertid inget sätt på vilket regleringen kan förbättra utfallet för det decentraliserade samhället.

Slutligen, i kapitel 4, vilket har titeln **Banklikviditet, deltagande**



**på värdepappersmarknaden och ekonomisk tillväxt** (“Bank Liquidity, Stock Market Participation, and Economic Growth”) och är samförfattat med Elena Mattana, utvecklar vi en teori med banker och marknader för att förena iakttagelsen att den relativa likviditeten i många finansiella system världen över uppvisar en långsiktigt fallande trend med hushållens ökande deltagande i handeln på direkta marknader. I detta syfte utvecklar vi en tillväxtmodell med överlappande generationer som spänner över två perioder, där agenterna, så som i de tidigare kapitlen, drabbas av en idiosynkratisk likviditetschock, vilken de försäkrar sig mot, antingen genom att öppna ett bankkonto eller genom att direkt handla på värdepappersmarknaden. Det är viktigt att agenterna kan öppna ett bankkonto utan kostnad, medan bankerna måste betala en sk proportionell kostnad på räntan av insättningarna, medan de agenter som investerar direkt på marknaden måste betala en fast inträdeskostnad, men sedan åtnjuter fullständig avkastning på sina långsiktiga investeringar. Samspelet mellan bankernas proportionella kostnader och kostnaderna för att komma in på marknaden utgör grundpelaren i vår analys. Tekniskt sett löser vi ett bankproblem som blir större om man inför en begränsning av deltagandet: bankkontraktet måste vara sådant att insättarna förväntas få minst samma positiva utfall som de skulle få om de handlade på marknaden. I denna modell visar vi att en renodlad bankjämvikt (dvs utan marknader) uppvisar en konstant relativ likviditet på lång sikt, i motsats till vad vi observerar i verkligheten. I problemet med begränsningar uppvisar istället den relativa likviditeten i hela banksystemet en icke-växande trend: vid låga nivåer på ekonomisk utveckling kan agenterna inte få tillgång till marknaderna, och de gör insättningar i banksystemet, vilket ger en hög relativ likviditet. Allteftersom samhället utvecklas blir de fasta kostnaderna för att komma in på marknaden emellertid allt mer försumbara och bankerna kan inte upprätthålla det konkurrensmässiga trycket från marknaden: banksystemets jämvikt kollapsar och agenterna investerar samtliga direkt i marknaden, där den relativa likviditeten är lägre. Vi avslutar vår analys med att testa det huvudsakliga påståendet i vår teori, dvs att ju lättare det är att komma

in på marknaden, desto lägre är den relativa likviditeten i det finansiella systemet. I detta syfte mäts den relativa likviditeten utifrån en panel av banklikviditetsreserver och bildar ett index av policyn på värdepappersmarknaden, vilket tillhandahålls av IMF, för att förklara tillgången på externa investeringsmöjligheter. Våra resultat visar att en ökning av detta index med en enhet är korrelerat med en kraftig minskning av den relativa likviditeten motsvarande mellan 13 och 22 procent.

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