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Federal Reserve Bank of Kansas City

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Working Paper

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Abstract

This paper presents a simple two-region banking model of liquidity mismatch to study the strategic interactions between national regulators. I show that banks hold insufficient liquidity, which has repercussions for other banks in an international financial market. The model justifies coordinated prudential liquidity regulation due to an international fire-sale externality. However, I theoretically and empirically argue that domestically oriented regulators from jurisdictions with a smaller banking sector do not internalize the global benefits of regulation and therefore do not adhere to international standards. The model justifies capital controls if countries do not cooperate. Although capital controls improve the welfare of regulating economies, they also align the interest of free-riding countries with international regulation.

Keywords: International Liquidity Regulation; Capital Controls; Welfare

JEL: D62, F36, F42 G15, G21

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1. Introduction

Safeguarding financial stability is a matter of global collective responsibility. [...] Preserving global financial stability requires jurisdictions to cooperate in identifying and mitigating risks to the financial system.

Pablo Hernández de Cos, Chair Basel Committee, 2020

Throughout history, banking crises follow similar patterns: they cause significant damage to the domestic economy and result in international spillovers. Domestic fiscal and monetary policymakers usually respond strongly to financial crises, but tend to neglect the international scope. For this reason, international regulatory efforts such as the Basel initiative set voluntary international macroprudential standards on bank capital adequacy, stress testing, and market liquidity.

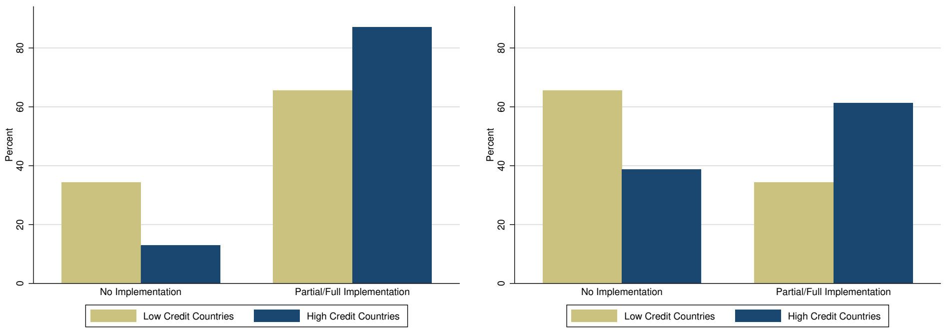
The rule setting body of the Basel framework, the so-called Basel committee, consists of 28 jurisdictions, but the adoption of specific guidelines is not limited to its member countries. The chair of the Basel committee at a recent symposium *"encourage[d] jurisdictions in Africa [i.e. non-member countries] to pursue a proportionate approach to their implementation of the Basel framework"* (Cos, 2020). Similarly, institutions like the World Bank and the IMF urged non-member countries to implement core principles (Drezner, 2007). However, a substantial share of non-member countries did not implement the two most recent proposals, the Basel II and III standards, as I highlight in Figure 1. Further, and this will be central for the research question addressed in this paper, countries with a smaller banking sector (proxied by domestic credit) are more reluctant to implement Basel II or III policies. Though most of these under-regulated financial sectors are small, they aggregate to a significant portion of the global financial market (see Table A2). A lack of regulation in these countries could therefore affect global financial stability.

My main contribution is to investigate how domestic banks operating both at home and abroad shape domestic regulation and the adoption of international standards. I show that countries with few banks may rationally decide to free-ride on the regulatory efforts of larger jurisdictions with no incentive to commit to joint regulation, despite global gains from cooperation due to inefficient spillovers. Global regulation is therefore not necessarily a Pareto improvement. This poses challenges for implementing common rules across countries.

The idea is that national regulators only internalize their own benefits from regulation. As such, they disregard the stabilizing effect of regulation on the global banking sector, which constitutes a positive externality. A country that is heavily invested in international financial markets internalizes a significant share of the externality. Domestic regulators who oversee a small banking sector barely internalize any gains from regulation. This leads to asymmetric preferences and may prevent a cooperative agreement. In an empirical exercise I show that internationally integrated countries with a small banking sector are indeed less likely to adhere to Basel II or III standards, despite a variety of control variables that proxy for obstacles as identified in the existing literature.

Figure 1: *Adherence to Basel Standards for Non-members as of 2015*

(a) *Basel II* ***(b)*** *Basel III*



Notes: *The histograms portray the share of countries (in %) with No vs. Partial/Full implementation of Basel II (Panel (a)) or Basel III (Panel (b)) standards as of 2015. The sample is split by the amount of domestic credit to the private sector by banks (in constant USD, threshold based on median) as a proxy for the size of the domestic banking sector. Each subsample sums up to 100%. Source: BIS (2015), World Bank and author's calculation. A list of included countries is available in Table A1 in the appendix.*

The second contribution of this paper is to provide two resolutions to the aforementioned limits to coordination. Due to inefficient international spillovers, gains from cooperation are positive on aggregate but potentially unequally distributed. Lump-sum transfers can solve this discrepancy. Because explicit transfers may be challenging to implement in practice, adoption of common macroprudential standards by smaller, mostly emerging market economies could be linked to open trade agreements or tied to rescue packages by the IMF or World Bank.

Alternatively, my model advocates capital controls imposed by regulating countries on free-riding countries if they cannot agree on common standards. Capital controls can restore constrained efficiency for both types of countries when paired with macroprudential regulation, if (i) leakages are minimal, and (ii) the individual banking sector is large enough to absorb financial shocks. Capital controls are hence a "free lunch" from the perspective of economies with sufficient financial market depth. They limit spillovers from unregulated countries, which enhances the stability of regulating countries. In addition, capital controls ensure that free-riding countries cannot benefit from financial stability provided by regulating countries, which makes regulation more targeted and efficient. Interestingly, capital controls in my model are beneficial from a global perspective as well. Specifically, they may force non-cooperating countries to adopt regulation in order to access international financial markets. A threat to impose capital controls can therefore align the interest of policymakers with a globally efficient outcome. This motivation is different from the existing literature which stresses that capital controls are used to maximize domestic welfare with no or adverse effects on global welfare (see, for example, Bianchi, 2011; Costinot et al., 2014; Schmitt-Grohe and Uribe, 2016).

I analyze these issues in a tractable two-region model of financial intermediation with idiosyncratic liquidity shocks that loosely follows the seminal works of Diamond and Dybvig (1983) and Allen and Gale (2005). The model has four crucial features: First, investors are subject to idiosyncratic liquidity shocks. This generates heterogeneity ex-post and hence a rationale for a global financial market in which distressed banks sell illiquid assets in exchange for liquidity. Second, distressed banks are subject to a balance sheet constraint which forces them to sell assets below their fair value. This leads to a fire-sale externality and justifies ex-ante (macroprudential) regulatory intervention via liquidity requirements, precisely because banks do not internalize the dependence between the equilibrium asset price, fire-sales and initial investments. Third, fire-sales spread globally via general equilibrium effects in the international asset market and ultimately justify cooperative regulation. In my model, banks are integrated in a global financial market and balance sheets depend on international asset prices. As a consequence, fire-sales by banks in either jurisdiction affect the required fire-sales in the other jurisdiction due to indirect balance sheet price effects. National regulators who only maximize domestic welfare do not internalize this dependency. Fourth, countries are heterogeneous in terms of their financial sector size and internalize varying degrees of the fire-sale externality. This generates asymmetric portfolio choices in an uncoordinated equilibrium and may ultimately impede cooperation.

In more detail, the model features two actors: investors and banks. Investors are ex-ante identical, but differ ex-post in their desire for early or late consumption. Banks operate on behalf of investors and have access to two technologies, a liquid and an illiquid asset. The latter has a higher return but takes time to materialize. As a consequence it is not accessible for early consumption. Distressed banks can however sell their illiquid assets on the international asset market. In equilibrium the price for illiquid assets is increasing in aggregate liquidity, as distressed banks supply less illiquid assets when they own more liquid assets for early consumption. Competitive banks do not internalize this dependence which leads to a fire-sale externality, also commonly refereed to as a pecuniary externality since it works trough equilibrium prices, and justifies liquidity regulation.

I solve the model from the perspective of the laissez-faire competitive equilibrium, a global social planner (regulator) and heterogeneous national regulators. The first two solutions provide a lower and upper bound on the desirability of liquidity. National regulators in contrast interact via Cournot competition. They only maximize domestic welfare, taking as given policies of the other country and ignoring spillovers. National regulators consequently fail to internalize the international aspect of the pecuniary externality. Crucially, national regulators oversee banking sectors of different sizes, which determines portfolio choices and the willingness to cooperate. As a result, coordination is not necessarily optimal from the perspective of individual countries, despite global welfare gains, which in turn justifies capital controls or transfers.

Related Literature

This paper connects with several strands of literature. The basic model of fire-sales draws on earlier work by Shleifer and Vishny (1992, 1997) and Kiyotaki and Moore (1997). Unlike these papers, I focus on spillovers from fire-sales in an international context. Empirical support for international asset fire-sales during financial crises has been articulated in Krugman (2000), Aguiar and Gopinath (2005), Devereux and Yetman (2010) or more recently Duarte and Eisenbach (2018). International fire-sales represent frictions in international financial markets and are a crucial ingredient to justify cooperation.

The presence of market failures has spurred a large literature that motivates ex-ante financial regulation from a second best perspective via macroprudential policies and capital controls. In Farhi and Werning (2016), Korinek and Simsek (2016), and Schmitt-Grohe and Uribe (2016) intervention is justified by an aggregate demand externality due to the zero lower bound or an international constraint on monetary policy, combined with nominal rigidities in goods or labor markets. Another series of papers (see, for example, Mendoza, 2002; Bianchi, 2011; Stein, 2012; Jeanne and Korinek, 2019) emphasize financial frictions and related borrowing constraints which trigger pecuniary externalities. This paper belongs to the second group. However the pecuniary externality arises due to a balance sheet effect rather than a borrowing limit similar to Lorenzoni (2008) and spreads internationally.

Because I focus on ex-ante liquidity regulation, this paper is related to work on sources and consequences of insufficient liquidity in the laissez-faire equilibrium under market incompleteness or informational frictions (see, for example, Diamond and Dybvig, 1983; Holmström and Tirole, 1998; Caballero and Krishnamurthy, 2001; Allen and Gale, 2005; Lorenzoni, 2008; Brunnermeier and Pedersen, 2009; Geromichalos and Herrenbrueck, 2016). Similar to this literature, investors in my model are subject to uninsurable liquidity shocks which force banks to sell illiquid assets below their fundamental value. I mainly deviate from this literature by analyzing liquidity demand and portfolio choices in an international context, in particular the discrepancy between the allocation of national and global regulators and how that affects cooperation.

The strategic interaction among national regulators follows the game theoretic approach on macroeconomic policy coordination pioneered by Hamada (1974, 1976, 1979), where governments set domestic policy to maximize national welfare while incorporating their impact on international prices. Cooper (1985), and Persson and Tabellini (1995) provide an extensive review of this literature. The idea that regulators maximize welfare subject to (inefficient) markets and hence achieve a constrained efficient allocation dates back to Stiglitz (1982) and Geanakoplos and Polemarchakis (1986).

This paper is closest to a smaller literature on the desirability of cooperation in international banking and financial markets. Importantly, as Korinek (2016) demonstrates, coordinated regulatory efforts are warranted whenever externalities work through international markets, although non-cooperative national regulators can achieve the global optimum if they internalize the revenue sources from Pigouvian taxes (Clayton and Schaab, 2020). National regulation may be inefficiently low due to moral hazard when foreign countries have an incentive to forgive debt (Farhi and Tirole, 2018), fickle capital flows (Caballero and Simsek, 2020), terms of trade manipulations (Bengui, 2014), or simply because national regulators do not internalize international spillovers as in my paper. Without any asymmetries however, coordination is always strictly welfare improving for national regulators. In Kara (2016), the profitability of investment opportunities as well as the utility function of national regulators differ across countries which may undermine cooperation despite overall welfare gains. Dell'ariccia and Marquez (2006) argue in favor of distinct preferences regarding the trade-off between financial stability and profits. In contrast to the aforementioned papers, I analyze the consequences of distinctive domestic banking sector sizes and show that this mechanism has empirical relevance. I also justify capital controls in case cooperation is not feasible, since they align the preferences of national regulators with a globally efficient outcome.

I structure the remaining paper as follows: Section 2 lays out the model and highlights the inefficiency related to the competitive equilibrium. Section 3 provides the key insights of this paper. I introduce national regulators and analyze their behaviour with respect to investment choices and cooperation. Section 4 discusses policy implications and motivates capital controls if countries are not willing to cooperate. Section 5 provides empirical support for banking sector size effects and contrasts its implications with alternative explanations in the literature. Section 6 concludes. All proofs and derivations are delegated to the appendix.

2. Framework

2.1. Environment

The model consists of three periods $t = 0, 1, 2$ and features two actors: investors and banks, each of measure one. Each investor is linked to one local bank, but each bank engages in an international asset market. A share $\omega \in (0, 1)$ of investors/banks reside in one region and the remaining $1 - \omega$ in the second region. The parameter ω hence characterizes the share of internationally operating domestic banks and, since each bank is of identical magnitude, also the size of the domestic banking sector.[1] There are three types of goods, a perishable consumption good and two investment projects referred to as short and long assets. I begin by characterizing the environment for each actor, followed by a description of the two financial markets in this model. The model structure is illustrated in Figure 2.

Investors: Investors are risk-neutral over period 2 consumption and endowed with e units of consumption goods at $t = 0$. Utility for an individual investor j is given by

$$U_j = E_0[s_j h(c_{j1}) + c_{j2}].$$

Preferences for period 1 consumption are determined by $h(c_{j1})$ and follow

$$\begin{aligned} h'(c_{j1}) \to \infty \quad &\text{if} \quad c_{j1} \leq c \\ h'(c_{j1}) < 1 \quad &\text{if} \quad c_{j1} > c, \end{aligned}$$

where c_{jt} is individual consumption at date t. The variable s_j captures a random idiosyncratic "liquidity shock", which materializes at the beginning of period 1. The shock follows a binomial distribution with two distinct realizations, zero and one. If $s_j = 1$, which occurs with probability q, investor j wishes to consume in period 1.

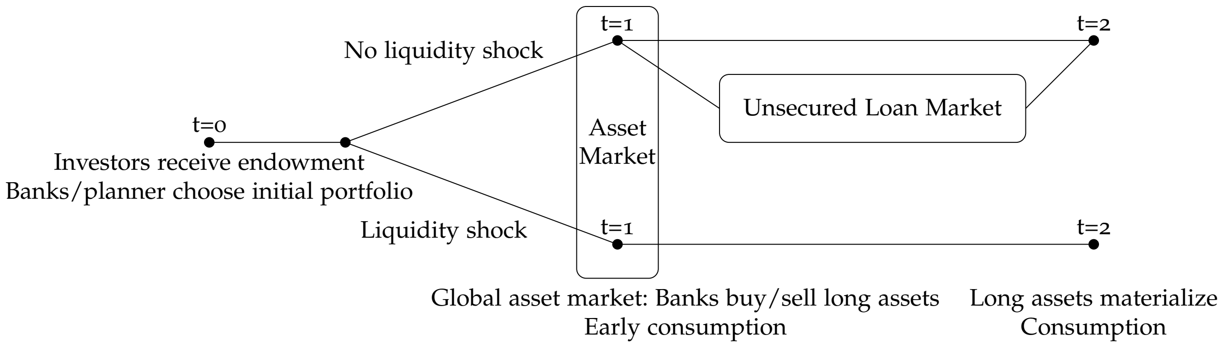
[1] The model does not distinguish between the number of banks and the banking sector size. Market concentration in the banking sector is however irrelevant for the adherence of regulatory standards as I highlight in the empirical section.

Expectations in period 0 are taken with respect to s_j. The specific functional assumption on $h'(c_{j1})$ simplifies the subsequent analysis: If investors receive an early consumption signal, they demand consumption equal to c with $c < e$.[2] [3]

I interpret period 1 as a global liquidity crisis. Due to the Law of Large Numbers, q investors demand payouts, which puts q banks in distress. This perspective matches empirical regularities: Even during severe international financial crises, only a limited number of banks are actually in distress.[4]

As apparent from the utility function, investors do not consume in $t = 0$. They also cannot store consumption goods, hence all endowment is deposited at the local bank. This is a rather strong assumption, as it ties the size of the domestic banking sector to endowments. In the appendix, I introduce a production technology which provides a real investment opportunity to investors. This feature does not change the results of the model. However, it breaks the link between endowment and financial investments, which will be helpful to distinguish the role of the domestic banking sector from pure country size effects.

Figure 2: *Model Structure*



Banks: Banks act in the interest of local investors, which may be motivated by free entry. As a consequence, banks maximize expected $t = 2$ consumption for investors and internalize the early consumption request if $s_j = 1$. Crucially, banks cannot insure themselves ex-ante against the liquidity shock, which is a standard assumption in the literature (see, for example, Holmström and Tirole, 1998; Caballero and Krishnamurthy,

[2] c can be arbitrarily close to e, but not equal due to efficiency losses when selling assets which I describe below.

[3] The assumption on $h'(c_{j1})$ is not essential for the results of this paper. Several alternative options are explored in the appendix: finite and continuous marginal utility over period 1 consumption, idiosyncratic $t = 1$ consumption and aggregate risk.

[4] The inefficiency in this paper is due to a negative general equilibrium effect among banks subject to the consumption request ("distressed" banks) as I explain below. I hence sidestep a more elaborate exposition on how banks became distressed in the first place. Papers on financial contagion include Allen and Gale (2000) and Caballero and Simsek (2013) among others.

2001; Lorenzoni, 2008; Stein, 2012). If banks cannot meet the early consumption outlay c, they go bankrupt, vanish from the market and all resources are lost. As I explain later, no bank will go bankrupt in equilibrium.

The distinctive feature of banks is their ability to transform $t = 0$ consumption goods into $t = 1$ or $t = 2$ consumption. In period 0, before the liquidity shock is realized, they decide upon two risk-free assets, a short asset (storage technology, the "liquid" asset) (l_j) and long assets (the "illiquid" asset) (k_j).[5] The short asset yields one unit of consumption in $t + 1$ per unit invested in period t and can be accessed both at date 0 and date 1. Long assets provide a gross return of $R > 1$ consumption goods in $t = 2$ per unit of investment in $t = 0$. Long assets are therefore more profitable, however not available for early consumption.

Asset Market: Banks may access a Walrasian international asset market in period 1, where they can buy (x_j^D) or sell (x_j^S) unfinished long investment projects in exchange for consumption goods from matured short assets. The market is fully collateralized. As a consequence all banks are able to trade on this market, including banks that are threatened to go bankrupt if they cannot meet the early consumption request ("distressed" banks). As an important feature, I assume that long assets are less profitable if sold in $t = 1$, which is a common assumption in the literature (see, for example, Stein, 2012).

It is worthwhile to compare this interbank asset market with actual financial markets during financial crises. First, the model emphasizes the interaction between banks, and not the linkages between a bank and multiple investors. Though this is a modelling choice, empirical evidence points to sizable international interbank markets in both advanced and emerging economies. Second, during financial crises unsecured lending on interbank markets tends to dry up (Allen and Carletti, 2008). The interbank asset market in this paper captures this feature: Banks in distress are not able to obtain unsecured loans and must collateralize their funding by selling illiquid assets.

Loan Market: Banks which are not subject to potential default due to early consumption ("intact" banks) have access to an unsecured loan market between periods 1 and 2. In this market, intact banks are able to access unsecured lines of credit ($\tilde{l}_j$). Credit corresponds to $t = 1$ consumption goods from other intact banks which are exchanged for future consumption claims. Loans can be used to purchase unfinished investment projects on the asset market. I introduce this market for technical reasons. In the national planner equilibrium, $t = 0$ portfolios are generally heterogeneous

[5] The liquidity of an asset is determined in equilibrium. However, as I show in Section 2.3, short assets are indeed more liquid.

across the two jurisdictions. With sufficient asymmetry, some intact banks might not have enough liquidity to purchase long assets from distressed banks, despite sufficient aggregate liquidity. This complicates aggregation on the asset demand side.

Because I focus on an environment with excess aggregate liquidity, but a shortage for some banks, there will always be enough supply of funds on the loan market. The gross interest rate ($\tilde{R}$) on loans consequently equals one, that is, the opportunity cost associated with short assets in $t = 1$. Constrained intact banks will rationally borrow and provide the proceeds to distressed banks (see footnote 9), while unconstrained intact banks are indifferent and hence willing to provide these loans. Crucially, these transactions are profitable until all intact banks are unconstrained.

Solution Strategy: I solve this model via backward induction. Hence, I first derive the asset market equilibrium in period 1 for a given initial asset mix (Section 2.2). Conditional on period 1 supply and demand schedules, I then proceed backward and solve for period 0 investment choices from three different perspectives: the laissez-faire competitive equilibrium (Section 2.3), a global social planner (Section 2.4) and national regulators (Section 3). I use the terms regulator and planner interchangeably. As I point out in subsequent sections, all three cases are associated with distinct initial investments. The global planner chooses the initial asset mix on behalf of all banks/investors, while national regulators only care about their domestic banks but still exert some influence on equilibrium prices. Because banks are perfectly integrated in international markets, the origin of a bank will only matter once I analyze national regulators.

2.2. Period 1 Asset Market

Banks enter period 1 with a portfolio of long and short assets (k_j, l_j). Once investors reveal their type based on the realization of the liquidity shock, banks can access a global asset market in order to meet investors' consumption demand in period 1 and to maximize period 2 consumption. Distressed banks will be required to obtain consumption goods on the asset market, while intact banks supply consumption goods in exchange for long assets.[6] Throughout the analysis I denote bank-specific variables by lower-case letters and aggregate variables by upper-case letters.

Intact Banks: Intact banks purchase long assets (x_j^D) at price $p(L)$ on the asset

[6]This statement is without loss of generality since banks carry insufficient short assets in period 1 to cover the consumption outlay if they are distressed. In other words, $l_j \geq c$ is not rational from the perspective of period 0. If $l_j \geq c$, a marginal shift in the investment mix towards the long asset provides a net return of $R - 1 > 0$ with certainty.

market in exchange for consumption goods from the proceeds of their own initial short investments or loans from other intact banks. $p(L)$ is an equilibrium object and, as I show later, depends on aggregate liquidity.

Newly purchased long assets provide a lower return compared to retained long assets. To be precise, x_j^D units of assets transform into $R\phi(x_j^D) < Rx_j^D$ consumption goods in period 2. I make the following assumption regarding the efficiency of purchased long assets in $t = 1$:[7]

Assumption 1 *Technology*

$$\phi'(x_j^D) > 0, \phi''(x_j^D) < 0, \phi'(0) = 1$$

The assumption captures the notion that newly acquired assets become increasingly less profitable. The concave technology implies decreasing returns from purchasing long assets in period 1 and, as a result, a downward sloping asset demand curve.[8]

Intact banks take the asset price $p(L)$ as given and maximize period 2 consumption $c_{j2}^{s=0}$. The optimization problem for intact banks is hence characterized as:

$$c_{j2}^{s=0}(k_j, l_j; L) = \max_{x_j^D, \tilde{l}_j}\{R \underbrace{(k_j + \phi(x_j^D))}_{\text{Effective Long Assets}} + \underbrace{l_j + \tilde{l}_j - p(L)x_j^D}_{\text{Short Assets}} - \underbrace{\tilde{R}\tilde{l}_j}_{\text{Loan Payment}}\} \quad \text{(P1:D)}$$

subject to a cash-in-the-market constraint

$$p(L)x_j^D \leq l_j + \tilde{l}_j. \quad (1)$$

The variable $\tilde{l}_j$ refers to the amount of borrowed funds on the loan market. $\tilde{R}$ denotes the gross interest rate on the loan market, which will equal one in equilibrium as I focus on an equilibrium with excess aggregate liquidity (Lemma 1). Period 2 consumption by intact banks is the sum of returns on period 0 and newly acquired long project, $R(k_j + \phi(x_j^D))$ and the amount of reinvested short assets $l_j + \tilde{l}_j - p(L)x_j^D$ minus loan repayments in period 2. The cash-in-the-market constraint (1) states that

[7]There are multiple ways to motivate $\phi(x_j^D)$. One may argue that traded projects become less productive due to transaction costs or inside knowledge and hence sell at a value below par. Lorenzoni (2008), Stein (2012) and Kara (2016) argue in favor of late-arriving outside technologies which force sellers to provide assets below their fundamental value. Lester et al. (2012) provide an adverse selection problem in a model of bilateral trades where agents can create low-quality securities free of charge, which mandates screening expenses. Geromichalos et al. (2016) motivate discounts based on search and bargaining frictions.

[8]This ingredient is crucial for the existence of a pecuniary externality (see, for example, Lorenzoni, 2008 or Stein, 2012). If demand was perfectly elastic, the equilibrium price would be independent of initial portfolio choices and regulators would not be able to improve upon the decentralized equilibrium.

long asset expenditures by intact bank j are limited by the amount of own and borrowed consumption goods.

The first order condition for x_j^D provides a simple implicit downward sloping demand schedule for intact banks:

$$(1+\lambda_j)p(L) = R\phi'(x_j^D).$$

The variable λ_j denotes the Lagrange multiplier associated with equation (1). Banks act competitively on the international asset market, hence they equate marginal revenue with marginal costs subject to available funds.[9] As a prelude to the subsequent sections, it is worth emphasizing that equation (1) does not bind in equilibrium, $\lambda_j = 0 \;\forall\; j$. There are two reasons: First, because of the assumption on technology, distressed banks purchase short assets exclusively to satisfy early consumption needs. Second, the equilibrium will be characterized by sufficient aggregate liquidity to cover early consumption needs. The loan market ensures that all intact banks have access to enough liquidity. The optimal loan size is therefore generally indeterminate as long as equation (1) does not bind.

Distressed Banks: Banks in distress are suppliers of long assets (x_j^S) and maximize investors' period 2 consumption ($c_{j2}^{s=1}$) subject to the withdrawal request. The optimization problem for any distressed bank j given $t=0$ choices is summarized as

$$c_{j2}^{s=1}(k_j, l_j; L) = \max_{x_j^S}\{R\underbrace{(k_j - x_j^S)}_{\text{Long Assets}} + \underbrace{l_j + p(L)x_j^S - c}_{\text{Short Assets}}\} \tag{P1:S}$$

subject to

$$p(L)x_j^S + l_j \geq c \tag{2}$$

$$x_j^S \leq k_j. \tag{3}$$

Period 2 consumption for investors hit by the liquidity shock is the sum of the returns on the remaining long projects, $R(k_j - x_j^S)$ and the amount of reinvested short assets $l_j + px_j^S$ minus the period 1 compensation c. Equation (2) captures the requirement for banks to obtain sufficient consumption goods and essentially represents a balance sheet constraint. Banks can use their own resources from initial short investments

[9]The equation explains why constrained intact banks ($\lambda_j > 0$) want to borrow on the loan market. By providing funds to distressed banks, constrained intact banks have a net profit margin of $R\phi'(x_j^D) - p(L) > 0$. Because $\tilde{R} = 1$, these banks would borrow funds on the loan market until $\lambda_j = 0$.

(l_j) plus consumption goods obtained from trading in the asset market ($p(L)x_j^S$). The second constraint, equation (3), is a feasibility constraint. Banks in distress must sell their long assets in exchange for additional consumption goods. However, if the asset price $p(L)$ is low, distressed banks might have to sell more than k_j assets in order to purchase $c - l_j$ consumption goods. Thus, if equation (3) binds, distressed banks are not able to raise enough consumption goods on the asset market.

Because $R > R\phi'(\cdot) = p(L)$ and because self-insurance is not rational, equation (2) binds. The endogenous constraint hence captures two salient features of banks in distress: the scarcity of liquidity and the requirement to sell illiquid assets below fundamental value. Constraint (2) can be rearranged and provides the inverse supply schedule

$$p(L) = \frac{c - l_j}{x_j^S} \quad \text{if} \quad x_j^S \leq k_j.$$

As $p(L)$ decreases, the balance sheet deteriorates and distressed banks are required to sell more long assets. This balance sheet effect together with the downward sloping demand curve leads to the fire-sale externality embedded in this model. As a final remark, the supply constraint $x_j^S \leq k_j$ may prevent the liquidation of sufficient long assets. This is ruled out via a mild constraint on the parameter space as I explain in Lemma 1 and Assumption 4.

Equilibrium: Due to the Law of Large Numbers, the unit mass of banks and the absence of aggregate uncertainty, q banks are in distress and supply long assets (demand consumption goods), while the remaining $1 - q$ banks purchase long assets (supply consumption goods).

To ease notation, I will drop the reference L in $p(L)$ from now on where it is not fundamental for the logic of a result.

Aggregate demand for long assets ($X^D = \int_0^{1-q} x_j^D dj$) equals

$$X^D(p) \equiv (1 - q)\phi'^{-1}\left(\frac{p}{R}\right),$$

as all intact banks purchase the same amount of long assets. $\phi'^{-1}(\cdot)$ refers to the inverse function of $\phi'(\cdot)$. The aggregate supply of long asset ($X^S = \int_{1-q}^{1} x_j^S dj$) is

$$X^S(p, L) = q\frac{c - L}{p}.$$

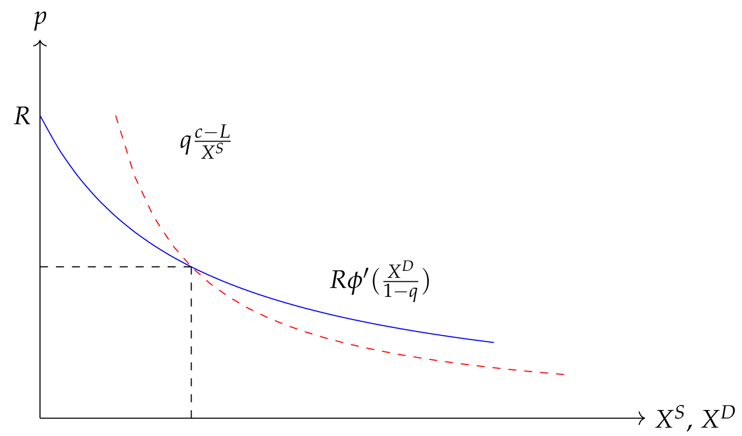
This expression exploits the idiosyncratic nature of liquidity shocks, which implies that $\int_{1-q}^{1} l_j dj = qL$.

Definition 1: (Asset Market Equilibrium) *The period* 1 *equilibrium given* $t = 0$ *portfolios* $\{k_j, l_j\}$ *consists of the asset price* $p(L)$ *and the transaction volume* $X(L)$ *such that*

1. *Intact and distressed banks optimally choose their demand and supply* $\{x_j^D, x_j^S\}$ *according to (P1:D) and (P1:S);*

2. *the asset market clears:*
$$X^S(p, L) = X^D(p). \tag{4}$$

***Figure 3:** Period 1 Asset Market*



***Notes:** The solid blue line characterizes the inverse aggregate demand and the dashed red line the inverse aggregate supply of long assets.*

Uniqueness and Existence of Asset Market Equilibrium

In order to ensure the uniqueness of the equilibrium as portrayed in Figure 3, I assume that demand is elastic. I summarize this in Assumption 2.

Assumption 2 *Elasticity*
$$\epsilon_{X^D,p} = -\frac{\partial X^D}{\partial p}\frac{p}{X^D} = -\frac{(1-q)\phi'(\frac{X^D}{1-q})}{\phi''(\frac{X^D}{1-q})X^D} > 1 \quad \forall \quad X^D > 0$$

The elasticity assumption is very common in the literature (see, for example, Bianchi, 2011; Kara, 2016; Korinek, 2018). It guarantees that expenditure on period 1 long assets is strictly increasing in X^D, that is, $\frac{\partial p(X^D)X^D}{\partial X^D} = p'X^D + p > 0$. From an intuitive point, the assumption guarantees that intact banks are bounded in terms of their capability to absorb long assets. If an equilibrium exists, the assumption ensures that aggregate supply intersects aggregate demand from above and exactly once due to constant expenditure along the supply curve.

The first lemma establishes conditions on the existence of the asset market equilibrium.

Lemma 1 *The asset market equilibrium exists if* $qc \geq \phi'^{-1}\left(\frac{q}{R-1+q}\right)\frac{qR}{R-1+q}$ *and* $\frac{c}{e} \leq \frac{qR}{R-1+q}$.

The first requirement ensures that overall liquidity is large enough to compensate impatient investors at a fraction q of banks ($L \geq qc$). The second condition guarantees that distressed banks have enough long assets, ($x_j^S \leq k_j$). In other words, the conditions imply that equations (1) and (3) do not bind. I assume that both requirements are satisfied throughout the entire analysis.

Assumption 3 *Enough Global Liquidity*

$$qc \geq \phi'^{-1}\left(\frac{q}{R-1+q}\right)\frac{qR}{R-1+q}$$

The assumption essentially imposes an upper bound on R. To see this notice that if R converges to one, $\phi'^{-1}\left(\frac{q}{R-1+q}\right)$ converges to zero and the assumption is necessarily satisfied.

Assumption 4 *Sufficient Long Assets*

$$\frac{c}{e} \leq \frac{qR}{R-1+q}$$

This requirement implies that banks in distress are not constrained by insufficient long assets, which, due to fire-sales, requires sufficient liquidity.[10] The assumption is not overly restrictive so long as R is not too high.

Comparative Statics

To illustrate the interdependence between the initial portfolio and the asset market equilibrium, I consider a simple experiment in which all banks exogenously increase their liquid asset investment. The comparative statics are displayed in Figure 4.

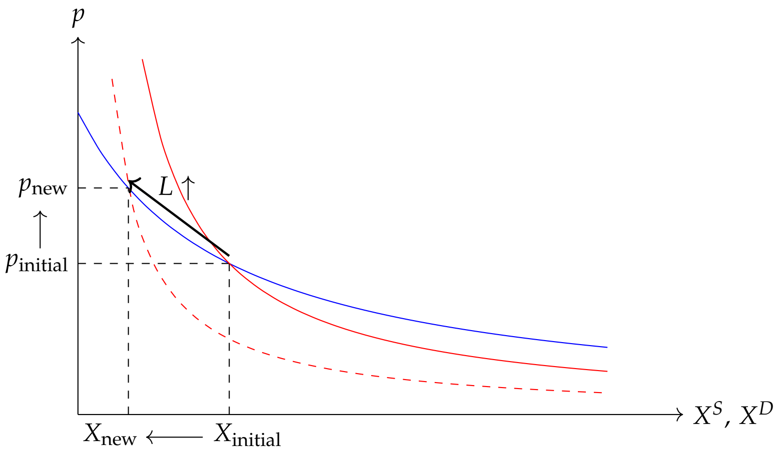
The new equilibrium is associated with a higher asset price and a lower transaction volume. The aggregate supply curve shifts left as distressed banks purchase less consumption goods, or equivalently sell less long assets for a given price. On the other hand, the additional liquidity in period 1 does not affect the demand schedule, since intact banks' cash-in-the-market constraint is slack. Liquidity therefore limits asset fire-sales and stabilizes the fire-sale price. I summarize these results in Lemma 2.

Lemma 2 *The equilibrium asset price* $p(L)$ *is increasing in aggregate liquidity,* $\frac{\partial p(L)}{\partial L} > 0$, *and the transaction volume* $X(L)$ *is decreasing in aggregate liquidity, hence* $\frac{\partial X(L)}{\partial L} < 0$.

This result is crucial for the subsequent analysis. Because competitive banks treat prices as given, regulators will be able to improve welfare by incorporating this dependency.

[10] Because $p < 1$ in equilibrium, an increase in l_j reduces x_j^S by more than one unit.

Figure 4: *Comparative Statics Asset Market: Effect of an Increase in* $l_j \ \forall \ j$



Notes: *The solid blue and red lines correspond to the initial inverse aggregate demand and supply schedules. More liquidity reduces the supply of long assets (dashed line) but does not affect demand.*

Expected Period 2 Consumption

The value function characterizing period 2 consumption in the distressed state $c_{j2}^{s=1}(k_j, l_j; L)$ is characterized as

$$c_{j2}^{s=1}(k_j, l_j; L) = R\left[k_j - \frac{c - l_j}{p(L)}\right].$$

The functional form is a result of the binding early consumption constraint and the asset supply schedule of distressed banks in period 1.

The value function for intact banks is

$$c_{j2}^{s=0}(k_j, l_j; L) = R\left[k_j + \phi\left(\phi'^{-1}\left(\frac{p(L)}{R}\right)\right)\right] + l_j - p(L)\phi'^{-1}\left(\frac{p(L)}{R}\right).$$

The expression follows from the definition of x_j^D.

Expected period 2 consumption as a function of initial portfolio choices is hence described as

$$E_0[c_{j2}(k_j, l_j; L)] = qc_{j2}^{s=1}(k_j, l_j; L) + (1-q)c_{j2}^{s=0}(k_j, l_j; L).$$

Optimality of Asset Market Equilibrium

In period 0 banks choose their investment portfolio anticipating that they will enter a functioning asset market in $t = 1$. Lemma 1 ensures that initial portfolio choices are indeed consistent with the asset market, however the asset market may not be an equilibrium ex-ante. In other words, it could be desirable to avoid the asset market and operate in autarky. I discuss this alternative equilibrium in the appendix and summarize the main insights in the following lemma. I focus on the asset market equilibrium during the remaining paper.

Lemma 3 *The asset market equilibrium and the autarky equilibrium are Nash equilibria. The asset market equilibrium is payoff dominant (Harsanyi and Selten, 1988), that is, it is Pareto superior to the autarky equilibrium.*

Intuitively, the asset market equilibrium outperforms the autarky equilibrium because it allows banks to hold less liquidity than c, which would be the dominant strategy in autarky. Banks anticipate that they would be able to obtain funds from other banks during distress, hence they are able to invest in more profitable long assets. This result rests on two premises: imperfectly correlated liquidity shocks and sufficient aggregate liquidity.[11]

2.3. Competitive Equilibrium

Before I analyze national regulators in Section 3, it is worthwhile to examine the competitive period 0 equilibrium and the global planner solution. The competitive equilibrium provides a lower bound and the global planner solution an upper bound for the desirability of liquidity. This is because banks in the competitive equilibrium take prices as given. A global planner in contrast fully internalizes the dependence between prices and initial portfolio choices. Due to the pecuniary externality in this model, the planner chooses strictly more liquid assets in $t = 0$. Both solutions provide useful reference points which I will contrast with the national planner equilibrium.

In the competitive equilibrium, each bank maximizes expected period 2 consumption

$$\max_{k_j \geq 0, l_j \geq 0} W_j^{CE}(k_j, l_j; L) = \max_{k_j \geq 0, l_j \geq 0} E_0[c_{j2}(k_j, l_j; L)] \tag{P0:CE}$$

subject to

$$k_j + l_j = e. \tag{5}$$

[11] In Allen and Gale (2000) banks hold claims on other banks ex-ante to insure themselves against liquidity shocks. Perfect risk-sharing is possible as long as liquidity shocks are imperfectly correlated and aggregate liquidity is sufficient. In this paper, banks only interact with each other ex-post, but the same two ingredients are vital to achieve a second-best solution.

Crucially, banks treat the asset price $p(L)$ as given. The optimization problem for banks is linear and the equilibrium price level has to equal

$$p^{CE} = \frac{qR}{R - 1 + q} < 1.$$

This specific price level makes every bank indifferent between long and short assets. Without loss of generality, I focus on a symmetric equilibrium.[12]

Definition 2: (Symmetric Competitive Equilibrium) *The competitive equilibrium consists of the period* 1 *asset price* $p^{CE}(L^{CE})$*, transaction volume* $X^{CE}(L^{CE})$*, initial allocations* $\{k^{CE}, l^{CE}\}$*, and the aggregate state characterized by* L^{CE} *such that*

1. *in period* 1*, intact and distressed banks optimally choose their demand and supply* $\{x_j^D, x_j^S\}$ *according to (P1:D) and (P1:S) given initial choices and the aggregate state* $\{k^{CE}, l^{CE}, L^{CE}\}$*;*
2. *the period* 1 *asset market clears;*
3. *banks in period* 0 *optimally determine their portfolio* $\{k^{CE}, l^{CE}\}$ *according to (P0:CE) taking asset prices as given;*
4. *the aggregate state of the economy described by* L^{CE} *is pinned down via* $L^{CE} = \int_0^1 l^{CE} dj = l^{CE}$*.*

Analysis and Comparative Statics

It is worthwhile to stress a few general properties of the equilibrium price. p is necessarily less than 1. If $p \geq 1$ it is not rational to invest in the short asset since long assets would provide a higher return even during distress. The fact that $p < 1$ further captures the notion that long assets are less liquid, that is, one long asset converts to less consumption goods if sold prematurely than a short asset.

Further, the asset price in the laissez-faire equilibrium is decreasing in the return of long assets, $\frac{\partial p^{CE}}{\partial R} < 0$. A higher return makes long assets more profitable which must be offset by larger losses during distress. A higher probability of distress increases the asset price in period 1, hence $\frac{\partial p^{CE}}{\partial q} > 0$. If liquidity shocks are more likely, short assets become relatively more profitable and holding long assets must be compensated by a higher price.

[12] p^{CE} pins down aggregate short assets L^{CE} via the market clearing condition (4). Any distribution of short and long assets across banks consistent with L^{CE} constitutes a competitive equilibrium. The efficiency of the competitive equilibrium relative to the global planner benchmark however depends entirely on the difference between L^{CE} and L^{GP}. Hence, every competitive equilibrium is equally inefficient.

2.4. Global Planner Equilibrium

The price taking behaviour of banks in conjunction with the binding balance sheet constraint creates a pecuniary externality which works entirely through equilibrium prices. Intuitively, banks do not internalize the relationship between liquidity, asset prices and fire-sales as emphasized in Lemma 2. Given this market failure, it is natural to ask how a social planner would want to regulate period 0 investment decisions. To this extent, I start with a constrained global planner who maximizes expected period 2 consumption on behalf of all banks. I follow the common approach of a constrained social planner who achieves a second best solution by allocating resources efficiently given the set of markets operating (Stiglitz, 1982; Geanakoplos and Polemarchakis, 1986). The solution is second best in the sense that the social planner does not intervene in the asset market in period 1. In other words, the planner acknowledges the balance sheet constraint. This excludes for example injections to banks in distress financed via lump-sum taxes on period 2 consumption or the provision of state contingent contracts which offer perfect insurance against period 1 liquidity shocks and thus lift the balance sheet constraint.

The optimization problem for the global planner is similar to the competitive equilibrium with three exceptions. First, the global planner aggregates over the objective function of each bank, that is, the planner maximizes

$$\max_{K \geq 0, L \geq 0} W^{GP}(K, L) = \max_{K \geq 0, L \geq 0} \int_0^1 E_0[c_{j2}(k_j, l_j; L)]dj \tag{P0:GP}$$

subject to

$$K + L = E. \tag{6}$$

Because banks are identical ex-ante, the objective function of a global planner is equivalent to a representative bank. Second, the planner internalizes the dependence between the period 0 portfolio and the equilibrium price in period 1, by choosing the aggregate portfolio $\{K, L\}$. In particular the planner recognizes that the equilibrium price $p(L)$ increases with aggregate liquid investments. Third, because banks have access to the same technologies, it is optimal to allocate identical portfolios to all banks irrespective of the specific jurisdiction.

I make one additional assumption regarding the profitability of long assets which establishes uniqueness of the global (and subsequently national) planner solution.

Assumption 5 *Regularity*

$$\phi'(x_j^D)\phi'''(x_j^D) - 2(\phi''(x_j^D))^2 \leq 0$$

The assumption holds whenever the inverse demand function $p = R\phi'(x_j^D)$ is log-concave, but it is weaker than log-concavity.[13] Log-concavity is a common assumption in Game Theory (Amir, 1996) and in monopoly theory (Caplin and Nalebuff, 1991) to ensure the existence and uniqueness of the equlibrium. In the context of this paper, it guarantees that $\frac{\partial^2 p(L)}{\partial^2 L} \leq 0$ and, as a result, a strictly concave objective function for national and global planners.

Definition 3: (Global Planner Equilibrium) *The global planner equilibrium consists of the period* 1 *asset price* $p^{GP}(L^{GP})$*, transaction volume* $X^{GP}(L^{GP})$*, bank-specific allocations* $\{k_j^{GP}, l_j^{GP}\}$*, and the aggregate state characterized by* L^{GP} *such that*

1. *in period* 1*, intact and distressed banks optimally choose their demand and supply* $\{x_j^D, x_j^S\}$ *according to (P1:D) and (P1:S) given initial allocations and the aggregate state* $\{k_j^{GP}, l_j^{GP}, L^{GP}\}$*;*

2. *the period* 1 *asset market clears;*

3. *the global planner in period* 0 *optimally determines the aggregate portfolio* $\{K^{GP}, L^{GP}\}$ *and hence aggregate state according to (P0:GP). The planner internalizes the dependency between asset prices and aggregate liquidity;*

4. *individual bank specific portfolios are proportionally allocated:* $k_j^{GP} = k^{GP} = K^{GP}$ *and* $l_j^{GP} = l^{GP} = L^{GP}$.

The planner's objective function yields the following first order condition:

$$p^{GP} = p^{CE}\left[1 + \overbrace{\underbrace{\frac{c - l^{GP}}{R}}_{\text{Base}} \underbrace{\frac{\partial p}{\partial L}}_{\text{Pecuniary Ext.}} \underbrace{\left[\frac{1}{\phi'(x_j^D)} - 1\right]}_{\text{Discount}}}^{>0}\right].$$

Discussion

The asset price is higher than in the competitive equilibrium, or equivalently, the global planner chooses strictly more liquid assets.[14] This is due to the nature of the competitive equilibrium in which individual banks do not internalize the dependence

[13] Log-concavity requires $\phi'(x_j^D)\phi'''(x_j^D) - (\phi''(x_j^D))^2 \leq 0$.

[14] Notice that $l^{GP} < c$ (see footnote 6) and $\phi'(x_j^D) < 1$.

between asset prices and initial investments. A higher price is negative for intact banks at it lowers their rent from asset purchases. Banks in distress however benefit, since they are forced to sell less assets at a higher price. The second effect dominates the first, precisely because assets are sold at a discount. The global planner internalizes this and therefore provides strictly more liquidity which results in expected first order welfare gains for all investors.

The desirability of short assets in the global planner equilibrium relates to three distinct components: $\frac{c-l^{GP}}{R}$ represents the tightness of the consumption constraint absent fire-sales. $c - l^{GP}$ refers to the amount of consumption goods banks in distress have to raise in period 1. This consumption gap is positive and divided by the profitability of unsold long assets. In other words, the fraction corresponds to the amount of long assets that would have to be sold at fair valuation in order to meet the consumption demand. The second term, $\frac{\partial p}{\partial L}$, measures the strength of the pecuniary externality, or equivalently, the ability of the global planner to affect asset prices in period 1. The third term, $\frac{1}{\phi'(\cdot)} - 1$, is equivalent to $\frac{R-p^{GP}}{p^{GP}}$ following the definition of the asset price, $p^{GP} = R\phi'(\cdot)$, and measures the fire-sale discount. A widening gap between R and p^{GP} raises fire-sales and in turn the attractiveness of liquid assets.

Implementation

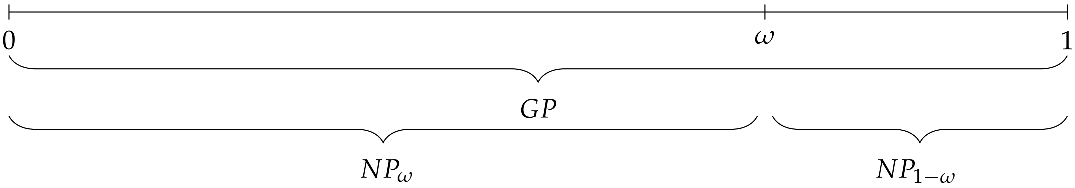
Before I continue to study national regulators, I emphasize the link between the aforementioned results and macroprudential liquidity regulation. The distinctive higher valuation of liquidity in the global equilibrium can be decentralized via, for example, a liquidity requirement like the Liquidity Coverage Ratio of the Basel III framework, or a Pigouvian tax on illiquid assets. These policies are macroprudential since they would be imposed in period 0, that is, prior to the liquidity crisis in $t+1$, and address systemic risk in financial markets. Because I focus on characterizing regulator preferences, I abstract from describing the implementation in detail. However, importantly, there is a one to one mapping between liquidity preferences and regulation. If a planner values liquidity more than banks, it is optimal to impose macroprudential regulatory standards. If a planner prefers less liquidity than banks, it is optimal to lower standards or even encourage banks to take on more risk.

3. National Regulators

This section provides the main insights of the paper. I examine the interaction between national regulators and the resulting implications on the investment portfolio and the willingness to cooperate in Sections 3.1 to 3.4.

Figure 5 contrasts the national planner setup with a single global planner. In terms of notation, one national regulator, henceforth denoted as ω-planner, supervises a share ω of banks with $0 < \omega < 1$, and the second regulator, referred to as 1-ω-planner, the remaining $1 - \omega$ banks.

Figure 5: Global Planner vs. National Planners



Though most of the upcoming results are derived under the general definition of $\phi(x_j^D)$, it is useful to provide a specific functional form.

Assumption 6 *Functional Form*

$$\phi(x_j^D) = ln(1 + x_j^D)$$

This functional form satisfies all previous assumptions.

3.1. National Planners Equilibrium

National regulators form a Cournot duopoly and only maximize welfare in their own jurisdiction. In particular, they take actions of the other regulator as given and disregard the price stabilizing effect of liquidity on foreign banks. National regulators therefore do not address the international aspect of the externality. Cournot competition is a standard assumption in the literature (see, for example, Dell'ariccia and Marquez, 2006; Bengui, 2014; Kara, 2016) and emphasizes the national mindset of regulators.

The ω-planner aggregates over the objective function of each bank in the ω-jurisdiction and hence maximizes

$$\max_{K_\omega \geq 0, L_\omega \geq 0} W_\omega^{NP}(K_\omega, L_\omega; L) = \max_{K_\omega \geq 0, L_\omega \geq 0} \int_0^\omega E_0[c_{j2}(k_j, l_j; L)]dj \qquad (\text{Po:NP}_\omega)$$

subject to

$$K_\omega + L_\omega = \omega E. \qquad (7)$$

The optimization problem for the 1-ω-planner is isomorphic:

$$\max_{K_{1-\omega}\geq 0, L_{1-\omega}\geq 0} W^{NP}_{1-\omega}(K_{1-\omega}, L_{1-\omega}; L) = \max_{K_{1-\omega}\geq 0, L_{1-\omega}\geq 0} \int_{\omega}^{1} E_0[c_{j2}(k_j, l_j; L)]dj \quad \text{(Po:NP}_{1-\omega}\text{)}$$

subject to

$$K_{1-\omega} + L_{1-\omega} = (1-\omega)E. \tag{8}$$

Definition 4: (National Planners Equilibrium) *The national planners equilibrium consists of the period* 1 *asset price* $p^{NP}(L^{NP})$*, transaction volume* $X^{NP}(L^{NP})$*, bank-specific allocations* $\{k_j^{NP}, l_j^{NP}\}$*, and the aggregate state characterized by* L^{NP} *such that*

1. *in period* 1*, intact and distressed banks optimally choose their demand and supply* $\{x_j^D, x_j^S\}$ *according to (P1:D) and (P1:S) given respective initial allocations and the aggregate state* $\{k_j^{NP}, l_j^{NP}, L^{NP}\}$*;*
2. *the period* 1 *asset market clears;*
3. *national planners in period* 0 *optimally determine their aggregate portfolios* $\{K_\omega^{NP}, L_\omega^{NP}\}$ *and* $\{K_{1-\omega}^{NP}, L_{1-\omega}^{NP}\}$ *according to (Po:NP*$_\omega$*) and (Po:NP*$_{1-\omega}$*) in Cournot competition. National planners internalize the dependency between asset prices and domestic aggregate liquidity;*
4. *individual bank specific portfolios are proportionally allocated:* $k_j^{NP} = k_\omega^{NP} = \frac{K_\omega^{NP}}{\omega}$ *and* $l_j^{NP} = l_\omega^{NP} = \frac{L_\omega^{NP}}{\omega}$ *if* $j \in (0, \omega]$ *or* $k_j^{NP} = k_{1-\omega}^{NP} = \frac{K_{1-\omega}^{NP}}{1-\omega}$ *and* $l_j^{NP} = l_{1-\omega}^{NP} = \frac{L_{1-\omega}^{NP}}{1-\omega}$ *if* $j \in (\omega, 1)$*;*
5. *the aggregate state of the global economy is described by* $L^{NP} = L_\omega^{NP} + L_{1-\omega}^{NP}$*.*

Lemma 4 *A unique interior Cournot equilibrium* ($L_\omega^{NP} > 0, L_{1-\omega}^{NP} > 0$) *exists as long as* $\omega \in (\underline{\omega}, \overline{\omega})$ *with* $0 < \underline{\omega} < 0.5 < \overline{\omega} = 1 - \underline{\omega} < 1$*. Otherwise, if* $\omega \geq \overline{\omega}$*,* $L_{1-\omega}^{NP} = 0$*, and if* $\omega \leq \underline{\omega}$*,* $L_\omega^{NP} = 0$*.*

Optimization in an interior Cournot equilibrium leads to two best response functions, one for each regulator.

$$BR_\omega : p^{NP} = p^{CE}\left[1 + \overbrace{\underbrace{\frac{\partial p}{\partial L}\omega}_{\omega \text{ Pecuniary Ext.}} \underbrace{\left[\frac{c - l_\omega^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R}\right]}_{\omega \text{ Fire-Sales}}}^{>0}\right]$$

$$BR_{1-\omega} : p^{NP} = p^{CE} \left[1 + \overbrace{\underbrace{\frac{\partial p}{\partial L}(1-\omega)}_{\text{1-}\omega\text{ Pecuniary Ext.}} \underbrace{\left[\frac{c - l^{NP}_{1-\omega}}{p^{NP}} - \frac{c - L^{NP}}{R} \right]}_{\text{1-}\omega\text{ Fire-Sales}}}^{>0} \right]$$

Discussion

As is apparent from the best response functions, the valuation of short assets does not coincide with the competitive equilibrium. The difference can be attributed to two factors, the degree to which regulators internalize the pecuniary externality, and the amount of fire-sales. $\frac{\partial p}{\partial L}\omega$ measures the strength of the pecuniary externality multiplied by the relative size of the domestic financial sector and hence represents the domestic share of the externality. The second term, $\frac{c-l^{NP}_{\omega}}{p^{NP}} - \frac{c-L^{NP}}{R}$, determines the amount of fire-sales. It corresponds to the difference between the actual bank-specific long asset supply and the hypothetical average supply without fire-sales. The product of these two components is equivalent among both regulators: the regulator who internalizes a larger share of the pecuniary externality, has less fire-sales and vice versa.

3.2. Aggregate Liquidity Provision

How does the level of aggregate liquidity in the national planners equilibrium compare with the competitive equilibrium and the global planner solution? In this section, I show that independent regulation is inefficient irrespective of the relative size of the national financial sector. The first proposition ranks aggregate liquidity in the national planners equilibrium with the global and competitive equilibrium.

Proposition 1

In an interior solution where both regulators chose a positive amount of liquidity the...

(i) ...amount of aggregate liquidity chosen by independent national regulators is strictly lower than the constrained efficient level of liquidity, $L^{GP} > L^{NP}$.

(ii) ...competitive equilibrium is characterized by strictly less overall liquidity than the national planners equilibrium, hence $L^{CE} < L^{NP}$.

With Assumption 6, (i) and (ii) hold in a corner solution when $0 < \omega \leq \underline{\omega}$ or $1 > \omega \geq \overline{\omega}$.

This proposition highlights that independent domestic regulation results in inefficiently low liquidity in an environment with international externalities. However, national regulators realize that more short assets relative to the competitive equilibrium benefit distressed banks in their jurisdiction by more than it harms intact banks. Hence, national regulation is more efficient than no regulation at all.[15]

3.3. Bank-Specific Liquidity Provision

How do national planners allocate investments to individual banks and how does that choice depend on the influence on global financial markets? To address this question, I analyze optimal investment choices by national planners as ω varies from 0 to 1. This section shows that initial portfolio choices are fundamentally linked to the size of the domestic banking sector.

Proposition 2

The following two effects emerge in an interior Cournot equilibrium.

(i) Externality Effect: Starting from equal domestic financial markets ($\omega = 0.5$), if ω increases the ω-planner internalizes a larger share of the global externality and prefers strictly more liquid assets for each bank ($\frac{\partial l_\omega^{NP}}{\partial \omega} > 0$). The 1-$\omega$-planner decreases bank-specific liquid investments ($\frac{\partial l_{1-\omega}^{NP}}{\partial \omega} < 0$).

(ii) Substitution Effect: Liquidity is a public good. Thus, if one planner decides to enhance regulation, the other planner has less incentives to regulate ($\frac{\partial l_\omega^{NP}}{\partial l_{1-\omega}^{NP}} < 0$).

(iii) The substitution effect reinforces the externality effect. Both interact with each other as summarized in the following formula evaluated at $\omega = 0.5$:

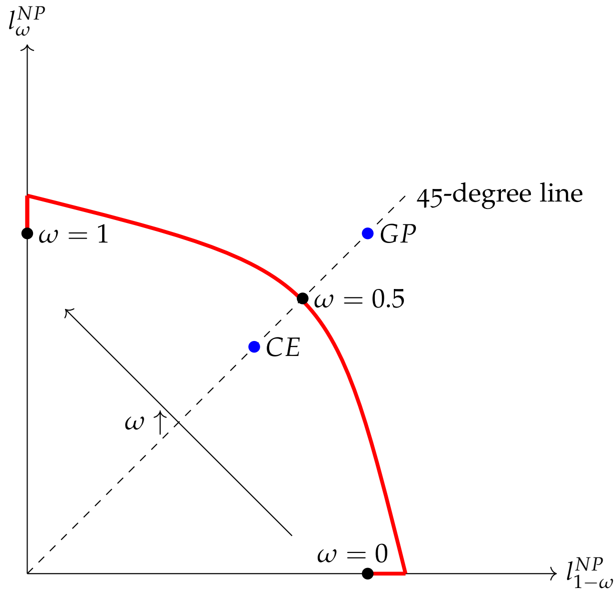
$$\left.\frac{\partial l_\omega^{NP}}{\partial \omega}\right|_{\text{total}} = \underbrace{\frac{\partial l_\omega^{NP}}{\partial \omega}}_{+} + \underbrace{\frac{\partial l_\omega^{NP}}{\partial l_{1-\omega}^{NP}}}_{-} \underbrace{\frac{\partial l_{1-\omega}^{NP}}{\partial \omega}}_{-} > 0.$$

The implications of Proposition 2 are displayed in Figure 6. The solid red line depicts the amount of liquidity chosen by both national planners for each of their banks $\{l_\omega^{NP}, l_{1-\omega}^{NP}\}$ as a function of the relative banking sector size ω. The two blue dots represent the global planner and competitive equilibrium. As mentioned in Proposition 1, a global planner provides strictly more liquid assets than national planners, who in turn jointly provide strictly more liquidity than banks in the competitive equilibrium.

In order to understand the intuition for these results, it is useful to examine the substitution and the externality effect separately.

[15] This result contrasts with Bengui (2014) who shows that national regulation can be less efficient than the competitive equilibrium. The different result in his model is a consequence of terms of trade manipulations, which only arise if jurisdictions are asymmetrically exposed to liquidity shocks.

Figure 6: National Planner Equilibria



Notes: *The red line depicts optimal bank-specific liquidity* $\{l_{\omega}^{NP}, l_{1-\omega}^{NP}\}$ *by national planners as a function of the relative banking sector size* ω*. The competitive (CE) and global planner equilibrium (GP) are marked for comparison.*

Substitution Effect

The public goods property of liquidity is well known in the literature (see, for example, Bengui, 2014 and Kara, 2016), and resonates with the strategic substitutability concept of Bulow et al. (1985). With more liquidity regulation, distressed banks in the same jurisdiction do not need to sell as many illiquid assets, which stabilizes the equilibrium asset price. The higher asset price in turn benefits distressed banks in the other jurisdiction. They have to sell less illiquid assets to obtain the same amount of consumption goods.

The expected return of illiquid assets is a weighted sum of the resale price during distress (p) and the period 2 return (R). A higher price combined with fewer fire-sales increases the marginal return of illiquid assets. Thus, if one jurisdiction mandates tighter liquidity standards, the regulator in the other jurisdiction optimally reduces liquidity regulation.

Externality Effect

A jurisdiction with a relatively larger banking sector tilts the bank-specific portfolio towards liquid assets. This effect is distinct from the substitution effect, materializes independently of the choice by the other regulator, and goes beyond pure size effects since planners alter their aggregate domestic short asset provision ($L_{\omega}^{NP}, L_{1-\omega}^{NP}$) beyond the required amount to compensate for the different number of domestic banks.

More influence on international asset markets grants planners more impact on equilibrium prices. Per se this does not justify a higher liquidity provision. However, due to the international aspects of the pecuniary externality, larger regulators internalize more of the inefficiency, which effectively increases the regulator's marginal return on liquid assets. Externality and substitution effects interact with each other, which generates a feedback loop that strengthens existing asymmetries.

Corner Solution

The previous narrative is based on an interior solution in which both planners provide a positive amount of liquidity. However, as Lemma 4 points out, a national planner overseeing few banks can be constrained by the non-negativity requirement on liquid asset holdings. This result emerges due to regulatory spillovers. A regulator can impose tight standards for domestic banks, but cannot prevent liquidity from flowing abroad. In other words, regulatory benefits are not exclusive to domestic banks, and foreign banks benefit from domestic regulation.

Interestingly, as apparent from Figure 6, a country with an increasingly larger banking sector decreases bank-specific liquidity requirements in a corner solution. Thus, cooperation may lead to reduction of restrictions in heavily regulated domestic financial markets. Put differently, the framework suggests that the tight regulatory standards of some countries may be too high relative to the optimal level with coordination.

3.4. Cooperation

Given the asymmetric portfolio choices by national planners, it is natural to ask whether both planners would be willing to surrender their authority and commit to common regulatory standards. It is a well-known fact from the Cournot games literature that each national planner has an incentive to deviate from cooperation. In other words, a global solution is not a Nash equilibrium. For this reason, I assume the existence of a commitment mechanism which ensures that national planners cannot deviate once both decided to surrender their authority. Alternatively, one could think about a repeated game between regulators, that is, an infinite sequence of the three period model in this paper. With appropriate punishment strategies when one planner deviates from the cooperative agreement, a cooperative solution can be achieved as a Nash equilibrium.

Some additional notation is necessary to set the stage for the subsequent analysis. I define gains from cooperation for both jurisdictions $\{\triangle_{\omega}, \triangle_{1-\omega}\}$ as:

$$\triangle_{\omega} = \omega W^{GP}(K^{GP}, L^{GP}) - W^{NP}_{\omega}(K^{NP}_{\omega}, L^{NP}_{\omega}; L^{NP})$$
$$\triangle_{1-\omega} = (1-\omega) W^{GP}(K^{GP}, L^{GP}) - W^{NP}_{1-\omega}(K^{NP}_{1-\omega}, L^{NP}_{1-\omega}; L^{NP}).$$

If national planners cooperate, a central regulator chooses the global planner solution which is by construction second best as it internalizes the entire externality. The period 2 consumption attributed to each jurisdiction in a global solution simply equals total $t = 2$ consumption (W^{GP}) multiplied by the relative size of each jurisdiction. If regulators do not cooperate, they continue to interact via Cournot competition and maximize period 2 consumption for their banks. A positive difference between the two outcomes leads to gains from cooperation for the respective planner, however cooperation is only feasible if both planners gain, which requires $\triangle_{\omega} > 0$ and $\triangle_{1-\omega} > 0$. It is worth stressing that aggregate gains from cooperation are always positive, that is, $\triangle_{\omega} + \triangle_{1-\omega} > 0 \;\forall\; \omega$. However as I show in the following proposition, the beneficial effects from an agreement are disproportionately distributed, which may ultimately prevent cooperation.

Proposition 3

(i) If national regulators oversee banking sectors of similar size ($\omega \approx 0.5$), both jurisdictions gain from cooperation, that is, $\triangle_{\omega} > 0$ and $\triangle_{1-\omega} > 0$.

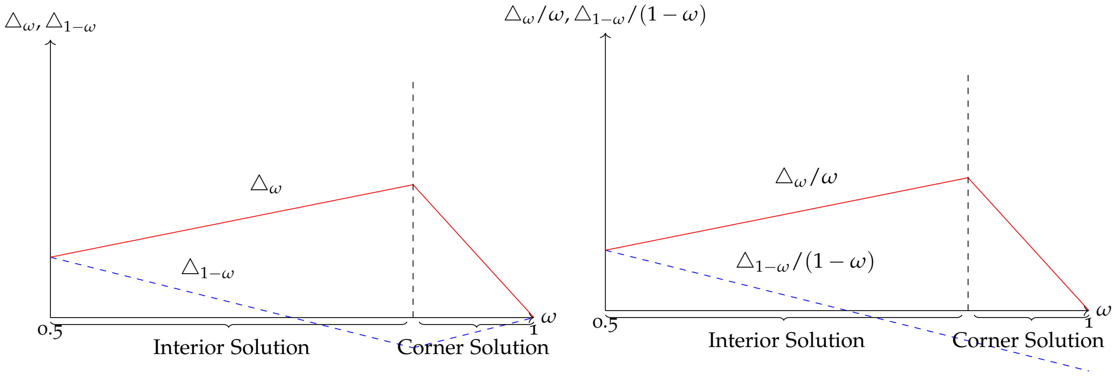
(ii) If banking sector sizes are too asymmetric, cooperation is not optimal. A jurisdiction with a small-banking sector looses from coordination, that is, either $\triangle_{\omega} < 0$ if $\omega < \underline{\underline{\omega}} < 0.5$ or $\triangle_{1-\omega} < 0$ if $\omega > \overline{\overline{\omega}} = 1 - \underline{\underline{\omega}} > 0.5$. As a consequence, coordination, albeit desirable from a global perspective, does not necessarily constitute a Pareto improvement.

Figure 7 illustrates Proposition 3. Panel (a) displays gains from cooperation for both jurisdictions $\{\triangle_{\omega}, \triangle_{1-\omega}\}$ as ω expands from 0.5 (symmetry) to 1, while Panel (b) displays gains from cooperation for individual banks within each jurisdiction $\{\triangle_{\omega}/\omega, \triangle_{1-\omega}/(1-\omega)\}$.

If both banking sectors are of similar size, both jurisdictions gain a similar amount by coordinating their regulatory efforts, that is $\triangle_{\omega} > 0$ and $\triangle_{1-\omega} > 0$. In contrast, a country with a small financial sector is less willing to adopt global standards which would require to increasingly scale up less profitable liquid investments relative to the uncoordinated equilibrium. This is captured by the downward sloping dashed line. In both panels, gains from cooperation turn negative, but they converge back to zero

Figure 7: Gains from Cooperation

(a) Aggregate *(b) Individual Bank*



Notes: *Panel (a) displays gains from cooperation for jurisdictions* $\{\triangle_\omega, \triangle_{1-\omega}\}$ *as a function of the relative financial sector size* ω*. Panel (b) shows gains from cooperation for individual banks of each jurisdiction* $\{\triangle_\omega/\omega, \triangle_{1-\omega}/(1-\omega)\}$*.* ω *varies from* 0.5 *(symmetry) to* 1*. The solid red (dashed blue) line refers to the* ω *(1-*ω*)-jurisdiction. The corner region corresponds to equilibria where* $l^{NP}_{1-\omega} = 0$*.*

when considering jurisdiction-wide benefits (Panel (a)). This effect is purely driven by the aggregation of an increasingly smaller share of banks in 1-ω-jurisdiction.

On the contrary, the planner who internalises a large share of the fire-sale externality needs to subsidize the other planner which results in positive gains from cooperation. Gains are first rising due to the growing free-riding behaviour of the other planner. As such, the large jurisdiction consistently increases implicit subsidies in terms of international liquidity provision. In a corner solution where the small jurisdiction decides to supply zero liquidity, gains from cooperation start to decrease but remain positive. Further, in the limit as ω approaches one, the Cournot solution of the large national planner converges to the solution of a single global planner and gains from cooperation are zero.

4. Policy Recommendations

The previous analysis emphasized aggregate gains from cooperation on macroprudential regulatory standards in a model with an international externality. However, as the last section points out, these gains may not be reaped as small jurisdictions prefer to free-ride on jurisdictions with a sizable banking sector. In this section I discuss two policy recommendations, transfers and capital controls that could align the interests of jurisdictions towards cooperation or alternatively limit spillovers between jurisdictions.

4.1. Transfer Payments

Transfer payments can resolve the discrepancy between aggregate benefits from cooperation and the unequal jurisdiction-specific distribution thereof. If free-riding prompts a jurisdiction to decline cooperation, then gains from coordination for the other jurisdiction necessarily outweigh the losses for the free-riding planner. As such, countries that already regulate could provide a compensation towards free-riding countries in return for cooperation.

Corollary 1 *There exists a level of transfers originating from the regulating jurisdiction towards the free-riding jurisdiction that makes both better-off with cooperation.*

The idea of transfer payments has a long tradition particularly in the environmental economics literature (Markusen, 1975). However, while such transfers are indeed implemented in practice, for example as part of the recent Paris Agreements, they are supposed to aid developing countries with a lack of funding. The transfers related to macroprudential cooperation in contrast would be necessary as some jurisdictions free-ride. With that in mind, it seems politically infeasible to convince large jurisdictions to subsidize free-riding behaviour.

As a more realistic alternative to pure transfers, adoption of common macroprudential standards by smaller, mostly emerging market economies could be linked to other agreements, which are primarily beneficial for emerging markets such as free trade agreements. Both, the US and the European Union maintain such agreements with a variety of emerging economies. The framework introduced earlier also points to a potential role of the IMF and World Bank. Both institutions frequently aid distressed countries and demand reforms in exchange. This paper justifies macroprudential standards on the list of requirements.

4.2. Capital Controls

The framework introduced previously justifies capital controls as a tool to reduce international spillovers and to incentivize free-riders.

Corollary 2

(i) Suppose capital controls are tight, strictly enforced and national markets are sufficiently large to accommodate fire-sales. Then capital controls can restore the constrained efficient allocation for both planners if paired with national macroprudential liquidity regulation.

(ii) Suppose, the regulated market is large enough to accommodate fire-sales. If capital controls are imposed on free-riding economies, regulated countries avoid inefficient spillovers and

regulation is more targeted. This increases welfare even when domestic regulation is not adjusted. Capital controls therefore act in the interest of countries with a regulated financial market.

(iii) If free-riding economies are threatened with capital controls and their domestic financial market is small, unregulated countries may be forced to adhere to international regulatory standards in order to access necessary financing during distress. In this case cooperation is third-best from the perspective of unregulated jurisdictions and capital controls serve as a commitment device.

The first part of Corollary 2 is straight forward. Tight and strict enforcement of capital controls would lead to two separate markets. As a consequence, both planners would internalize the entire remaining externality and national regulation is constrained efficient. This result is best viewed as a benchmark, whose conditions are hardly ever met in practice. Capital controls are usually not tight (Fernández et al., 2016) and subject to leakages (Ahnert et al., 2018; Bengui and Bianchi, 2018). However, even though capital controls do not separate markets in reality, they may reduce the international aspect of the externality.

Parts (ii) and (iii) of Corollary 2 are potentially more relevant in practice. Most regulating countries are advanced economies with a large joint financial sector. These countries could levy capital controls on free-riding economies and still absorb financial shocks amongst themselves. Even if capital controls are not perfect in practice, they could limit spillovers from unregulated economies. This would be welfare improving for regulated economies precisely because it increases the average amount of liquidity in the remaining international market.

The previous results follow from the Law of Large Numbers, that is, the presence of sufficient intact banks in the domestic market to absorb financial shocks. With few domestic banks, there is a positive probability that a substantial share of banks within a jurisdiction are in distress and as a consequence there would not be enough intact banks to purchase distressed assets. Given that particularly countries with a small banking sector do not regulate (Proposition 2) nor cooperate (Proposition 3), unregulated countries most likely do not have the ability to absorb liquidity needs by distressed banks on their own. In this case capital controls could be used as a threat against uncooperative countries and force them to adopt international regulatory standards as a third-best option in exchange for access to international financing.

The aforementioned motivation for capital controls is distinct from the literature. In the literature, capital controls are imposed to improve domestic welfare by addressing a domestic externality (see, for example, Bianchi, 2011; Schmitt-Grohe and Uribe, 2016) or by gaining an advantage relative to other countries via terms of trade manipulations (De Paoli and Lipinska, 2012; Costinot et al., 2014). In the context of this paper however, capital controls can be welfare improving for *both* jurisdictions, or if levied upon unregulated jurisdictions with a small banking sector, force unregulated economies to follow international regulatory guidelines.

5. Empirical Support

The analysis so far highlighted regulatory free-riding by jurisdictions with minor domestic banking sectors and hence limited impact on international financial markets. Ultimately, countries may refuse common regulatory standards out of self interest despite global welfare gains from international agreements. In this section, I provide empirical evidence for this mechanism and compare it with alternative explanations in the literature. In particular, I formulate, test and confirm the following hypothesis, which is an immediate consequence of Proposition 3:

H_a: *The size of the domestic banking sector predicts the adherence to international regulatory standards.*

The Basel agreements are the most comprehensive cross-sectional regulatory effort for banks and hence an obvious candidate to evaluate this hypothesis and other models in the literature. I use survey data on the implementation of Basel II and III standards from the BIS (2015) to extract information about cooperative behaviour. The survey is restricted to non-member countries, therefore two remarks are in place: First, as mentioned in the Introduction, non-member countries have been repeatedly encouraged by the Basel Committee, World Bank and IMF to comply with regulatory standards (Drezner, 2007; Cos, 2020). Second, Basel member countries have a large banking sector *and* are committed to implement the framework, which supports the formulated hypothesis.

It is useful to elaborate on the correspondence with the analytical framework. The Basel II guidelines are generally perceived as insufficient and therefore tightened with Basel III. However, even Basel III appears to lack rigor as pointed out in the literature. I therefore view the Basel framework, and particularly Basel II, as a lower bound on international standards that some countries adhere to or even exceed (the "regulating" jurisdictions), while others do not (the "free-riders"), which maps the current status-quo to the national regulator framework in Section 3.

The Basel framework goes well beyond liquidity regulation and hence my model. In fact, liquidity regulation is only part of the Basel III framework. I discuss the Basel framework and details regarding the empirical exercise in the appendix. I show that the overall size of the domestic banking sector is positively associated with cooperation on liquidity regulation. However, the idea that national regulators internalize varying degrees of an international externality, which in turn determines the willingness to regulate should extend beyond liquidity regulation.

5.1. Adherence to Basel Standards

In what follows, I capture the adherence to Basel standards based on a simple statistic which I refer to as the Basel II or III Index. The index counts the number of Basel II or III guidelines that each country implemented at each point in time. Two comments are in order: First, certain Basel guidelines are complex and hence challenging to implement for emerging markets and developing countries (see, for example, FSB, IMF and World Bank, 2011 Gottschalk, 2016; Jones and Knaack, 2019). A partial implementation of the Basel frameworks is therefore expected. The relevant question is hence whether countries with a larger banking sector are more likely to adhere to a larger set of the regulatory guidelines. The Basel Index that I construct measures this non-binary choice. Second, several countries in the survey have a negligible financial sector, which renders financial regulation obsolete. To be conservative, I therefore truncate the original sample and exclude jurisdictions with a banking sector size below the 25 percentile (threshold: 2.05 billion USD) which yields a sample of 63 countries.

Figure 8 plots the Basel II Index for the year 2015. Panel (a) focuses on countries with a small banking sector (proxied by domestic credit) while Panel (b) provides the distribution for countries with a large banking sector.[16] The Basel II framework is split into 10 components, hence the specific range on the horizontal axis. Each bar represents the share of countries that incorporated a specific number of policies. Clearly, the vast majority of countries did not follow the lead of the Basel Committee on Basel II standards. Further and related to this paper, countries with a sizable banking sector tend to be less reluctant to adopt Basel II policies. On average countries with a large banking sector adopt 4.5 policies, while countries with a smaller banking sector implement 2.9 policies.

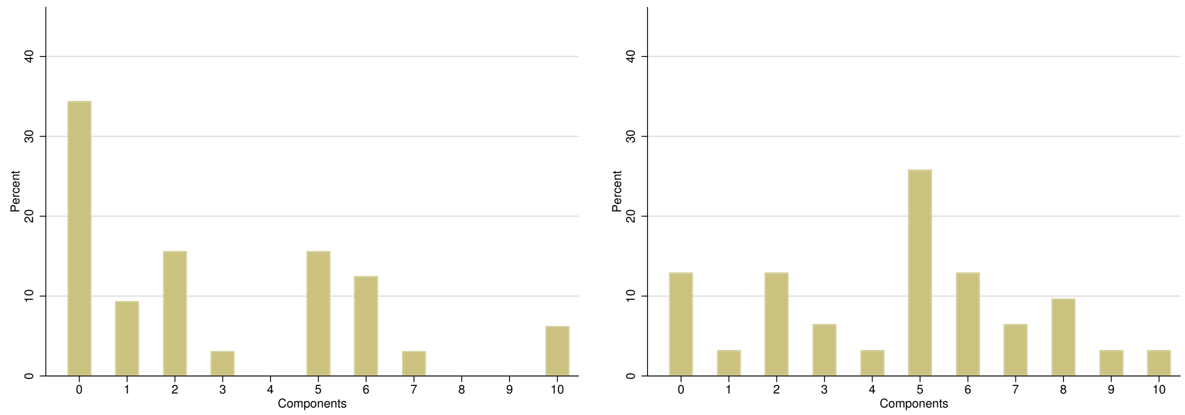
5.2. Explanatory Variables

I consider several potential explanatory variables, most importantly the size of the domestic banking sector, which I proxy by the amount of domestic credit towards the

[16] A similar graph for the Basel III Index is delegated to Figure E2 in the appendix.

Figure 8: *Basel II Implementation for Non-members as of 2015*

(a) Low Credit Countries | *(b) High Credit Countries*



Notes: *The vertical axes portray the share of countries (in %) that implemented a specific number of Basel II components. Panel (a) (Panel (b)) considers countries with low (high) domestic credit to the private sector by banks (in constant USD, threshold based on median) as a proxy for the size of the domestic banking sector. Each subsample sums up to 100%.*

private sector by banks in constant USD. Domestic credit has been frequently used to proxy for the development/size of the financial sector and is available for all countries in this sample (see Beck et al. (2010) for an overview). The analytical framework introduced earlier emphasized the international interlinkages of the domestic banking sector. As such, the previous results technically only apply to countries with an internationally integrated financial sector. To make headway on this issue, I analyze countries with open financial markets as a robustness check. Reassuringly, I find that banking sector size effects are primarily relevant for countries without tight capital controls.

I also include GDP (in constant USD) as a control variable in some regressions in order to distinguish the banking sector from simple country size effects. Just to be clear, it is important to distinguish credit from GDP. The willingness to cooperate on standards in my model is based on the degree to which national regulators internalize a global externality in the banking sector.[17] The relevant metric is hence the size of the domestic banking sector and not the credit to GDP ratio that some studies (see, for example, Jones and Zeitz, 2017) use to proxy for financial development. To make this point clear, consider Israel and Panama. Both countries have about the same credit to GDP ratio, but the absolute size of the banking sector as measured by domestic credit

[17]The banking sector size is equivalent to GDP in the baseline model. I solve this discrepancy with an extension in the appendix. The extension introduces an alternative investment opportunity for investors unrelated to financial investments which decouples the banking sector from GDP.

is about 5.5 times larger in Israel. Israel implemented half of the Basel II guidelines while Panama only 1 out of 10 components as of 2015.

The existing literature on international financial cooperation stresses multiple obstacles: different legal or political systems and informational asymmetries (Barth et al., 2006; Beck and Wagner, 2016; Ostry and Ghosh, 2016), different risk versus return trade-offs (Dell'ariccia and Marquez, 2006; Kara, 2016), varying profitability of the banking sector (Kara, 2016), or the market concentration in the banking sector (see, for example, Allen and Gale, 2004; Repullo, 2004; Schaeck et al., 2009; Jones and Zeitz, 2017).

I proxy political considerations with an institutional quality index. This index accounts for the quality of governance, the degree of corruption, the establishment of a proper legal framework, and the stability of the government. Risk versus return trade-offs are based on preferences, which are challenging to measure in reality. To obtain some, albeit imperfect insights, I include a financial crisis indicator. If a country experienced a crisis, it may be more likely to internalize the beneficial effects of sufficient financial regulation and hence prefer less risk at the expense of lower returns. This notion is supported by Aizenman (2009) who finds that prolonged periods of financial stability are associated with a lower regulation intensity. The profitability of banks is proxied by the returns on assets in each country. From an opportunity cost perspective, we would expect that regulators avoid tight standards if the banking sector is very profitable. Last but not least, I consider a variable that measures the asset share of the three largest banks in order to test for agglomeration effects. The literature has not reached a consensus as to whether market concentration actually increases or decreases the willingness to regulate the financial market. Details on the construction of each variable are available in the appendix.

5.3. Results

Table 1 provides estimates from an ordered logit model. The dependent variable corresponds to the Basel II Index for the year 2015, which marks the last year of available data. All explanatory variables (except for the banking crisis indicator) represent averages over the 2003-2015 period to reduce the noise in the data and to account for the notion that fundamental decisions to adopt financial regulation tend to be based on medium or long-run considerations.[18] Credit, institutional quality and

[18]The sample period reflects the initial publication of the Basel II framework in 2004 and the last available survey in 2015.

GDP are further standardized. The concentration and return on asset measures are expressed in %.

Clearly, domestic credit as a proxy for the banking sector size is able to explain the adoption of Basel standards at the 1% level of significance while all other explanatory variables except for GDP are insignificant (columns (1)-(6)). To be more precise, a one standard deviation increase in domestic credit increases the odds of implementing more Basel II components by a factor of $exp(1.06) = 2.89$ (column (1)). The remaining explanatory variables are insignificant but have the predicted sign. A previous banking crisis and a better institutional quality are loosely associated with more implemented Basel II policies, though both explanatory variables have essentially zero or opposite effects once more regressors added. On the contrary, a higher average return on assets represents opportunity costs in adopting standards and are associated with insignificantly less adopted Basel guidelines. The degree of banking sector concentration in the economy has no explanatory power.

Table 1: *Adherence to Basel II Standards: Ordered Logit Regression Results*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Avg. Credit	1.06***						1.01***	1.71***	0.78**
	(0.27)						(0.30)	(0.54)	(0.41)
Banking Crisis		0.12					-0.00	-0.34	0.03
		(0.45)					(0.62)	(0.70)	(0.64)
Avg. Inst. Quality			0.30				-0.03	-0.24	0.05
			(0.29)				(0.29)	(0.38)	(0.34)
Avg. ROA				-0.70			-0.62	-1.01*	-0.60
				(0.43)			(0.51)	(0.61)	(0.52)
Avg. Concentration					0.01		0.03	0.05	0.03
					(0.02)		(0.02)	(0.03)	(0.02)
Avg. GDP						0.79***			0.25
						(0.25)			(0.29)
Pseudo R^2	0.06	0.00	0.01	0.02	0.00	0.04	0.10	0.22	0.10
Countries	All	All	All	All	All	All	All	Open	All
Observations	63	63	55	62	61	63	54	30	54

Notes: Dependent variable: Basel II Index as of 2015. The independent variables represent averages (Avg.) over the 2003-2015 period except for the Banking Crisis indicator which is 1, if a country experienced a systemic banking crisis since 1990. Credit, institutional quality and GDP are standardized to ease comparison. Concentration and ROA are measured in %. Basel non-member countries only. Column (8) further excludes economies with tight capital controls. Huber-White robust standard errors are reported in parenthesis. Stars indicate significance levels (*10%, **5%, ***1%).

Because GDP predicts the adoption of Basel standards (column (6)), one might be worried that credit simply proxies for the size of the economy. However, once all regressors are considered, the credit variable remains the only significant variable (column (9)). In other words, the credit variable is not just a proxy for the overall size of the economy. This empirical result therefore mirrors Proposition 3.

As a further robustness check, I exclude all countries with tight capital controls in column (8). Tight capital controls in this context refer to restrictions above the 75 percentile across all countries in the sample. Domestic credit remains the most relevant predictor and becomes even more quantitatively important. The coefficient on credit increases from 1.01 to 1.71 (columns (7) and (8)). The return on asset variable turns slightly significant at the 10% level and keeps its negative sign. Overall, the explanatory power of the regression improves by a factor of 2.2, which is consistent with the narrative of Section 4.2. Sufficient capital controls limit the necessity to adopt international regulatory standards. One should therefore expect banking sector size effects primarily for countries that are integrated in international financial markets.

Table 2: *Adherence to Basel III Standards: Ordered Logit Regression Results*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Avg. Credit	0.67***						0.57***	0.56***	0.48
	(0.21)						(0.20)	(0.18)	(0.41)
Banking Crisis		0.44					-0.06	-0.66	-0.05
		(0.50)					(0.56)	(0.72)	(0.56)
Avg. Inst. Quality			0.05				-0.10	-0.29	-0.06
			(0.33)				(0.37)	(0.46)	(0.44)
Avg. ROA				-0.37			-0.43	-0.69	-0.43
				(0.29)			(0.34)	(0.84)	(0.34)
Avg. Concentration					0.00		0.02	0.07*	0.02
					(0.02)		(0.02)	(0.04)	(0.02)
Avg. GDP						0.60***			0.11
						(0.21)			(0.40)
Pseudo R^2	0.05	0.00	0.00	0.01	0.00	0.04	0.06	0.13	0.06
Countries	All	All	All	All	All	All	All	Open	All
Observations	63	63	55	62	61	63	54	30	54

Notes: Dependent variable: Basel III Index as of 2015. The independent variables represent averages (Avg.) over the 2003-2015 period except for the Banking Crisis indicator which is 1, if a country experienced a systemic banking crisis since 1990. Credit, institutional quality and GDP are standardized to ease comparison. Concentration and ROA are measured in %. Basel non-member countries only. Column (8) further excludes economies with tight capital controls. Huber-White robust standard errors are reported in parenthesis. Stars indicate significance levels (*10%, **5%, ***1%).

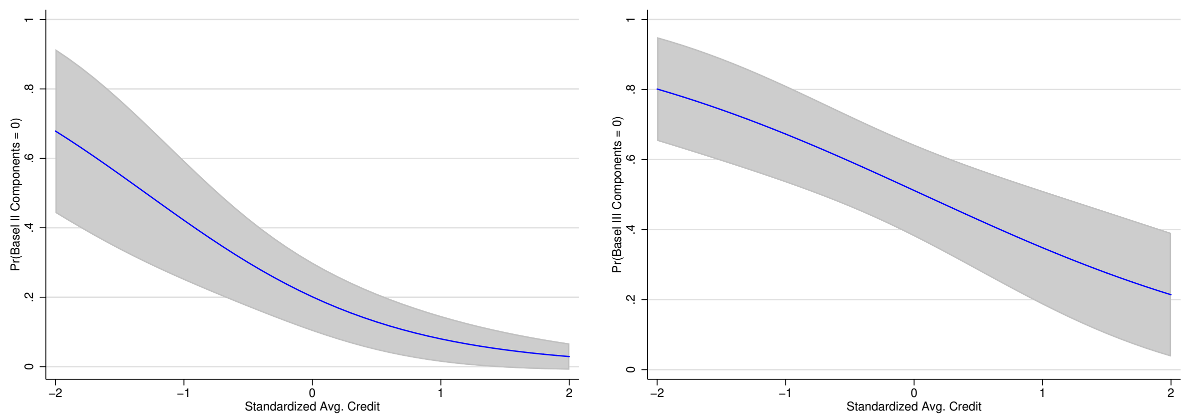
A closely related pattern emerges for Basel III standards. Results are displayed in Table 2. The underlying regressions are identical to the ones in Table 1, except that I replaced the Basel II Index with its Basel III counterpart. Domestic credit continues to be the dominant factor while proxies capturing alternative explanations in the literature are not able to predict the adoption of Basel III standards. However as column (9) suggests, it is more challenging to distinguish the size of the banking sector from GDP. Though credit is no longer significant at the 10% level, it maintains a z-statistic above one. Nevertheless, given that Basel III requirements were just about to be implemented in 2015, generally lower significance levels are somewhat expected.[19]

A more nuanced perspective based on Margins Plots

I visualize the dependence between the adherence to Basel guidelines and the size of the domestic banking sector with margins plots in Figure 9. Specifically, I compute the probability of adhering to zero (vertical axes) versus at least one Basel II or III policy by the end of 2015 as a function of domestic credit (standardized, averaged over the period 2003-2015). The margins plots reveal a negative relationship between domestic credit and the probability of implementing zero policies. This is particularly true for Basel II (Panel (a)) but also visible when examining Basel III standards (Panel (b)). In other words, the larger the banking sector, the more likely a country adopts at least one component of the Basel II or III framework.

Figure 9: *Conditional Probability of Implementing Zero Basel Policies*

(a) *Basel II* ***(b)*** *Basel III*



Notes: The vertical axes display the probability of installing zero Basel II (Panel (a)) or III policies (Panel (b)) by the end of the year 2015. The horizontal axes represent the amount of domestic credit to the private sector by banks (standardized, averaged over the period 2003-2015). Shaded areas indicate 95% confidence intervals. The plot is based on an ordered logit regression with credit as the only control variable.

[19]Further evidence on this is presented in the appendix. The distribution of Basel III standards across countries does not appear stationary as of 2015 (Figure E4).

Discussion

The banking sector size appears to be the most relevant explanatory variable for the adherence to the Basel standards, as predicted by the analytical framework. Before I conclude this section, I discuss two concerns with the regression results: non-response and reverse causality. The survey relies on self-reported voluntary responses from official authorities. As such, the data may be vulnerable to a selection bias since complying regulators could be more likely to respond. The non-reporting countries are primarily central African, Middle Eastern and Central Asian countries all of which have a small financial sector. A possible reporting bias should hence understate the importance of banking sector size effects. Another issue pertains to reverse causality. The level of financial regulation may affect the size of the domestic banking sector. With the plausible prior that regulation decreases the size of the financial sector, the presented estimates should understate banking sector size effects. That said, the purpose of this section is not to claim causality, but to provide evidence that banking sector size effects matter more than other mechanisms proposed in the literature.

6. Conclusion

A significant share of the global banking sector is not or only partially regulated. But what determines the adherence to multinational financial regulatory standards? In this paper I propose a novel mechanism based on the interlinkages between domestic and foreign banks. I analytically show that countries with a larger financial sector are more likely to commit to international macroprudential regulation. Countries with limited influence on international financial markets in contrast may rationally decline to cooperate on common standards and free-ride on foreign regulation, even when cooperation is globally welfare improving.

My argument is based on international fire-sales that operate through a global asset market: countries with a relatively small banking sector do not internalize inefficient financial spillovers. Equivalently, they ignore the positive externality associated with additional liquidity, which reduces asset fire-sales during distress. Large jurisdictions in contrast oversee a fair share of the global market and hence internalize a significant portion of this externality. This has inevitable consequences for domestic macroprudential regulation and the desirability of coordinated efforts: domestic regulation is too low, particular for free-riding economies. As a consequence, they would be required to significantly increase regulation to comply with joint regulatory standards, which reduces investments in productive assets. This drawback can outweigh the benefits from an agreement. Joint regulation is hence not necessarily a Pareto improvement for countries with few internationally operating banks.

Subsequently I support this mechanism by empirical evidence. The size of the domestic financial sector is the only significant explanatory variable for the adoption of Basel II and III standards despite a variety of control variables that proxy recently proposed explanations in the literature.

Though the lack of cooperation is potentially negative for the stability of global financial markets, I highlight two mechanisms that could alleviate this dilemma. One possibility would be subsidies by jurisdiction which benefit from cooperation. However transfers are challenging to implement in practice due to political obstacles with subsidizing free-riding countries. This points to a special role of the IMF or World Bank, which could mandate the adherence to Basel standards as a condition for financial aid. The second option are capital controls. Capital controls limit international spillovers and hence reduce the inefficiency of national regulation by aligning national interests with a global efficient outcome. This paper therefore advocates the implementation of national macroprudential regulation and capital controls, if countries cannot agree on international regulation. However, the favorable treatment of capital controls is tied to two major restrictions. First, capital controls would need to be strictly enforced, which creates additional costs that are not considered in my model. Second, the domestic banking sector would have to be large enough to absorb financial shocks. The second condition is jointly satisfied by regulating advanced economies. They could therefore consider capital controls as a device to strengthen the incentives of free-riders to agree on common standards as a third-best outcome in order to access international financial markets.

A. Appendix: Introduction

Table A1: *Country List*

Albania	Costa Rica	Macedonia, FYR	Paraguay
Algeria	Dominican Republic	Malaysia	Peru
Angola	Ecuador	Mauritius	Philippines
Armenia	Egypt	Mongolia	Qatar
Bahamas	El Salvador	Montenegro	Serbia
Bahrain	Georgia	Morocco	Sri Lanka
Bangladesh	Ghana	Mozambique	Tanzania
Barbados	Guatemala	Namibia	Thailand
Belarus	Honduras	Nepal	Trinidad and Tobago
Bolivia	Iceland	New Zealand	Tunisia
Bosnia and Herzigovina	Israel	Nigeria	Uganda
Botswana	Jamaica	Norway	United Arab Emirates
Brunei Darussalam	Jordan	Oman	Uruguay
Chile	Kenya	Pakistan	Vietnam
China, P.R.: Macao	Kuwait	Panama	Zimbabwe
Colombia	Lebanon	Papua New Guinea	.

Table A2: *Unregulated/Partially Regulated Financial Sector Size relative to the US*

N	0	1	2	3	4	5	6	7	8	9	10
Basel II	.06	.07	.1	.11	.11	.21	.26	.27	.37	.41	.48
Basel III	.14	.21	.31	.34	.38	.47	.48	.48	.48	.	.

Notes: Domestic credit relative to the US aggregated over all countries with less or equal to the specified number of implemented Basel II (row 1) or III (row 2) components. Basel II (III) has 10 (8) subcomponents. Calculations are for the year 2015. Credit is defined as bank credit to the private sector.

B. Appendix: Section 2

Proof of Lemma 1: Existence of the period 1 equilibrium requires, first, sufficient liquidity in the market and, second, enough long assets to ensure that distressed banks are able to purchase consumption goods. In other words, the constraints (1) and (3) must be slack.

In order to satisfy period 1 consumption demand, available consumption goods by intact banks must be at least as large as the consumption shortage by distressed banks, that is $(1-q)L \geq q(c-L)$, which is equivalent to $L \geq qc$. If $L \geq qc$, then $c - L \leq c(1-q)$. With asset market clearing, the statement is equivalent to $qc \geq \phi'^{-1}\left(\frac{p}{R}\right)p$. The term on the left is constant while the term on the right corresponds to the $t = 1$ expenditure by an intact bank which increases in x_j^D via Assumption 2. Because demand and prices are inversely related, expenditure decreases with p. The price of the competitive equilibrium, $p^{CE} = \frac{qR}{R-1+q}$, is strictly lower than the price level with global or national planners (Proposition 1). To guarantee $L \geq qc$ I thus set $p = p^{CE}$, which results in $qc \geq \phi'^{-1}\left(\frac{q}{R-1+q}\right)\frac{qR}{R-1+q}$.

With regard to the long asset supply, we must have that $x_j^S = \frac{c-l_j}{p} \leq k_j$, or equivalently $\frac{c-l_j}{e-l_j} \leq p$ since $e = k_j + l_j$. The fraction on the left decreases in l_j as $e > c > l_j$ and is largest when $l_j = 0$. The term on the right obtains its minimum at $p = p^{CE}$. $\frac{c}{e} \leq \frac{qR}{R-1+q}$ is therefore a sufficient condition. ■

Proof of Lemma 2: The proof exploits the market clearing condition (4) in conjunction with the implicit function theorem:

$$\frac{\partial p}{\partial L} = -\frac{\partial X^S/\partial L}{\partial X^S/\partial p - \partial X^D/\partial p}.$$

$\partial X^S/\partial L = -q/p$, $\partial X^S/\partial p = -\frac{X^S}{p}$ and $\partial X^D/\partial p = \frac{1}{\phi''\left(\frac{X^D}{1-q}\right)\frac{R}{1-q}}$. In equilibrium, $X^S = X^D = X$. Therefore,

$$\frac{\partial p}{\partial L} = \frac{q}{-X - \frac{p}{\phi''\left(\frac{X}{1-q}\right)\frac{R}{1-q}}}.$$

Because $p = R\phi'\left(\frac{X}{1-q}\right)$ one obtains

$$\frac{\partial p}{\partial L} = \frac{-\frac{q}{1-q}\phi''\left(\frac{X}{1-q}\right)}{\frac{X}{1-q}\phi''\left(\frac{X}{1-q}\right) + \phi'\left(\frac{X}{1-q}\right)} > 0. \tag{B.1}$$

The derivative is positive, since both numerator and denominator are larger than zero due to Assumptions 1 and 2 respectively.

The proof for $\frac{\partial X(L)}{\partial L} < 0$ follows a similar logic. The market clearing condition (4) can be expressed in terms of the price differential $p^S(X, L) - p^D(X) = 0$ with $p^S(X, L) = q\frac{c-L}{X}$ and $p^D(X) = R\phi'\left(\frac{X}{1-q}\right)$. As a result,

$$\frac{\partial X}{\partial L} = -\frac{\partial p^S/\partial L}{\partial p^S/\partial X - \partial p^D/\partial X} = \frac{-q}{R\left(\frac{X}{1-q}\phi''\left(\frac{X}{1-q}\right) + \phi'\left(\frac{X}{1-q}\right)\right)} < 0.$$

■

Proof of Lemma 3: The marginal utility from early consumption converges to infinity if $c_{j1} \leq c$. Autarky therefore implies $l_j = c$.

Expected period 2 consumption in autarky is

$$E_0[c_{j2}^{\text{Autarky}}] = qR(e-c) + (1-q)\left(R(e-c)+c\right) = R(e-c) + (1-q)c.$$

The asset market equilibrium provides the following $t = 2$ expected consumption:

$$\begin{aligned} E_0[c_{j2}^{\text{Market}}] &= q\left[R\left[e - l_j - \frac{c-l_j}{p}\right]\right] + (1-q)\left[R\left[e - l_j + \phi\left(x_j^D\right)\right] + l_j - px_j^D\right] \\ &= R(e-l_j) - qR\frac{c-l_j}{p} + (1-q)R\underbrace{\left[\phi\left(x_j^D\right) - \phi'(x_j^D)x_j^D\right]}_{>0 \quad \text{Assumption 1}} + (1-q)l_j \\ &> R(e-c) + (1-q)c + R(c-l_j) - (1-q)(c-l_j) - \frac{qR}{p}(c-l_j). \end{aligned}$$

The asset market equilibrium dominates the autarky equilibrium if $E_0[c_{j2}^{\text{Market}}] > E_0[c_{j2}^{\text{Autarky}}]$, which based on the previous manipulations requires

$$R(c-l_j) - (1-q)(c-l_j) - \frac{qR}{p}(c-l_j) \overset{!}{\geq} 0.$$

Because $c > l_j$ in the asset market equilibrium, the statement can be expressed as

$$R \overset{!}{\geq} 1 - q + \frac{qR}{p}.$$

The asset price p is an equilibrium object. Because the equilibrium price of the competitive equilibrium is strictly lower than in the planner's solution (Proposition 1), the right hand side is maximized if $p = p^{CE} = \frac{qR}{R-1+q}$. With this substitution, the equation simplifies to $R \geq R$. The asset market equilibrium is therefore payoff dominant.

However, autarky remains a Nash equilibrium. No individual bank has an incentive to deviate from autarky and participate in the asset market due to potential default with an insufficient mass of banks in the asset market. On the other hand, no bank has an incentive to deviate from the asset market equilibrium. ■

Competitive Equilibrium: Derivation

Each bank in period 0 maximizes

$$\max_{k_j \geq 0, l_j \geq 0} W_j^{CE}(k_j, l_j; L) = \max_{k_j \geq 0, l_j \geq 0} \Bigg\{ q \left[R \left[k_j - \frac{c - l_j}{p(L)} \right] \right] + (1-q) \left[R \left[k_j + \phi \left(\phi'^{-1} \left(\frac{p(L)}{R} \right) \right) \right] + l_j - p(L) \phi'^{-1} \left(\frac{p(L)}{R} \right) \right] \Bigg\}$$

subject to

$$k_j + l_j = e.$$

Banks treat the asset price $p(L)$ as given. The objective function is therefore linear from the perspective of individual banks. Substituting k_j with $e - l_j$, the first order condition determines the equilibrium asset price that makes every bank indifferent between short and long assets.

$$\frac{\partial W_j^{CE}}{\partial l_j} = q \left[R \left[-1 + \frac{1}{p^{CE}} \right] \right] + (1-q) \left[-R + 1 \right] \stackrel{!}{=} 0.$$

The equation can be rearranged and immediately implies $p^{CE} = \frac{qR}{R-1+q}$.

Global Planner: Derivation

The optimization problem is rewritten for convenience:

$$\max_{K \geq 0, L \geq 0} W^{GP}(K, L) = \max_{K \geq 0, L \geq 0} \Bigg\{ q \left[R \left[K - \frac{c - L}{p(L)} \right] \right] + (1-q) \left[R \left[K + \phi \left(\phi'^{-1} \left(\frac{p(L)}{R} \right) \right) \right] + L - p(L) \phi'^{-1} \left(\frac{p(L)}{R} \right) \right] \Bigg\}$$

subject to

$$K + L = E.$$

I consequently substitute K with $E - L$ in the objective function. Optimality requires

$$\frac{\partial W^{GP}}{\partial L} = q \left[R \left[-1 + \frac{1}{p^{GP}} + \frac{c - L^{GP}}{[p^{GP}]^2} \frac{\partial p}{\partial L} \right] \right] + (1-q) \left[-R + 1 + \left[\left[R\phi'(\cdot) - p^{GP} \right] \frac{1}{R\phi''(\cdot)} - \phi'^{-1} \left(\frac{p^{GP}}{R} \right) \right] \frac{\partial p}{\partial L} \right] \stackrel{!}{=} 0.$$

The derivative can be simplified since $p^{GP} = R\phi'(\cdot)$. Further in equilibrium, $X^D = X^S$, hence $\phi'^{-1}\left(\frac{p^{GP}}{R}\right) = \frac{q}{1-q}\frac{c-L^{GP}}{p^{GP}}$ and

$$\frac{\partial W^{GP}}{\partial L} = q\left[R\left[-1+\frac{1}{p^{GP}}+\frac{c-L^{GP}}{[p^{GP}]^2}\frac{\partial p}{\partial L}\right]\right]+(1-q)\left[-R+1-\frac{q}{1-q}\frac{c-L^{GP}}{p^{GP}}\frac{\partial p}{\partial L}\right]=0.$$

Rearranging yields

$$R-1+q = qR\left[\frac{1}{p^{GP}}+\frac{\partial p}{\partial L}\left[\frac{c-L^{GP}}{[p^{GP}]^2}-\frac{c-L^{GP}}{p^{GP}R}\right]\right].$$

Because $p^{CE} = \frac{qR}{R-1+q}$ and $l^{GP} = L^{GP}$, the statement is equivalent to

$$p^{GP} = p^{CE}\left[1+\frac{c-l^{GP}}{R}\frac{\partial p}{\partial L}\left[\frac{1}{\phi'(\cdot)}-1\right]\right].$$

I subsequently compute the second derivative. It is convenient to rewrite the first order condition as

$$\frac{\partial W^{GP}}{\partial L} = 1-q-R+q\frac{R}{p(L)}+\left[\frac{R}{p(L)}X^S(p(L),L)-X^D(p(L))\right]\frac{\partial p}{\partial L}.$$

The second derivative corresponds to

$$\begin{aligned}\frac{\partial^2 W^{GP}}{\partial^2 L} =& \underbrace{-q\frac{R}{p^2}\frac{\partial p}{\partial L}}_{-}+\underbrace{\left[\frac{R}{p}X^S(p,L)-X^D(p)\right]}_{+}\frac{\partial^2 p}{\partial^2 L}\\ &+\left[\underbrace{-\frac{R}{p^2}X^S(p,L)\frac{\partial p}{\partial L}}_{-}+\frac{R}{p}\frac{\partial X^S}{\partial L}+\frac{R}{p}\frac{\partial X^S}{\partial p}\frac{\partial p}{\partial L}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\underbrace{\frac{\partial p}{\partial L}}_{+}.\end{aligned}$$

The first term and the first term in the second parenthesis are negative as $\frac{\partial p}{\partial L} > 0$. Further, $\frac{R}{p}X^S - X^D > 0$ in equilibrium as $R > p$. In what follows, I show that $\frac{\partial^2 p}{\partial^2 L} \leq 0$ and $\frac{R}{p}\frac{\partial X^S}{\partial L}+\frac{R}{p}\frac{\partial X^S}{\partial p}\frac{\partial p}{\partial L}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L} \leq 0$.

The first derivative $\frac{\partial p}{\partial L}$ is defined in (B.1). Consequently,

$$\frac{\partial^2 p}{\partial^2 L} = \frac{\left[\frac{X}{1-q}\phi''(\cdot)+\phi'(\cdot)\right]\left[-\frac{q}{1-q}\phi'''(\cdot)\frac{1}{1-q}\frac{\partial X}{\partial L}\right]+\left[\frac{q}{1-q}\phi''(\cdot)\right]\left[\phi''(\cdot)+\frac{X}{1-q}\phi'''(\cdot)+\phi''(\cdot)\right]\frac{1}{1-q}\frac{\partial X}{\partial L}}{\left[\frac{X}{1-q}\phi''(\cdot)+\phi'(\cdot)\right]^2}.$$

Most terms cancel and it turns out $\frac{\partial^2 p}{\partial^2 L} \leq 0$ whenever $\phi'(\cdot)\phi'''(\cdot) - 2(\phi''(\cdot))^2 \leq 0$ which is guaranteed by Assumption 5.

Because $\frac{\partial X^S}{\partial L} = -\frac{q}{p}$, $\frac{\partial X^S}{\partial p} = -q\frac{c-L}{p^2}$, and $\frac{\partial X^D}{\partial p} = \frac{1-q}{R\phi''(\cdot)}$, it follows that

$$\frac{R}{p}\frac{\partial X^S}{\partial L} + \frac{R}{p}\frac{\partial X^S}{\partial p}\frac{\partial p}{\partial L} - \frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L} \leq 0 \iff -\left[\frac{R}{p}q\frac{c-L}{p} + (1-q)\frac{p}{R\phi''(\cdot)}\right]\frac{\partial p}{\partial L} \leq q\frac{R}{p}.$$

In equilibrium $X = X^S = q\frac{c-L}{p}$. Further, $p = R\phi'(\cdot)$ and since $R > p$ the inequality from the previous equation holds if

$$-\left[\frac{X}{1-q}\phi''(\cdot) + \phi'(\cdot)\right]\frac{\partial p}{\partial L} \geq \frac{q}{1-q}\frac{R}{p}\phi''(\cdot).$$

With the definition of $\frac{\partial p}{\partial L}$ in (B.1), the inequality simplifies to $p \leq R$ which is always true in equilibrium. The objective function is therefore strictly concave and the solution is a unique global maximum.

C. Appendix: Section 3

National Planner: Derivation of Best Response Functions

I subsequently derive the best response function for the ω-planner. The procedure for the 1-ω-planner is isomorphic and hence omitted. The optimization problem for the ω planner is

$$\max_{K_\omega \geq 0, L_\omega \geq 0} W^{NP}_\omega(K_\omega, L_\omega; L) = \max_{K_\omega \geq 0, L_\omega \geq 0} \Bigg\{ q\left[R\left[K_\omega - \frac{\omega c - L_\omega}{p(L)}\right]\right]$$
$$+ (1-q)\left[R\left[K_\omega + \omega\phi\left(\phi'^{-1}\left(\frac{p(L)}{R}\right)\right)\right] + L_\omega - \omega p(L)\phi'^{-1}\left(\frac{p(L)}{R}\right)\right]\Bigg\}$$

subject to

$$K_\omega + L_\omega = \omega E.$$

I substitute K_ω with $\omega E - L_\omega$ in the objective function. If the non-negativity constraint does not bind, the first order condition satisfies

$$\frac{\partial W^{NP}_\omega}{\partial L_\omega} = q\left[R\left[-1 + \frac{1}{p^{NP}} + \frac{\omega c - L^{NP}_\omega}{[p^{NP}]^2}\frac{\partial p}{\partial L}\right]\right]$$
$$+ (1-q)\left[-R + 1 + \left[\left[R\phi'(\cdot) - p^{NP}\right]\frac{1}{R\phi''(\cdot)} - \phi'^{-1}\left(\frac{p^{NP}}{R}\right)\right]\frac{\partial p}{\partial L}\omega\right] \stackrel{!}{=} 0.$$

The equation is evaluated in equilibrium, hence $X^D = X^S$ and $\phi'^{-1}\left(\frac{p^{NP}}{R}\right) = \frac{q}{1-q}\frac{c-L^{NP}}{p^{NP}}$. Further, $p^{NP} = R\phi'(\cdot)$. Therefore,

$$\frac{\partial W_\omega^{NP}}{\partial L_\omega} = q\left[R\left[-1+\frac{1}{p^{NP}}+\frac{\omega c - L_\omega^{NP}}{[p^{NP}]^2}\frac{\partial p}{\partial L}\right]\right]+(1-q)\left[-R+1-\frac{q}{1-q}\frac{c-L^{NP}}{p^{NP}}\frac{\partial p}{\partial L}\omega\right]=0.$$

Rearranging yields

$$R-1+q = qR\left[\frac{1}{p^{NP}}+\frac{\partial p}{\partial L}\omega\left[\frac{c-l_\omega^{NP}}{[p^{NP}]^2}-\frac{c-L^{NP}}{p^{NP}R}\right]\right],$$

which can be further simplified to

$$p^{NP} = p^{CE}\left[1+\frac{\partial p}{\partial L}\omega\left[\frac{c-l_\omega^{NP}}{p^{NP}}-\frac{c-L^{NP}}{R}\right]\right]$$

as $p^{CE} = \frac{qR}{R-1+q}$.

Proof of Lemma 4: I first proof the uniqueness of an interior Cournot equilibrium. Because $p(L)$ is a function of aggregate liquidity $L = L_\omega + L_{1-\omega}$, I can define $BR_\omega\left(L_\omega(L_{1-\omega}), L_{1-\omega})\right) = 0$ as the first order condition (or best response function) of the ω-planner for a given choice of the 1-ω-planner. The interior equilibrium is unique if both best responses are contractions. If BR_ω is a contraction, it must satisfy

$$\left|\frac{\partial L_\omega}{\partial L_{1-\omega}}\right| = \left|-\frac{\frac{\partial BR_\omega}{\partial L_{1-\omega}}}{\frac{\partial BR_\omega}{\partial L_\omega}}\right| \overset{!}{<} 1 \iff \left|\frac{\partial BR_\omega}{\partial L_{1-\omega}}\right| \overset{!}{<} \left|\frac{\partial BR_\omega}{\partial L_\omega}\right|.$$

$\frac{\partial BR_\omega}{\partial L_\omega}$ is the second derivative of the objective function, $\frac{\partial^2 W_\omega^{NP}}{\partial^2 L_\omega}$. $\frac{\partial BR_\omega}{\partial L_{1-\omega}}$ is the derivative of the first order condition with respect to $L_{1-\omega}$, $\frac{\partial^2 W_\omega^{NP}}{\partial L_\omega \partial L_{1-\omega}}$. I subsequently derive both expressions.

To derive $\frac{\partial BR_\omega}{\partial L_\omega}$ it is convenient to re-express the first derivative as

$$\frac{\partial W_\omega^{NP}}{\partial L_\omega} = 1-q-R+q\frac{R}{p(L)}+\left[\frac{R}{p(L)}\frac{X_\omega^S(p(L),L_\omega)}{\omega}-X^D(p(L))\right]\frac{\partial p}{\partial L}\omega$$

with $X_\omega^S(p(L),L_\omega) = q\frac{\omega c - L_\omega}{p(L)}$. The second derivative is

$$\frac{\partial^2 W_\omega^{NP}}{\partial^2 L_\omega} = \underbrace{-q\frac{R}{p^2}\frac{\partial p}{\partial L}}_{-}+\left[\frac{R}{p}\frac{X_\omega^S}{\omega}-X^D\right]\underbrace{\frac{\partial^2 p}{\partial^2 L}}_{\leq 0}\omega \tag{C.1}$$

$$+\left[\underbrace{-\frac{R}{p^2}\frac{X^S_\omega}{\omega}\frac{\partial p}{\partial L}}_{-}+\frac{R}{p}\frac{\partial X^S_\omega}{\partial L_\omega}\frac{1}{\omega}+\frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\underbrace{\frac{\partial p}{\partial L}}_{+}\omega.$$

The first term and the first term in the second parenthesis are negative as $\frac{\partial p}{\partial L} > 0$. Further, $\frac{\partial^2 p}{\partial^2 L} \leq 0$. The second derivative is negative if $\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D \geq 0$ and $\frac{R}{p}\frac{\partial X^S_\omega}{\partial L_\omega}\frac{1}{\omega} + \frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega} - \frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L} \leq 0$.

Conjecture 1 *I conjecture that* $\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D > 0$ *in an interior Cournot equilibrium.*

I subsequently verify that $\frac{R}{p}\frac{\partial X^S_\omega}{\partial L_\omega}\frac{1}{\omega} + \frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega} - \frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L} \leq 0$. Because $\frac{\partial X^S_\omega}{\partial L_\omega} = -\frac{q}{p}$, $\frac{\partial X^S_\omega}{\partial p} = -q\frac{\omega c - L_\omega}{p^2}$ and $\frac{\partial X^D}{\partial p} = \frac{1-q}{R\phi''(\cdot)}$, the following two expressions are equivalent:

$$\frac{R}{p}\frac{\partial X^S_\omega}{\partial L_\omega}\frac{1}{\omega}+\frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\leq 0 \iff -\left[\frac{R}{p}q\frac{c-l_\omega}{p}+(1-q)\frac{p}{R\phi''(\cdot)}\right]\frac{\partial p}{\partial L}\omega \leq q\frac{R}{p}.$$

Conjecture 1 implies that $\frac{R}{p}q\frac{c-l_\omega}{p} > q\frac{c-L}{p}$. Further using $p^{NP} = R\phi'(\cdot)$, the inequality from the previous equation holds if

$$-\left[\frac{X}{1-q}\phi''(\cdot)+\phi'(\cdot)\right]\frac{\partial p}{\partial L}\omega \geq \frac{q}{1-q}\frac{R}{p}\phi''(\cdot).$$

With the definition of $\frac{\partial p}{\partial L}$ in (B.1), the inequality simplifies to $\omega p \leq R$, which is always satisfied. The objective function is therefore strictly concave and $\frac{\partial BR_\omega}{\partial L_\omega} < 0$.

I subsequently focus on $\frac{\partial BR_\omega}{\partial L_{1-\omega}}$:

$$\frac{\partial^2 W^{\mathrm{NP}}_\omega}{\partial L_\omega \partial L_{1-\omega}} = -q\frac{R}{p^2}\frac{\partial p}{\partial L}+\left[\underbrace{\frac{R}{p}\frac{X^S_\omega}{\omega}-X^D(p)}_{+}\right]\underbrace{\frac{\partial^2 p}{\partial^2 L}\omega}_{-}$$
$$+\left[\underbrace{-\frac{R}{p^2}\frac{X^S_\omega}{\omega}\frac{\partial p}{\partial L}}_{-}+\frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\underbrace{\frac{\partial p}{\partial L}\omega}_{+}.$$

Because $\frac{\partial p}{\partial L} > 0$, $\frac{\partial^2 p}{\partial^2 L} \leq 0$ and $\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D > 0$ (by conjecture), the cross-derivative is negative if $-q\frac{R}{p^2}\frac{\partial p}{\partial L} + \left[\frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega} - \frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\frac{\partial p}{\partial L}\omega \leq 0$. Because, $\frac{\partial X^S_\omega}{\partial p} = -q\frac{\omega c - L_\omega}{p^2}$ and $\frac{\partial X^D}{\partial p} = \frac{1-q}{R\phi''(\cdot)}$, it must be that

$$-q\frac{R}{p^2}\frac{\partial p}{\partial L}+\left[\frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega}-\frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\frac{\partial p}{\partial L}\omega \le 0 \iff -\left[\frac{R}{p}q\frac{c-l_\omega}{p}+(1-q)\frac{p}{R\phi''(\cdot)}\right]\frac{\partial p}{\partial L}\omega \le q\frac{R}{p},$$

which I already verified. Thus, $\frac{\partial BR_\omega}{\partial L_\omega}<0$ and $\frac{\partial BR_\omega}{\partial L_{1-\omega}}<0$. This implies that

$$\left|\frac{\partial BR_\omega}{\partial L_{1-\omega}}\right| < \left|\frac{\partial BR_\omega}{\partial L_\omega}\right| \iff \frac{\partial BR_\omega}{\partial L_{1-\omega}} > \frac{\partial BR_\omega}{\partial L_\omega}.$$

Based on previous expressions for the second and cross derivative, $\frac{\partial BR_\omega}{\partial L_{1-\omega}} > \frac{\partial BR_\omega}{\partial L_\omega}$ is equivalent to

$$0 > \frac{R}{p}\frac{\partial X^S_\omega}{\partial L_\omega}\frac{\partial p}{\partial L}.$$

Because $\frac{\partial X^S_\omega}{\partial L_\omega}=-\frac{q}{p}<0$ and $\frac{\partial p}{\partial L}>0$, the above statement is true. I hence proved that $\left|\frac{\partial L_\omega}{\partial L_{1-\omega}}\right|<1$. The best response function of the ω-planner is a contraction. Due to symmetry the previous steps generalize to the 1-ω-planner, hence $\left|\frac{\partial L_{1-\omega}}{\partial L_\omega}\right|<1$. The interior Cournot equilibrium is therefore unique.

I subsequently verify the existence of a corner solution. First I show that if ω converges to 1, the 1-ω-planner is constrained by the non-negativity restriction on liquid assets. The best response functions are derived under the premise that the non-negativity constraint does not bind, that is, $\frac{\partial W^{NP}_\omega}{\partial L_\omega}=\frac{\partial W^{NP}_{1-\omega}}{\partial L_{1-\omega}}=0$. Combining both best response functions yields

$$\omega\left[\frac{c-l^{NP}_\omega}{p^{NP}}-\frac{c-L^{NP}}{R}\right]=(1-\omega)\left[\frac{c-l^{NP}_{1-\omega}}{p^{NP}}-\frac{c-L^{NP}}{R}\right]. \tag{C.2}$$

Without loss of generality, suppose that $\omega\to 1$. Then $l^{NP}_\omega\to L^{NP}$ and $L^{NP}\to L^{GP}$ since $\frac{\partial W^{NP}_\omega}{\partial L_\omega}\to\frac{\partial W^{GP}}{\partial L}$. Further $\left[\frac{c-L^{GP}}{p^{GP}}-\frac{c-L^{GP}}{R}\right]>0$ as $p<R$. The left hand side of (C.2) therefore converges to a finite and positive number by the multiplication rule for limits. The right hand side must converge to the same limit in an interior solution. $(1-\omega)$ converges to 0. The second term $\left[\frac{c-l^{NP}_{1-\omega}}{p^{NP}}-\frac{c-L^{NP}}{R}\right]$ is finite when $l^{NP}_{1-\omega}\ge 0$. The right hand side of (C.2) therefore converges to 0 for any non-negative value of $l^{NP}_{1-\omega}$. The equality in (C.2) breaks and there is no interior solution in which both planners optimally choose a non-negative amount of liquid assets.

Further, due to continuity, there must exist a $\delta>0$, such that for $\overline{\omega}=1-\delta<1$, $\overline{\omega}\left[\frac{c-l^{NP}_\omega}{p^{NP}}-\frac{c-\overline{\omega}l^{NP}_\omega}{R}\right]=(1-\overline{\omega})\left[\frac{c}{p^{NP}}-\frac{c-\overline{\omega}l^{NP}_\omega}{R}\right]$. Therefore every $\omega\ge\overline{\omega}>0.5$

corresponds to $l^{NP}_{1-\omega} = 0$. Similarly, due to symmetry there must be a threshold $\underline{\omega} = 1 - \overline{\omega}$, such that any $\omega \leq \underline{\omega}$ results in $l^{NP}_{\omega} = 0$. ■

Proof of Conjecture 1: In the previous proof of Lemma 4, I conjectured that $\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D > 0$ in an interior Cournot equilibrium. I subsequently proof this claim. In equilibrium $X^D = q\frac{c-L}{p}$, hence

$$\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D \overset{EQ}{=} \frac{R}{p} q \frac{c - l_\omega}{p} - q\frac{c-L}{p} = q\frac{R}{p}\left[\frac{c-l_\omega}{p} - \frac{c-L}{R}\right].$$

In an interior solution the best response functions of both national planners imply

$$\underbrace{p^{CE}\left[1 + \frac{\partial p}{\partial L}\omega\left[\frac{c - l^{NP}_\omega}{p^{NP}} - \frac{c - L^{NP}}{R}\right]\right]}_{p^{NP}} = \underbrace{p^{CE}\left[1 + \frac{\partial p}{\partial L}(1-\omega)\left[\frac{c - l^{NP}_{1-\omega}}{p^{NP}} - \frac{c - L^{NP}}{R}\right]\right]}_{p^{NP}}.$$

From Proposition 1, I know that $p^{NP} > p^{CE}$. Further, $\frac{\partial p}{\partial L} > 0$ due to Lemma 2. As a consequence it must be that $\frac{c-l^{NP}_\omega}{p^{NP}} - \frac{c-L^{NP}}{R} > 0$ and $\frac{c-l^{NP}_{1-\omega}}{p^{NP}} - \frac{c-L^{NP}}{R} > 0$. ■

Proof of Proposition 1: I first focus on an interior solution and show that $L^{GP} > L^{NP}$. As a preliminary step, I relate the global planner first order condition with the two national planner best response functions.

$$\begin{gathered}
\frac{1}{p^{GP}}\left[1 + \left.\frac{\partial p}{\partial L}\right|_{L=L^{GP}}\left[\frac{c-L^{GP}}{p^{GP}} - \frac{c-L^{GP}}{R}\right]\right] \\
= \\
\frac{1}{p^{NP}}\left[1 + \left.\frac{\partial p}{\partial L}\right|_{L=L^{NP}}\omega\left[\frac{c-l^{NP}_\omega}{p^{NP}} - \frac{c-L^{NP}}{R}\right]\right] \\
= \\
\frac{1}{p^{NP}}\left[1 + \left.\frac{\partial p}{\partial L}\right|_{L=L^{NP}}(1-\omega)\left[\frac{c-l^{NP}_{1-\omega}}{p^{NP}} - \frac{c-L^{NP}}{R}\right]\right]
\end{gathered} \tag{C.3}$$

The second equality is an identity that must hold in any interior Cournot equilibrium. I prove $L^{GP} > L^{NP}$ by contradiction. In particular, I will show that the first equality in (C.3) fails to hold if $L^{GP} = L^{NP}$ or $L^{GP} < L^{NP}$.

Suppose $L^{GP} = L^{NP}$. Then $p^{GP} = p^{NP}$ via Lemma 2. Further $\frac{\partial p}{\partial L}|_{L=L^{GP}} = \frac{\partial p}{\partial L}|_{L=L^{NP}}$.

If $\omega = 0.5$, both regulators are identical. Hence, $l^{NP}_\omega = l^{NP}_{1-\omega} = L^{NP}$. However this immediately contradicts the first equality of (C.3) because $\omega \neq 1$.

If $\omega \neq 0.5$, $l_{\omega}^{NP} \neq l_{1-\omega}^{NP}$. Without loss of generality assume that $l_{\omega}^{NP} > l_{1-\omega}^{NP}$ and therefore $l_{\omega}^{NP} > L^{NP}$. Then $\left[\frac{c-L^{GP}}{p^{GP}} - \frac{c-L^{GP}}{R}\right] > \omega \left[\frac{c-L^{NP}}{p^{NP}} - \frac{c-L^{NP}}{R}\right] > \omega \left[\frac{c-l_{\omega}^{NP}}{p^{NP}} - \frac{c-L^{NP}}{R}\right]$ which contradicts (C.3). $L^{GP} = L^{NP}$ is not a solution.

Suppose $L^{GP} < L^{NP}$. Then $p^{GP} < p^{NP}$ via Lemma 2 and $\frac{\partial p}{\partial L}|_{L=L^{GP}} \geq \frac{\partial p}{\partial L}|_{L=L^{NP}}$ as $\frac{\partial^2 p}{\partial^2 L} \leq 0$. In this case, the equalities in (C.3) require

$$\frac{c - L^{GP}}{p^{GP}} - \frac{c - L^{GP}}{R} < \omega \left[\frac{c - l_{\omega}^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R}\right] = (1 - \omega) \left[\frac{c - l_{1-\omega}^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R}\right].$$

If $\omega = 0.5$, $l_{\omega}^{NP} = l_{1-\omega}^{NP} = L^{NP}$. But,

$$[c - L^{GP}] \left[\frac{1}{p^{GP}} - \frac{1}{R}\right] > [c - L^{NP}] \left[\frac{1}{p^{NP}} - \frac{1}{R}\right],$$

a contradiction to (C.3). If $\omega \neq 0.5$, $l_{\omega}^{NP} \neq l_{1-\omega}^{NP}$. Without loss of generality assume that $l_{\omega}^{NP} > l_{1-\omega}^{NP}$ and hence $l_{\omega}^{NP} > L^{NP}$. Then,

$$[c - L^{GP}] \left[\frac{1}{p^{GP}} - \frac{1}{R}\right] > [c - L^{NP}] \left[\frac{1}{p^{NP}} - \frac{1}{R}\right] > \frac{c - l_{\omega}^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R},$$

which contradicts (C.3). $L^{GP} < L^{NP}$ is hence not a solution for any level of size asymmetry in an interior solution. I thus proved $L^{GP} > L^{NP}$.

I subsequently verify that $L^{CE} < L^{NP}$ in an interior equilibrium which is the second part of Proposition 1. If $L^{CE} < L^{NP}$, then $p^{CE} < p^{NP}$ via Lemma 2. Using the best response functions, $p^{CE} < p^{NP}$ holds whenever

$$\omega \left[\frac{c - l_{\omega}^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R}\right] = (1 - \omega) \left[\frac{c - l_{1-\omega}^{NP}}{p^{NP}} - \frac{c - L^{NP}}{R}\right] \overset{!}{>} 0.$$

The equality is an identity in any interior equilibrium. If $\omega = 0.5$, $l_{\omega}^{NP} = L^{NP}$. Therefore $\frac{c-l_{\omega}^{NP}}{p^{NP}} - \frac{c-L^{NP}}{R} > 0$ since $p^{NP} < R$. If $\omega \neq 0.5$, $l_{\omega}^{NP} \neq l_{1-\omega}^{NP}$. Without loss of generality assume that $l_{\omega}^{NP} > l_{1-\omega}^{NP}$ and hence $l_{1-\omega}^{NP} < L^{NP}$. This implies $\frac{c-l_{1-\omega}^{NP}}{p^{NP}} - \frac{c-L^{NP}}{R} > 0$. I thus proved $L^{CE} < L^{NP}$.

The derivation so far was based on an interior solution which allowed me to equate both best response functions. At a corner solution the smaller national planner provides zero liquidity (Lemma 4). Without loss of generality suppose that $L_{1-\omega}^{NP} = 0$. In this case, $L^{NP} = L_{\omega}^{NP}$. I subsequently show that aggregate liquidity increases with more asymmetry if I impose Assumption 6, that is, $\frac{\partial L_\omega^{NP}}{\partial \omega} > 0$ when $\omega \in [\overline{\omega}, 1)$. I rewrite the first order condition for convenience.

$$\underbrace{p^{CE}\left[1 + \frac{\partial p}{\partial L}\omega\left[\frac{c - L_\omega^{NP}/\omega}{p^{NP}} - \frac{c - L_\omega^{NP}}{R}\right]\right] - p^{NP}}_{g(L_\omega^{NP}(\omega),\omega)=0} = 0$$

The first order condition contains two endogenous objects, p^{NP} and L_ω^{NP}. The equilibrium price $p^{NP}(L_\omega^{NP})$ is however only a function of L_ω^{NP}. I can therefore apply the Implicit Function Theorem.

$$\frac{\partial L_\omega^{NP}}{\partial \omega} = -\frac{\frac{\partial g(\cdot)}{\partial \omega}}{\frac{\partial g(\cdot)}{\partial L_\omega^{NP}}}$$

The numerator $\frac{\partial g(\cdot)}{\partial \omega}$

$$\frac{\partial g(\cdot)}{\partial \omega} = p^{CE}\frac{\partial p}{\partial L}\left[\frac{c}{p^{NP}} - \frac{c}{R} + \frac{L_\omega^{NP}}{R}\right] > 0$$

is positive as $R > p^{NP}$ and $\frac{\partial p}{\partial L} > 0$. $\frac{\partial g(\cdot)}{\partial L_\omega^{NP}}$ is negative with Assumption 6:

$$\frac{\partial g(\cdot)}{\partial L_\omega^{NP}} = p^{CE}\left[\frac{\partial^2 p}{\partial^2 L}\omega\left[\frac{c - L_\omega^{NP}/\omega}{p^{NP}} - \frac{c - L_\omega^{NP}}{R}\right] + \frac{\partial p}{\partial L}\left[\underbrace{-\frac{1}{p^{NP}} + \frac{\omega}{R} - \frac{\omega c - L_\omega^{NP}}{[p^{NP}]^2}\frac{\partial p}{\partial L}}_{-}\right]\right] - \frac{\partial p}{\partial L} < 0.$$

$-\frac{1}{p^{NP}} + \frac{\omega}{R} - \frac{\omega c - L_\omega^{NP}}{[p^{NP}]^2}\frac{\partial p}{\partial L} < 0$ as $\omega < 1$, $\frac{\partial p}{\partial L} > 0$ and $R > p^{NP}$. With Assumption 6, $\frac{\partial^2 p}{\partial^2 L} = 0$. Thus $\frac{\partial g(\cdot)}{\partial L_\omega^{NP}} < 0$, which implies $\frac{\partial L_\omega^{NP}}{\partial \omega} > 0$. Next, I show that L_ω^{NP} uniquely maximizes the objective function when $\omega \in [\overline{\omega}, 1)$: with Assumption 6, the second derivative (C.1) simplifies to

$$\frac{\partial^2 W_\omega^{NP}}{\partial^2 L_\omega} = -q\frac{R}{p^2}\frac{\partial p}{\partial L} + \left[-\frac{R}{p^2}\frac{X_\omega^S}{\omega}\frac{\partial p}{\partial L} + \frac{R}{p}\frac{\partial X_\omega^S}{\partial L_\omega}\frac{1}{\omega} + \frac{R}{p}\frac{\partial X_\omega^S}{\partial p}\frac{\partial p}{\partial L}\frac{1}{\omega} - \frac{\partial X^D}{\partial p}\frac{\partial p}{\partial L}\right]\frac{\partial p}{\partial L}\omega.$$

Imposing the specific functional form on technology, the second derivative is negative whenever

$$-2\left[\frac{q}{1-q}\omega\frac{c - l_\omega}{p} + 1\right] + \omega \overset{!}{<} 0.$$

This condition is always satisfied as $c > l_\omega$ and $\omega \in (0,1)$. $\frac{\partial L^{NP}_\omega}{\partial \omega} > 0$ is hence optimal.

Further, notice that the national planner equilibrium converges to the global planner solution when $\omega \to 1$ and that $L^{NP} > L^{CE}$ at $\overline{\omega}$. Therefore, $L^{GP} > L^{NP} > L^{CE}$ when $\omega \in [\overline{\omega}, 1)$ or $\omega \in (0, \underline{\omega}]$. The latter result follows from the symmetry of the setup. ■

Proof of Proposition 2: Focusing on an interior equilibrium, bank-specific liquid assets among national planners are strategic substitutes if $\frac{\partial l^{NP}_\omega}{\partial l^{NP}_{1-\omega}} < 0$. The objective functions of both planners are strictly concave (see Lemma 4). The previous condition therefore holds if $\frac{\partial^2 W^{\text{NP}}_\omega}{\partial l_\omega \partial l_{1-\omega}} < 0$ and $\frac{\partial^2 W^{\text{NP}}_{1-\omega}}{\partial l_{1-\omega} \partial l_\omega} < 0$.

The first derivative of the ω-planner with respect to bank-specific short assets is

$$\frac{\partial W^{\text{NP}}_\omega}{\partial l_\omega} = \frac{\partial W^{\text{NP}}_\omega}{\partial L_\omega}\frac{\partial L_\omega}{\partial l_\omega} = \frac{\partial W^{\text{NP}}_\omega}{\partial L_\omega}\omega$$

Therefore,

$$\frac{\partial^2 W^{\text{NP}}_\omega}{\partial l_\omega \partial l_{1-\omega}} = \frac{\partial^2 W^{\text{NP}}_\omega}{\partial L_\omega \partial L_{1-\omega}}\frac{\partial L_{1-\omega}}{\partial l_{1-\omega}}\omega = \underbrace{\frac{\partial W^{\text{NP}}_\omega}{\partial L_\omega \partial L_{1-\omega}}}_{-\ \text{see Lemma 4}}\ \omega(1-\omega) < 0.$$

The same logic applies to the 1-ω-planner. Bank-specific liquid assets are therefore strategic substitutes.

With regard to the externality effect, I prove that $\frac{\partial l^{NP}_\omega}{\partial \omega} > 0$ and $\frac{\partial l^{NP}_{1-\omega}}{\partial \omega} < 0$ starting at $\omega = 0.5$. Due to concavity it is sufficient to show that $\frac{\partial^2 W^{\text{NP}}_\omega}{\partial l_\omega \partial \omega} > 0$ and $\frac{\partial^2 W^{\text{NP}}_{1-\omega}}{\partial l_{1-\omega} \partial \omega} < 0$.

$$\frac{\partial^2 W^{\text{NP}}_\omega}{\partial l_\omega \partial \omega} = \underbrace{\frac{\partial W^{\text{NP}}_\omega}{\partial L_\omega}}_{0\ \text{at interior solution}} + \frac{\partial^2 W^{\text{NP}}_\omega}{\partial L_\omega \partial \omega}\omega$$

$$\begin{aligned}\frac{\partial^2 W^{\text{NP}}_\omega}{\partial L_\omega \partial \omega} = &\left[\underbrace{\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D}_{+\ \text{Conjecture 1}}\right]\frac{\partial p}{\partial L} + \frac{\partial^2 p}{\partial^2 L}\underbrace{[l_\omega - l_{1-\omega}]}_{=0\ \text{at}\ \omega=0.5}\omega\left[\frac{R}{p}\frac{X^S_\omega}{\omega} - X^D\right] \\ &+ \frac{\partial p}{\partial L}\underbrace{[l_\omega - l_{1-\omega}]}_{=0\ \text{at}\ \omega=0.5}\left[-q\frac{R}{p^2} + \frac{\partial p}{\partial L}\omega\left[-\frac{R}{p^2}\frac{X^S_\omega}{\omega} + \frac{R}{p}\frac{\partial X^S_\omega}{\partial p}\frac{1}{\omega} - \frac{\partial X^D}{\partial p}\right]\right] \overset{\omega=0.5}{>} 0\end{aligned}$$

At $\omega = 0.5$, $l^{NP}_\omega = l^{NP}_{1-\omega}$, hence terms involving the difference $l_\omega - l_{1-\omega}$ drop out. Therefore $\frac{\partial l^{NP}_\omega}{\partial \omega} > 0$ starting from $\omega = 0.5$. It is straight forward to verify that $\frac{\partial l^{NP}_{1-\omega}}{\partial \omega} < 0$ under the same circumstances. ■

Proof of Proposition 3: If $\omega = 0.5$, then $l_{\omega}^{NP} = l_{1-\omega}^{NP}$ and by definition $W_{\omega}^{NP}(K_{\omega}^{NP}, L_{\omega}^{NP}; L^{NP}) = W_{1-\omega}^{NP}(K_{1-\omega}^{NP}, L_{1-\omega}^{NP}; L^{NP}) \equiv W^{NP}(\frac{K^{NP}}{2}, \frac{L^{NP}}{2}; L^{NP})$. Period 2 consumption with a global planner equals $W^{GP}(K^{GP}, L^{GP})$ and is based on the joint maximization over both jurisdictions. The global planner's allocation deviates from national planners, since $L^{GP} > L^{NP}$. Thus by revealed preferences, $W^{GP}(K^{GP}, L^{GP}) > W_{\omega}^{NP}(K_{\omega}^{NP}, L_{\omega}^{NP}; L^{NP}) + W_{1-\omega}^{NP}(K_{1-\omega}^{NP}, L_{1-\omega}^{NP}; L^{NP}) = 2W^{NP}(\frac{K^{NP}}{2}, \frac{L^{NP}}{2}; L^{NP})$. Therefore $\triangle_{\omega} = 0.5W^{GP}(K^{GP}, L^{GP}) - W_{\omega}^{NP}(K_{\omega}^{NP}, L_{\omega}^{NP}; L^{NP}) > 0$ and $\triangle_{1-\omega} = 0.5W^{GP}(K^{GP}, L^{GP}) - W_{1-\omega}^{NP}(K_{1-\omega}^{NP}, L_{1-\omega}^{NP}; L^{NP}) > 0$. Because gains from cooperation are continuous, there must be a γ close but unequal to zero, such that $\triangle_{\omega} > 0$ and $\triangle_{1-\omega} > 0$ if $\omega = 0.5 + \gamma$.

Next, I show that the 1-ω-planner is unwilling to cooperate when ω approaches 1. As $\omega \to 1$, $l_{\omega}^{NP} \to l^{GP}$. Further $l_{1-\omega}^{NP} = 0$ based on Lemma 4. Joint regulation would force the 1-ω-planner to allocate l^{GP} to each bank, while the ω-planner would provide the same liquidity as before, which immediately implies $\triangle_{1-\omega} < 0$ because aggregate liquidity does not change. Due to continuity, there must be a $\epsilon > 0$, such that for $\overline{\overline{\omega}} = 1 - \epsilon < 1$, $\triangle_{1-\overline{\overline{\omega}}} = 0$. The region defined by $\omega > \overline{\overline{\omega}} > 0.5$ is associated with $\triangle_{1-\omega} < 0$. The same reasoning can be reversed. There must be a threshold $\underline{\underline{\omega}} = 1 - \overline{\overline{\omega}}$ which characterizes a region below any $\omega < \underline{\underline{\omega}} < 0.5$ results in $\triangle_{\omega} < 0$. ■

D. Appendix: Section 4

Proof of Corollary 1: Any transfer T that satisfies $\triangle_{\omega} - T \geq 0$ and $\triangle_{1-\omega} + T \geq 0$ leads to a cooperative solution. If $\triangle_{\omega} \geq 0$ and $\triangle_{1-\omega} \geq 0$ transfers are not necessary and $T = 0$ provides an admissible solution. Without loss of generality I assume $\triangle_{1-\omega} < 0$. This necessarily implies that $\triangle_{\omega} > 0$ since $\triangle_{\omega} + \triangle_{1-\omega} > 0 \ \forall \ \omega$. Suppose that $T = \underline{T}$ with $\triangle_{1-\omega} + \underline{T} = 0$. Because $\triangle_{\omega} - \underline{T} + \triangle_{1-\omega} + \underline{T} > 0 \ \forall \ \omega$ one obtains $\triangle_{\omega} - \underline{T} > 0$. The promised transfer $\underline{T}$ leads to a cooperative solution. ■

Proof of Corollary 2: For part (i), I showcase the equivalence between the bank-specific investment portfolio of a global planner and the ω-planner in autarky. The procedure for the 1-ω-planner is equivalent and hence omitted.

The ω-planner in autarky maximizes

$$\max_{K_{\omega} \geq 0, L_{\omega} \geq 0} W_{\omega}^{NP}(K_{\omega}, L_{\omega}) = \max_{K_{\omega} \geq 0, L_{\omega} \geq 0} \left\{ q \left[R \left[K_{\omega} - \frac{\omega c - L_{\omega}}{p_{\omega}(L_{\omega})} \right] \right] \right.$$
$$\left. + (1-q) \left[R \left[K_{\omega} + \omega \phi \left(\phi'^{-1} \left(\frac{p_{\omega}(L_{\omega})}{R} \right) \right) \right] + L_{\omega} - \omega p_{\omega}(L_{\omega}) \phi'^{-1} \left(\frac{p_{\omega}(L_{\omega})}{R} \right) \right] \right\}$$

subject to

$$K_\omega + L_\omega = \omega E.$$

Substituting the resource constraint, the solution satisfies

$$\begin{aligned}\frac{\partial W_\omega^{NP}}{\partial L_\omega} =& q\left[R\left[-1+\frac{1}{p_\omega^{NP}}+\frac{\omega c - L_\omega^{NP}}{[p_\omega^{NP}]^2}\frac{\partial p_\omega}{\partial L_\omega}\right]\right] \\ &+(1-q)\left[-R+1+\left[\left[R\phi'(\cdot)-p_\omega^{NP}\right]\frac{1}{R\phi''(\cdot)}-\phi'^{-1}\left(\frac{p_\omega^{NP}}{R}\right)\right]\frac{\partial p_\omega}{\partial L_\omega}\omega\right] \stackrel{!}{=} 0.\end{aligned}$$

The equation is evaluated in equilibrium, hence $X_\omega^D = X_\omega^S$ or $(1-q)\omega\phi'^{-1}\left(\frac{p_\omega^{NP}}{R}\right) = q\frac{\omega c - L_\omega^{NP}}{p_\omega^{NP}}$. Further, $p_\omega^{NP} = R\phi'(\cdot)$. Therefore,

$$\frac{\partial W_\omega^{NP}}{\partial L_\omega} = q\left[R\left[-1+\frac{1}{p_\omega^{NP}}+\frac{\omega c - L_\omega^{NP}}{[p_\omega^{NP}]^2}\frac{\partial p_\omega}{\partial L_\omega}\right]\right]+(1-q)\left[-R+1-\frac{q}{1-q}\frac{\omega c - L_\omega^{NP}}{p_\omega^{NP}}\frac{\partial p_\omega}{\partial L_\omega}\right] = 0.$$

Rearranging yields

$$R-1+q = qR\left[\frac{1}{p_\omega^{NP}}+\frac{\partial p_\omega}{\partial L_\omega}\left[\frac{\omega c - L_\omega^{NP}}{[p_\omega^{NP}]^2}-\frac{\omega c - L_\omega^{NP}}{p_\omega^{NP} R}\right]\right],$$

which can be further simplified to

$$p_\omega^{NP} = p^{CE}\left[1+\frac{\omega c - L_\omega^{NP}}{R}\frac{\partial p_\omega}{\partial L_\omega}\left[\frac{1}{\phi'(\cdot)}-1\right]\right].$$

Moreover, based on the asset market clearing condition with ω-banks (D.1), one obtains that $\frac{\partial p}{\partial L} = \omega\frac{\partial p_\omega}{\partial L_\omega}$. Hence,

$$p_\omega^{NP} = p^{CE}\left[1+\frac{c - l_\omega^{NP}}{R}\frac{\partial p}{\partial L}\left[\frac{1}{\phi'(\cdot)}-1\right]\right].$$

Thus $p_\omega^{NP} = p^{GP}$ if $l_\omega^{NP} = l^{GP}$.

Liquid assets are pinned down by the planner's first order condition and the asset market clearing condition. Market clearing with ω-banks only corresponds to:

$$(1-q)\omega\phi'^{-1}\left(\frac{p_\omega^{NP}}{R}\right) = q\frac{\omega c - L_\omega^{NP}}{p_\omega^{NP}}. \tag{D.1}$$

Once the expression is divided by ω, the equation resembles market clearing in a global market. Thus $l_{\omega}^{NP} = l^{GP}$ if $p_{\omega}^{NP} = p^{GP}$. Because market clearing and the first order condition are unique, the only admissible solution is $p_{\omega}^{NP} = p^{GP}$ and $l_{\omega}^{NP} = l^{GP}$. The allocation is therefore constrained efficient.

For part (ii), assume without loss of generality that $\omega > 0.5$ and hence $l_{\omega}^{NP} > l_{1-\omega}^{NP}$. Suppose the 1-$\omega$-jurisdiction is excluded from the asset market and that the ω-planner does not adjust liquidity requirements. As $l_{\omega}^{NP} > L^{NP}$, the remaining banks in the asset market demand less liquidity on average. This reduces the average supply of illiquid assets and therefore increases the equilibrium asset price, $p_{\omega}^{NP} > p^{NP}$. A higher price level ceteris paribus improves welfare due to the fire-sale externality in this model. More formally, expected period 2 consumption increases in p for a fixed portfolio:

$$\frac{\partial W_j}{\partial p} = qR\left[\frac{c - l_j}{p^2}\right] + (1-q)\left[\left[\underbrace{R\phi'(\cdot) - p}_{0}\right]\frac{\partial x_j^D}{\partial p} - x_j^D\right] > 0.$$

With market clearing, the inequality simplifies to $R > p$, which is always satisfied.

Lastly, regarding part (iii), suppose capital controls are levied against a national planner without sufficient resources to absorb liquidity shocks, that is, the small jurisdiction when $\omega \to 0$ or $\omega \to 1$. To avoid potential bankruptcy, the small jurisdiction would be forced to set $l_j = c$ and hence implement the autarky equilibrium. The autarky equilibrium is however Pareto inferior to the global planner equilibrium (Lemma 3). The small planner would therefore prefer to adopt the global planner solution as a third-best outcome. ■

E. Appendix: Section 5

Background on the Basel Agreements

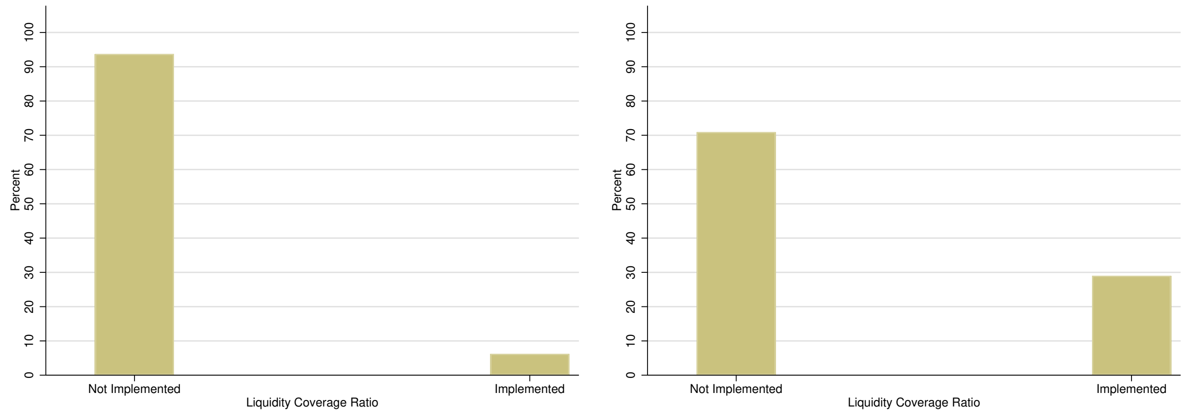
The Basel II Accord was initially published in June 2004 and focused on minimum bank capital requirements related to credit, market, and operational risk (Pillar 1), supervisory oversight (Pillar 2) and policies regarding the public disclosure of important information (Pillar 3). Basel III was agreed upon in 2010, but its implementation was delayed. In 2015, the last year of survey data, non-member countries were still in the process to implement the guidelines (Figure E4). The agreement extends Basel II primarily by countercyclical capital buffers and liquidity regulation.

Liquidity Coverage Ratio

Figure E1 splits the adherence to the Liquidity Coverage Ratio (Basel III) by countries with large and small financial sectors (proxied by domestic credit). As apparent, the share of countries that implemented the Liquidity Coverage Ratio (vertical axes) is considerably higher among high credit countries compared to low credit countries (29% versus 6%).

Figure E1: *Liquidity Coverage Ratio Implementation as of 2015*

(a) *Low Credit Countries* ***(b)*** *High Credit Countries*



Notes: *Vertical axes display the share of Basel non-member countries (in %) that implemented/did not implement the Liquidity Coverage Ratio (Basel III). Panel (a) (Panel (b)) considers countries with low (high) domestic credit to the private sector by banks (in constant USD, threshold based on median) as a proxy for the size of the domestic banking sector. Each subsample sums up to 100%.*

This difference is further highly statistically significant as Table E1 emphasizes. A two-sample proportions test rejects the Null hypothesis of equal Liquidity Coverage Ratio implementation among high and low credit countries with a p-value of 0.02.

Table E1: *Two-sample Proportions Test*

	Difference	SE	z-statistic	p-value
Liquidity Coverage Ratio	-0.23	0.10	-2.38	0.02

Notes: Null hypothesis: Equal likelihood for liquidity regulation among high and low credit countries. The first column displays $p_L - p_H$, where p_i, $i \in \{L, H\}$ denotes the share of countries that implemented liquidity regulation among low and high credit countries. The second column presents the corresponding pooled standard error. The z-statistic is defined as $z = \frac{p_L - p_H}{SE}$.

Variables and Data Sources

Banking Crisis: Binary indicator equal to 1 if a country experienced (at least) one systemic banking crisis since 1990, otherwise 0. (Source: Laeven and Valencia (2018) and author's calculation)

Basel II and III Index: The indices count the number of implemented Basel II and III standards in a given year.[20] The survey reports 5 distinct responses: 1. "Draft regulation not published", 2. "Draft regulation published", 3. "Final rule published", 4. "Final rule in force", 5. "Not applicable". The indices are constructed as the sum of categories with a "Final rule in force". Surveys were conducted in 2004, with follow-ups in 2006, 2008, 2010, 2013 and 2015. The last two surveys also contain information on Basel III. I utilize the 2015 survey for the most recent information. (Source: BIS (2015) and author's calculation)

Capital Controls: The index measures overall restrictions among all asset groups and inflow/outflows. (Source: Fernández et al. (2016))

Concentration: The variable is defined as the asset value from the three largest banks relative to the assets of all commercial banks in %. (Source: Beck et al. (2010))

Credit: Domestic credit to private sector by banks in constant 2010 USD. (Source: World Bank, and author's calculation)

GDP: Series in constant 2010 USD. (Source: World Bank)

Institutional Quality: Index is the sum over all 12 political risk categories from the International Country Risk Guide. (Source: The PRS Group)

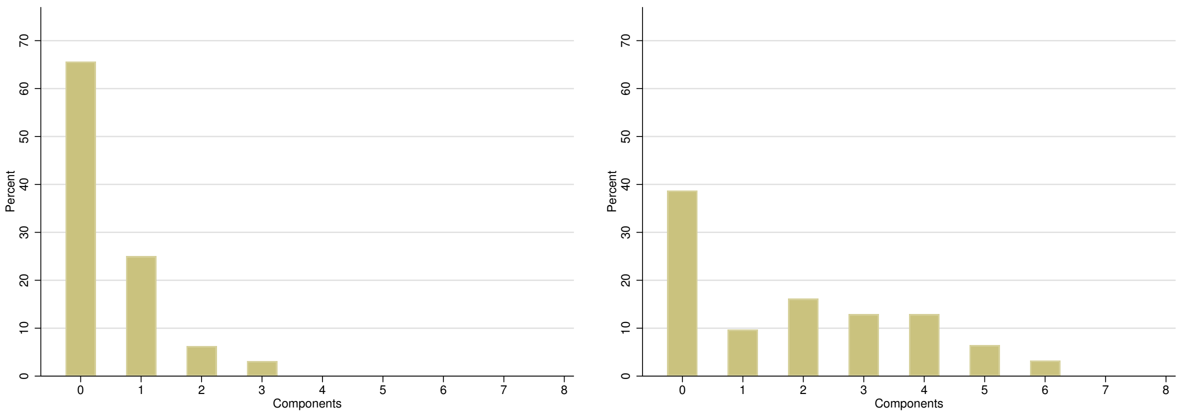
ROA: Bank return on assets defined as net income over total assets in %. (Source: Beck et al. (2010))

[20] Basel II has 10 subcomponents. The first eight components are related to Pillar 1: (i) standardized approach to credit risk, (ii) foundation internal ratings-based approach to credit risk, (iii) advanced internal ratings-based approach to credit risk, (iv) basic indicator approach to operational risk, (v) standardized approach to operational risk, (vi) advanced measurement approach to operational risk, (vii) standardized measurement method for market risk, and (viii) internal models approach to market risk. The remaining two components are (ix) Pillar 2 (Supervision), and (x) Pillar 3 (Market Discipline). Basel III is composed of 8 subcomponents: (i) liquidity standard, (ii) definition of capital, (iii) risk coverage, (iv) capital conservation buffer, (v) countercyclical capital buffer, (vi) leverage ration, (vii) domestic systemically important banks, and (viii) global systemically important banks.

Additional Figures

Figure E2: *Basel III Implementation for Non-members as of 2015*

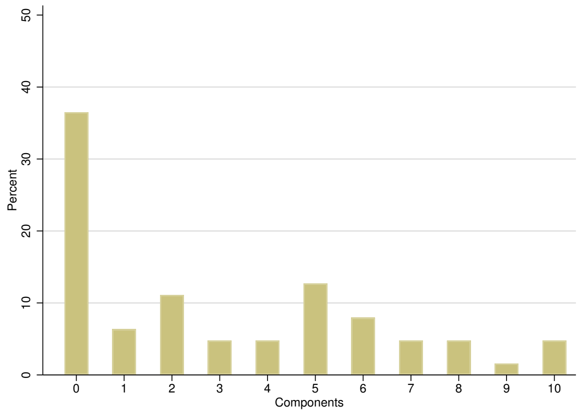
(a) *Low Credit Countries* ***(b)*** *High Credit Countries*



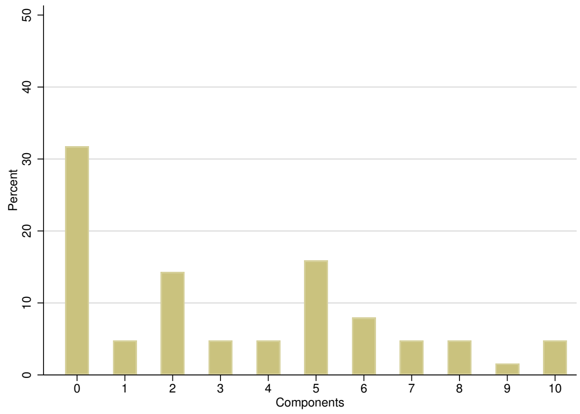
Notes: *The vertical axes portray the share of countries (in %) that implemented a specific number of Basel III components. Panel (a) (Panel (b)) considers countries with low (high) domestic credit to the private sector by banks (in constant USD, threshold based on median) as a proxy for the size of the domestic banking sector. Each subsample sums up to 100%.*

Figure E3: *Basel II Implementation during the Years 2012-2015*

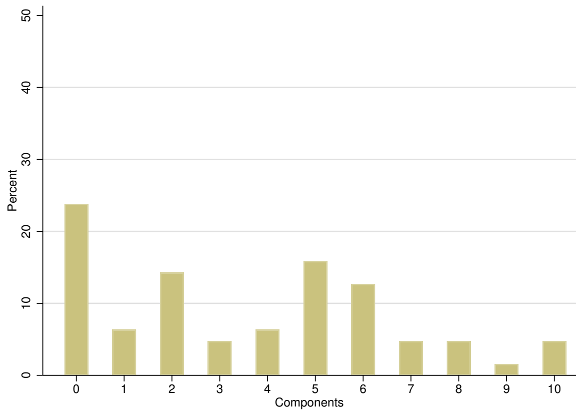
(a) *Year 2012*



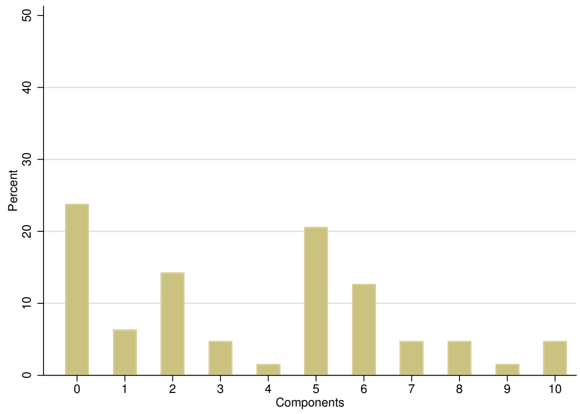
(b) *Year 2013*



(c) *Year 2014*



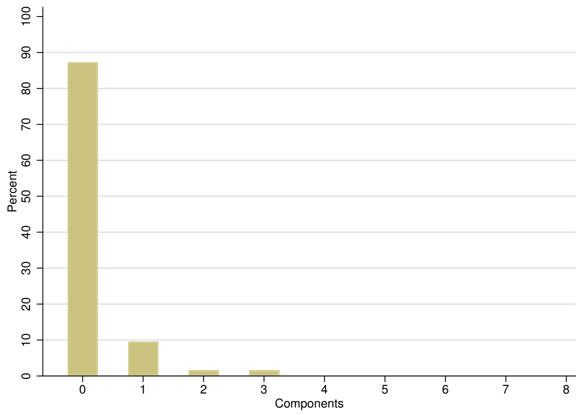
(d) *Year 2015*



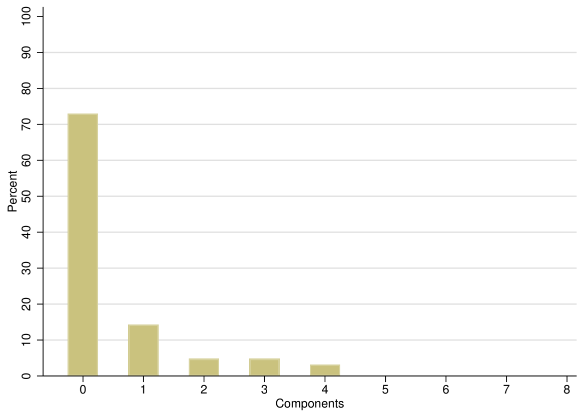
Notes: *The graphs display the cross-sectional distribution of the Basel II Index. The vertical axes portray the share of countries (in %) that implemented a specific number of Basel II components during the years 2012-2015.*

Figure E4: *Basel III Implementation during the Years 2012-2015*

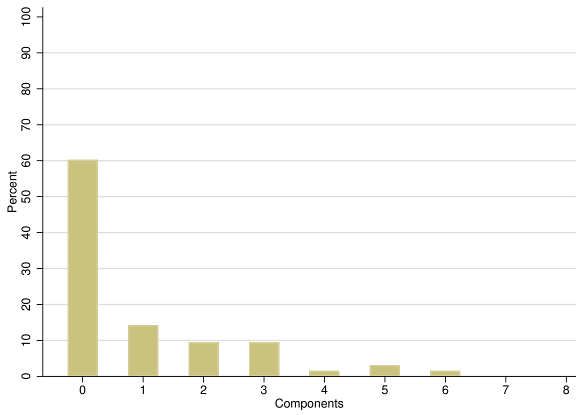
(a) Year 2012



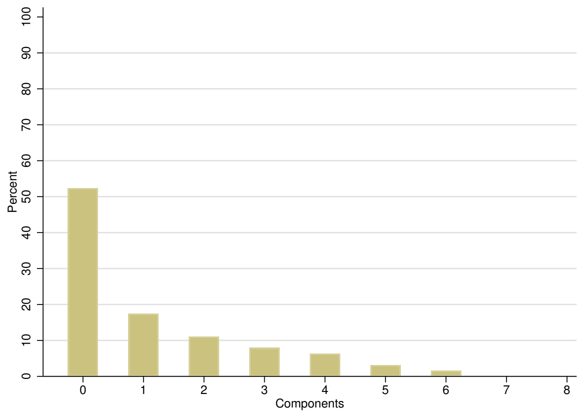
(b) Year 2013



(c) Year 2014



(d) Year 2015



Notes: *The graphs display the cross-sectional distribution of the Basel III Index. The vertical axes portray the share of countries (in %) that implemented a specific number of Basel III components during the years 2012-2015.*

F. Appendix: Model Extensions

Production Economy

I introduce a real production technology that grants investors an alternative to their investment at banks. As a consequence, initial deposits no longer equal endowment, and the size of the domestic banking sector is different from the size of the overall domestic economy. Suppose real investments in period 0 transform into $t = 2$ output according to:

$$y_{j2} = f(i_j).$$

The term i_j reflects the amount of real investment by investor j and $f(\cdot)$ the production technology, which is not investor specific. $f(\cdot)$ is concave.

As an additional feature I assume that financial investments entail an efficiency loss ζ per unit of financial investment which reduces the effective amount of funds directed towards banks to $(1 - \zeta)e_j^{\text{bank}}$. ζ can result from poorly developed domestic financial sectors or a poor legal environment. A higher value of ζ makes financial investments less profitable and induces investors to spend more funds on real production. Each investor continues to have an initial endowment of e.

When deciding on whether to physically invest or provide funds to banks, each investor maximizes expected period 2 consumption according to

$$\max_{i_j, e_j^{\text{bank}}} E_0[c_{2j}(i_j, e_j^{\text{bank}})] = \max_{i_j, e_j^{\text{bank}}} \{f(i_j) + E_0[\overline{R}_j](1 - \zeta)e_j^{\text{bank}}\} \tag{F.1}$$

subject to

$$e = i_j + e_j^{\text{bank}}. \tag{F.2}$$

The gross return on financial investments ($\overline{R}_j$) depends on the realization of the liquidity shock among others. The expected return is however not j-specific, as investors are identical from the perspective of $t = 0$.

The first order condition determines real investments:

$$f'(i_j) = E_0[\overline{R}_j](1 - \zeta).$$

It is reasonable to assume that $f'(0) = E_0[\overline{R}_j]$. Absent efficiency losses, banks are superior in channelling funds towards productive investments and receive all endowment ($i^* = 0$). However, if $\zeta > 0$, investors will always directly invest in production *and* provide funds to banks.

This setup captures the notion that financially less developed countries (high ζ) have a smaller banking sector relative to the overall size of the economy. More importantly, it delinks deposits from endowments and all derivations of the baseline model carry over, with e replaced by $(1-\zeta)e^{*\text{bank}}$.

Endogenously Varying Period 1 Consumption

Early consumption is inelastic in the baseline model. I subsequently relax this assumption. As a result, the laissez-faire equilibrium becomes more inefficient under reasonable preferences.

To fix ideas, suppose that investors choose their $t = 1$ consumption level at the start of period 1 if they receive a positive liquidity shock.[21] Period 2 consumption as a function of $t = 1$ consumption is

$$c_{j2}^{s=1}(k_j, l_j, c_{j1}; L) = R\left[k_j - \frac{c_{j1} - l_j}{p(L)}\right]. \tag{F.3}$$

Suppose further that preferences for $t = 1$ consumption are characterized by $h(c_{j1})$ with $h'(c_{j1}) > 0$, $h'(0) < \frac{R}{p(L)}$, and $h''(c_{j1}) > 0$. Investors with early consumption demand maximize

$$\max_{c_{j1}, c_{j2}^{s=1}} \{h(c_{j1}) + c_{j2}^{s=1}\} \tag{F.4}$$

subject to equation (F.3). The first order condition yields

$$p(L)h'(c_{j1}) = R.$$

The term on the left reflects the marginal utility from selling illiquid assets in period 1. The term on the right captures the marginal utility from retaining the illiquid asset. The assumption $h'(0) < \frac{R}{p(L)}$ paired with $h''(c_{j1}) > 0$ guarantees that it is optimal

[21] Banks or planners understand how investors determine their early consumption demand. Thus, for the same reasons as in the baseline model, it is not optimal to hoard enough liquidity ex-ante to cover these expenses. The early consumption constraint for banks therefore binds.

to consume in $t = 1$. All investors demand the same level of consumption, which I denote as $c_1^* = h'^{-1}\left(\frac{R}{p(L)}\right)$.

Period 2 consumption for impatient investors is therefore

$$c_{j2}^{s=1}(k_j, l_j; L) = R\left[k_j - \frac{h'^{-1}\left(\frac{R}{p(L)}\right) - l_j}{p(L)}\right].$$

Individual banks treat period 1 consumption as given, since it only depends on aggregate liquidity. Consequently, the competitive equilibrium is characterized by the same price as in the baseline model, $p^{CE} = \frac{qR}{R-1+q}$. Regulators however internalize the relationship between $t = 1$ consumption and aggregate portfolio choices. For the sake of brevity, I focus on the global planner. Following the same steps as in the baseline model, the planner's objective function yields the following first order condition:

$$p^{GP} = p^{CE}\left[1 + \frac{c_1^* - l^{GP}}{R}\frac{\partial p}{\partial L}\left[\frac{1}{\phi'(x_j^D)} - 1 + \underbrace{\frac{R}{[p^{GP}]^2 h''(c_{j1})}}_{\text{Feedback Effect}}\right]\right].$$

The baseline formula is hence augmented by the last term on the right. The term can be positive or negative depending on the sign of $h''(c_{j1})$. However, during crises it is reasonably to assume that withdrawals increase with the fragility of the financial system ($h''(c_{j1}) > 0$), which ensures that c_1^* decreases in L. As a consequence, the planner chooses strictly more liquidity than in the baseline model. Because the competitive equilibrium is unchanged, it is optimal to impose tighter liquidity regulation.

The derivations in the baseline model carry over. The only requirement is that $h'''(c_{j1}) < 0$, which provides a sufficient condition for the uniqueness of the global and national planner solution.

Idiosyncratic Period 1 Consumption

Suppose period 1 consumption for investor j follows a cumulative distribution $G(\cdot)$ with $c_{j1} \in (0, e)$. If $s_j = 1$, the investor makes one iid draw from $G(\cdot)$. Due to the idiosyncratic nature of the shock in combination with the Law of Large Numbers, aggregate required liquidity is certain and equal to $qE(c_{j1})$. Therefore a similar logic as in Lemma 1 applies with c replaced by $E(c_{j1})$. In particular, there is a level of

R close enough to 1 that guarantees the existence of the asset market equilibrium. In what follows, I derive the aggregate demand and supply schedule in $t = 1$ and argue that the equilibrium is subject to the same externality as in the baseline model. Subsequently, I briefly highlight the modifications to the $t = 0$ optimization problem.

Aggregate demand for illiquid assets consists of demand by intact banks and distressed banks with $c_{j1} \leq l_j$. In the national planner environment, which is the most general scenario due to potentially distinct period 0 portfolio choices, aggregate demand is characterized as

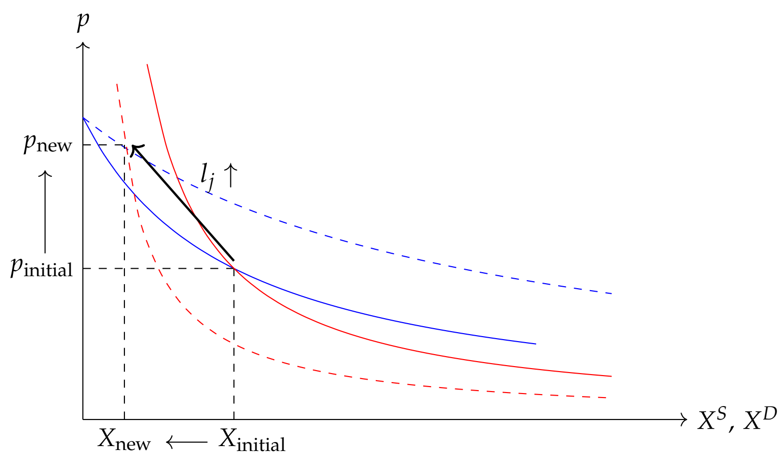
$$X^D(p, l_\omega, l_{1-\omega}) \equiv \left[\underbrace{(1-q)}_{\text{Intact Banks}} + \underbrace{q\left[\omega G(l_\omega) + (1-\omega)G(l_{1-\omega})\right]}_{\text{Distressed Banks with enough Liquidity}} \right] \phi'^{-1}\left(\frac{p}{R}\right).$$

The term $(1-q)$ represents the share of intact banks. $q\omega$ refers to the number of distressed banks in the ω jurisdiction and $G(l_\omega) = Pr(c_{j1} \leq l_\omega)$ characterizes the share thereof with sufficient liquidity to cover early consumption.

The aggregate supply of illiquid assets is determined by distressed banks which are hit by a high realization of c_{j1} and therefore request additional liquidity:

$$\begin{aligned} X^S(p, l_\omega, l_{1-\omega}) =& \frac{q}{p}\Big[\omega(1 - G(l_\omega))\left[E(c_{j1}|c_{j1} > l_\omega) - l_\omega\right] \\ &+ (1-\omega)(1 - G(l_{1-\omega}))\left[E(c_{j1}|c_{j1} > l_{1-\omega}) - l_{1-\omega}\right]\Big]. \end{aligned}$$

Figure F1: *Comparative Statics Asset Market: Effect of an Increase in l_j $\forall$ j*



Notes: *The solid blue (red) line corresponds to the initial inverse aggregate demand (supply) schedule of illiquid assets. More liquidity increases demand and reduces supply (dashed lines).*

Figure F1 highlights the interdependence between liquidity and the equilibrium asset price in this more general setting. Additional liquidity continues to decrease aggregate supply as $G'(\cdot) > 0$ and $\frac{\partial E(c_{j1}|c_{j1}>l_j)-l_j}{\partial l_j} < 0$. However, compared to the baseline model, aggregate demand is now increasing in liquidity as more distressed banks are able to satisfy $t = 1$ consumption with their own funds.

The period 0 optimization is similar to the baseline model apart from two modifications. First, since c is unknown, it is replaced by its conditional expectation. Second, additional liquidity increases the likelihood of sufficient funds during distress.

Accordingly, expected period 2 consumption for distressed banks is defined as:

$$
\begin{aligned}
E_0[c_{j2}^{s=1}(k_j, l_j; L)] =& G(l_j) \left[\underbrace{R \left[k_j + \phi \left(\phi'^{-1} \left(\frac{p(L)}{R} \right) \right) \right] + l_j - E(c_{j1}|c_{j1} \leq l_j) - p(L)\phi'^{-1} \left(\frac{p(L)}{R} \right)}_{\text{Expected consumption with sufficient Liquidity}} \right] \\
&+ (1 - G(l_j)) \qquad \underbrace{R \left[k_j - \frac{E(c_{j1}|c_{j1} > l_j) - l_j}{p(L)} \right]}_{\text{Expected consumption with insufficient Liquidity}}.
\end{aligned}
$$

The characterization of period 2 consumption for intact banks remains unchanged.

Aggregate Risk

To introduce aggregate uncertainty, I assume that early consumption c is stochastic and follows the cumulative distribution $G(\cdot)$ with $c \in (0, e)$. There are at most three equilibria: banks either go bankrupt, have insufficient liquidity but access the asset market to cover the outstanding consumption needs, or have sufficient funds to self insure. The equilibria as a function of c are portrayed in Figure F2.

Figure F2: *Equilibria as a Function of c*

If the realization of c is below $\underline{c}$, where $\underline{c}$ is defined as $\underline{c} \equiv \max c \;\text{ s.t. }\; c \leq l_j \;\; \forall \;\; j$, all distressed banks have sufficient funds to avoid selling long assets. The asset market is obsolete. Contrary, if c is above $\bar{c}$ defined as $\bar{c} \equiv \min c \;\text{ s.t. }\; L < q\bar{c}$, there is insufficient liquidity in the market to cover the consumption outlay and distressed banks go bankrupt. There is no equilibrium on the asset market and hence no price for long assets which would eliminate the pecuniary externality. In other words, just as with the self insurance equilibrium, the planner's choice would coincide with the competitive equilibrium and there is no justification for liquidity regulation. The relevant equilibrium for macroprudential regulation is hence the asset market equilibrium. Consequently, in order to derive similar conclusions as in the main body of the paper, the asset market equilibrium must exist with positive probability from the perspective of period 0. This can be guaranteed by appropriately calibrating R, which in turn determines liquidity and therefore the thresholds $\{\underline{c}, \overline{c}\}$.

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