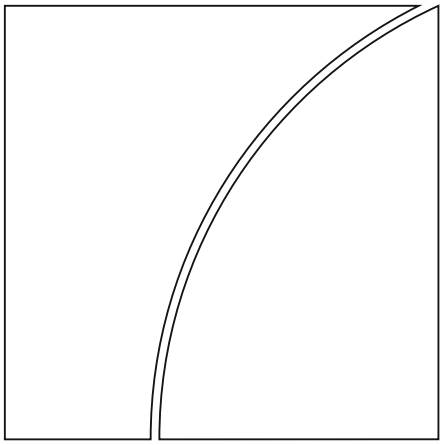

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by Morten L. Bech and Todd Keister

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On the economics of committed liquidity facilities

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Abstract

We study the effects of the new Basel III liquidity regulations in jurisdictions with a limited supply of high-quality liquid assets. Using a model based on Bech and Keister (2013), we show how introducing a liquidity coverage ratio in such settings can have significant side effects, leading to a large liquidity premium and pushing the short-term interest rate to the floor of the central bank's rate corridor. Adding a committed liquidity facility allows the central bank to mitigate these effects. By pricing committed liquidity appropriately, the central bank can determine either the equilibrium liquidity premium or the quantity of liquid assets held by banks, but not both. We argue that the optimal pricing arrangement will depend on local market conditions.

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1. Introduction

As part of the regulatory response to the recent global financial crisis, the Basel Committee on Banking Supervision (BCBS) announced a new international regulatory framework for banks, known as Basel III. One important component of Basel III is the Liquidity Coverage Ratio (LCR), which aims to ensure that banks hold a more liquid portfolio of assets and rely on the central bank for funding only as a last resort. Specifically, the LCR requires each bank to hold a sufficient quantity of highly liquid assets to survive a 30-day period of market stress; this requirement is scheduled to be phased in gradually beginning in January 2015. In the process of designing and calibrating the LCR rules, it became clear that some jurisdictions do not have sufficient high-quality liquid assets (HQLA) for their banking system to meet this new requirement. Australia and South Africa are cases in point, as both have limited amounts of sovereign debt and other qualifying securities; see Debelle (2011), Heath and Manning (2012) and South African Reserve Bank (2012). In such jurisdictions, the regulation offers the central bank the option of providing, for an up-front fee, contractual committed liquidity lines that count toward a bank's stock of liquid assets. Stein (2013) argues that such lines have the potential to be a useful safety valve in other situations as well, since they can place an upper bound on the cost of the liquidity regulation.

This type of committed liquidity facility (CLF) is an innovation within central banking and raises several interesting questions. How should these facilities be designed and priced? How will they interact with other parts of central banks' missions? Should such facilities be used only in jurisdictions with a shortage of HQLA or should they be part of all central banks' toolkits? With a view to providing a framework for addressing these questions, we develop a model that extends our earlier work on implementing monetary policy in the presence of an LCR requirement (Bech and Keister 2013). We show how the LCR requirement can have significant side effects in a jurisdiction with a limited supply of HQLA, leading to a large regulatory liquidity premium and pushing the short-term interest rate to the floor of the central bank's rate corridor. Introducing a CLF allows the central bank to mitigate these effects, regardless of whether it is implemented as a fixed-price standing facility or using a fixed-quantity auction format. By pricing the CLF appropriately, the central bank can control either the equilibrium liquidity premium or the quantity of liquid assets held by banks, but not both. We argue that the optimal pricing arrangement will need to balance the costs of higher interest rate spreads against the benefits of having more liquid assets in the banking system and will depend on local bond market conditions. Moreover, given the uncertainty about equilibrium relationships in the new regulatory environment, we argue that central banks are likely to want to take a flexible approach to CLF pricing, adjusting terms as more experience is gained with this new policy tool.

We provide a brief overview of the new regulatory framework in the next Section, then present our model in Section 3. We derive banks' demand for assets and CLF drawing rights in Section 4 and study equilibrium quantities and interest rates in Section 5. We use the model to discuss CLF pricing and related issues in Section 6 before concluding in Section 7.

2. The Regulatory Framework

In this Section, we describe the regulations governing the LCR and the use of CLFs. Our discussion is based on the revised rules issued in January 2013 by the Basel Committee on Banking Supervision (BCBS 2013).

2.1 The liquidity coverage ratio (LCR)

The liquidity coverage ratio builds on traditional methodologies used internally by banks to assess exposure to contingent liquidity events. The regulation will require that a bank's stock of unencumbered HQLA be larger than its projected net cash outflows (NCOF) over a 30-day horizon under a stress scenario specified by supervisors, that is:

$$\text{LCR} = \frac{\text{Stock of unencumbered high-quality liquid assets}}{\text{Net cash outflows over the next 30 calendar days}} = \frac{HQLA}{NCOF} \geq 100 \text{ per cent} \quad (1)$$

This requirement is scheduled to be phased in gradually, beginning with 60 per cent coverage in January 2015 and rising 10 percentage points each year to reach 100 per cent in January 2019.

Two types (or "levels") of assets can be counted toward the calculation of HQLA in the numerator of the ratio. Level 1 assets include cash, central bank reserves and certain marketable securities backed by sovereigns and central banks; these assets can be used without limit to meet the requirement. Level 2 assets enter the calculation in a more restricted way and are divided into two subgroups. Level 2A assets include certain government securities, corporate debt securities and covered bonds, while Level 2B assets include lower-rated corporate bonds, residential mortgage-backed securities and equities that meet certain conditions. Level 2A assets can account for a maximum of 40 per cent of a bank's total stock of HQLA, whereas Level 2B assets can account for a maximum of 15 per cent of the total.

The denominator of the ratio, NCOF, is calculated by multiplying the size of various types of liabilities and off-balance sheet commitments by the rates at which they run off or are drawn down in the specified stress scenario. This scenario is designed to include a partial loss of retail deposits, significant loss of wholesale funding, contractual outflows from derivative positions associated with a three-notch ratings downgrade, and substantial calls on off-balance sheet exposures. From these outflows, banks are permitted to subtract expected inflows during the next 30 calendar days. In order to prevent banks from relying solely on anticipated inflows to meet their liquidity requirement, the fraction of outflows that can be offset this way is capped at 75 per cent.

2.2 Committed liquidity facilities (CLFs)

The LCR rules recognise that, in some jurisdictions, the relatively small stock of assets qualifying as HQLA could make implementing the LCR requirement problematic. Debelle (2011) describes the situation in Australia as follows:

> [T]here is a marked shortage of high quality liquid assets that are outside the banking sector (that is, not liabilities of the banks). As a result of prudent fiscal policy over a large run of years at both the Commonwealth and state level, the stock of Commonwealth and state government debt is

low. At the moment, the gross stock of Commonwealth debt on issue amounts to around 15 per cent of GDP, state government debt (semis) is around 12 per cent of GDP. These amounts fall well short of the liquidity needs of the banking system.

To address such situations, the BCBS has developed a number of policy options, one of which is for the central bank to operate a CLF.[3] The LCR rules specify that:

> [T]hese facilities are contractual arrangements between the central bank and the commercial bank with a maturity date which, at a minimum, falls outside the 30-day LCR window ... Such facilities are only permissible if there is also a fee for the facility which is charged regardless of the amount, if any, drawn down against that facility. (BCBS 2013, paragraph 58)

The Reserve Bank of Australia (RBA) and the South African Reserve Bank (SARB) have both indicated their intention to provide committed liquidity facilities and have published details on how the facilities are to be designed; the term sheets are summarised in Table 1. The two facilities are similar in many respects but differ in some dimensions. In both facilities, the up-front fee is lower than the spread between the rate for the central bank's standing lending facility and the target for the overnight rate. Moreover, both facilities charge banks the overnight lending facility rate for drawdowns and have limits on the usage of the facilities. The set of eligible collateral is larger than what is normally accepted at each central bank's other facilities. One key difference is that the up-front fee is fixed for the RBA but is determined by a progressive scale dependent on the quantity contracted for the SARB.

CLF Term Sheets — Table 1

	Reserve Bank of Australia	South African Reserve Bank
Pricing		
Policy corridor	±25 bps	±100 bps
Up-front fee	fixed (15 bps)	scaled (15–45 bps)
Drawdown rate	= o/n lending facility rate	= o/n lending facility rate
Maximum amount	determined by supervisor	40% of NCOF
Collateral		
Assets eligible	> lending facility	> lending facility
Additional assets	self-securitised RMBS	self-securitised ABS
Haircuts	= other RBA facilities	= other SARB facilities

Notes: RMBS = residential mortgage-backed securities, ABS = asset-backed securities

Sources: RBA (2011) and SARB (2012)

[3] The other options are using foreign currency HQLA to cover domestic currency liquidity needs and increasing the use of Level 2 assets with a higher haircut; see BCBS (2013).

3. The Model

The analysis here builds on Bech and Keister (2013), which studies monetary policy implementation in the presence of an LCR requirement.[4] We introduce two new features into this framework: (i) banks' asset portfolios are endogenous rather than fixed; and (ii) the central bank operates a CLF. In this Section, we describe the role of banks and of the various markets in the model, as well as the basic design features of the CLF.

3.1 Banks

There is a continuum of identical banks, indexed by $i \in [0,1]$, all of which behave competitively in the sense that they take market interest rates as given and aim to maximise expected profits.

3.1.1 Balance sheets and decisions

The model plays out over the course of a period with four stages. Bank i begins the period with a balance sheet of the form:

Assets		Liabilities	
Loans	L^i	Deposits	$\bar{D}$
Bonds	B^i		
Reserves	R^i	Equity	$\bar{E}$

To simplify the analysis, we take the values of deposits $\bar{D}$ and equity $\bar{E}$ as given; these values are determined by activities outside the scope of the model. In the first stage, banks distribute their fixed resources across the three assets shown in the balance sheet: loans, bonds, and reserves. In the second stage, the central bank offers banks an opportunity to acquire rights to draw funds under its CLF. Let F^i denote the quantity of such rights acquired by bank i, which is an off-balance-sheet item. After the CLF has closed, each bank experiences a payment shock in which an amount ε^i of customer deposits is sent as a payment to another bank. If ε^i is negative, the shock represents an inflow of funds. The value of ε^i is drawn from a common, symmetric distribution G with zero mean. Depending on the size of this shock, a bank may need to borrow from the central bank to meet its regulatory requirements. This borrowing takes place in the fourth and final stage; let $X^i \geq 0$ denote the amount borrowed.[5] Bank i's end-of-period balance sheet is then:

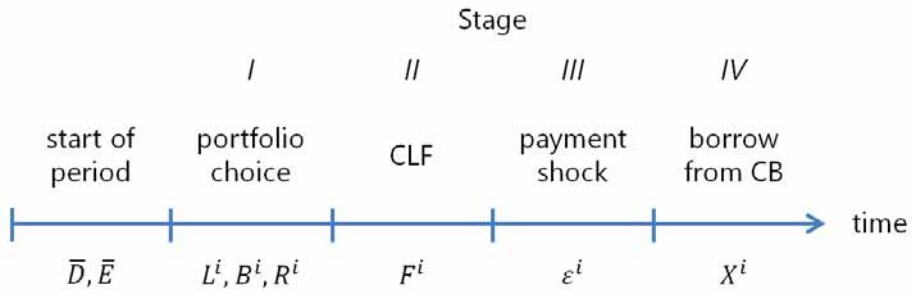
[4] Our model is in the tradition of Poole (1968) and many others. Much of this literature focuses on interbank markets and the implementation of monetary policy through open market operations. Our focus here, in contrast, is on how banks' portfolio choices are affected by liquidity regulation.

[5] To simplify the presentation, we assume a bank always has sufficient collateral in the form of loans L^i so that it can borrow as much as needed from the central bank to satisfy its regulatory requirements.

Assets		Liabilities	
Loans	L^i	Deposits	$\bar{D} - \varepsilon^i$
Bonds	B^i	Central bank borrowing	X^i
Reserves	$R^i - \varepsilon^i + X^i$	Equity	$\bar{E}$

Figure 1 illustrates the sequence of events and summarises when banks choose each decision variable.

Timeline Figure 1



3.1.2 The reserve requirement

Each bank faces a reserve requirement of the form:

$$R^i - \varepsilon^i + X^i \geq \bar{K} \equiv 0\,. \tag{2}$$

The left-hand side of this expression is the bank's reserve holdings at the end of the period, taking into account the payment shock and any borrowing from the central bank. The right-hand side is the requirement for the period. To conserve on notation, we study a system with no reserve requirements by setting $\bar{K}$ to zero, so that Equation (2) simply requires each bank to avoid an overdraft in its reserve account at the end of the period. If the bank violates this requirement after the realisation of the payment shock, it borrows funds from the central bank to ensure that Equation (2) holds.

3.1.3 The LCR requirement

In the context of our model, bank i 's LCR requirement is:

$$LCR^i = \frac{B^i + R^i - \varepsilon^i + X^i + F^i}{\theta(\bar{D} - \varepsilon^i)} \geq 100\% \tag{3}$$

Recall from Equation (1) that the numerator of the ratio is the total value of the bank's HQLA (its end-of-period holdings of bonds and reserves) plus any rights to draw on the CLF it has purchased. The denominator measures the 30-day NCOF assumed under the stress scenario, which in our model equals a fraction $\theta > 0$ of

the bank's deposits.[6] Notice that contracting with the CLF (increasing F^i) has the same effect on a bank's LCR as holding more bonds (increasing B^i).

3.1.4 Bank profits

The bank earns the interest rates r_L and r_B on its loans and bond holdings, respectively, and pays an interest rate r_D on customer deposits. The bank pays the central bank ϕ per unit of CLF rights purchased. It earns r_R on any positive reserve balances and faces a penalty rate $r_X > r_R$ for any funds borrowed from the central bank's overnight lending facility.

In comparing interest rates across assets, differences in credit risk and liquidity risk are clearly important. To account for these differences, we introduce a fixed premium τ that reflects both the credit and liquidity risk associated with loans in our model, so that the risk-adjusted benefit to the bank of making a unit of loans is given by $r_L - \tau$. We assume that bonds and reserves are both short-term, risk-free assets and, hence, the premium associated with these assets is zero.[7] Bank i 's profit for the period, net of credit and liquidity risk, can then be written as:

$$\pi^i(\varepsilon^i) = (r_L - \tau)L^i + r_B B^i - r_D(\bar{D} - \varepsilon^i) - \phi F^i + r_R \max\{R^i + X^i - \varepsilon^i, 0\} - r_X X^i . \qquad (4)$$

Note that the quantity of CLF rights purchased affects two terms in this expression: it creates an expense of ϕF^i on the first line and it potentially decreases the amount X^i of borrowing from the central bank.

3.2 Markets

To help maintain tractability, we assume that the markets in which banks trade in Stage I of Figure 1 are competitive and operate without frictions. We assume the loan market is completely passive – banks can make whatever quantity of loans they want at the equilibrium interest rate r_L^*. We describe the markets for reserves and bonds below.

[6] The LCR rules assign a minimum run-off rate of either 3 per cent or 5 per cent to retail deposits covered by an effective deposit insurance scheme. Retail deposits deemed to be less stable are assigned a minimum run-off rate of 10 per cent; see BCBS (2013) for more detail. Secured transactions with the central bank are assigned a 0 per cent run-off rate. However, the LCR is a minimum standard and, hence local authorities can set a higher value for these run-off rates at their discretion. See Bech and Keister (2013) for an analysis of the effects of an LCR requirement when loans from the central bank are assigned a positive run-off rate.

[7] The bonds in our model should, therefore, be interpreted as short-term bills. It would be straightforward to include long-term bonds that carry a term premium; what matters for our analysis is the spread between the interest rates on loans and bonds after accounting for risk and term premia.

3.2.1 The market for reserves

The central bank determines the total supply of reserves $\bar{R}$ at the beginning of the period.[8] To simplify our analysis, we assume the central bank sets the supply of reserves equal to total required reserves, which implies

$$\bar{R} = \bar{K} = 0 .$$

In an environment with no LCR requirement, this policy would steer the overnight interest rate to the midpoint of the central bank's corridor $[r_R, r_X]$ in the standard way (see, for example, Whitesell 2006). We denote this midpoint by

$$\bar{r} \equiv \frac{r_x + r_R}{2} \tag{5}$$

and note that, in the absence of an LCR requirement, $\bar{r}$ would be the risk-free, short-term interest rate in the economy.

3.2.2 The bond market

An important goal of our model is to determine how the quantity of bonds held by banks depends on the LCR requirement and on the design features of the CLF. Any bonds not held by banks are held by non-bank entities, including other financial institutions, households and foreign entities. We assume that the total quantity of bonds in the economy is fixed at $\bar{B}$ and that the demand for bonds by non-bank entities is a continuous, weakly increasing function of the interest rate r_B. As a result, the supply of bonds to the banking sector – that is, the quantity of bonds not held by non-banks – is a continuous, weakly decreasing function of r_B. We denote this supply function by $\mu(B)$. While we allow this function to take many different shapes, we impose one regularity condition to simplify the analysis:

$$\mu(0) = \bar{r} . \tag{6}$$

This condition states that if all bonds are held outside the banking system, their interest rate will equal the midpoint of the central bank's interest rate corridor. It implies that, in the absence of an LCR requirement, bonds would earn the same rate of return as other risk-free assets.[9]

Figure 2 depicts two different bond supply functions. In panel (a), the bond market is both large and liquid in the sense that banks' purchases of bonds have relatively little effect on their price. In this situation, the interest rate on bonds remains close to $\bar{r}$ over a wide range of bond holdings by banks. Panel (b), in contrast, depicts a situation in which the total quantity of bonds $\bar{B}$ is much smaller and the demand for bonds by non-banks is inelastic in some regions. This panel captures important features of the market for government bonds in jurisdictions like

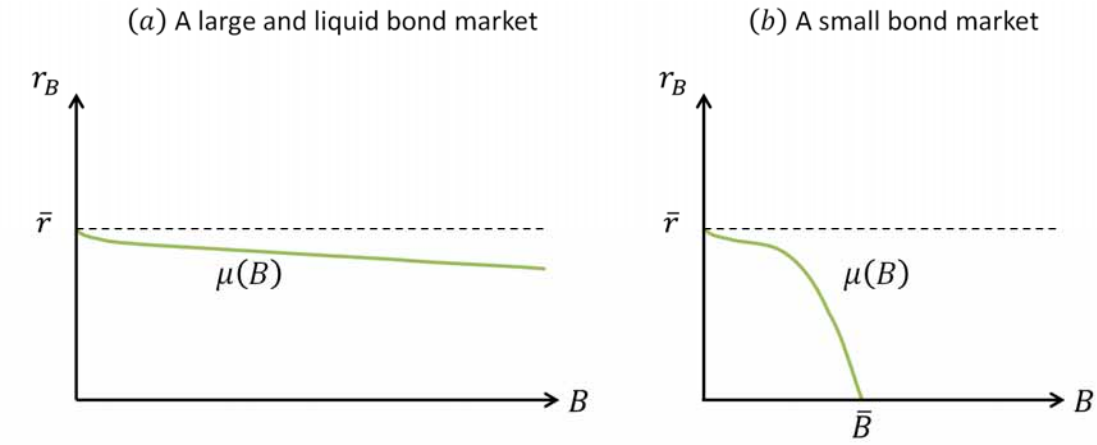
[8] We do not explicitly model open market operations here, but any operations can be thought of as taking place in the market where bonds are bought and sold in Stage I of Figure 1. See Bech and Keister (2013) for a detailed study of the effects of open market operations in the presence of an LCR constraint.

[9] In general, bonds may yield a lower return than other risk-free assets because they provide additional, non-pecuniary services. These services can be especially valuable for non-bank entities, which cannot hold reserves and may value bonds for liquidity or hedging purposes, or for currency diversification.

Australia where, according to Davis (2011, p 5), '[a]s banks attempt to increase their holdings of government debt, their demand will drive down its yield relative to other investments'. Debelle (2013) adds that '[a]t some point, the scarcity of available [government debt] securities would cause their yields to fall to a particularly low level'. In the analysis below, we show how the effect of introducing an LCR requirement depends crucially on the shape of the bond supply function μ, which may vary over time as well as across countries.

Supply of bonds to the banking system

Figure 2



3.3 The committed liquidity facility (CLF)

In general terms, the design of the CLF is characterised by a non-decreasing price function $\phi(F)$ that specifies the fee the central bank will charge for CLF rights if the total quantity of rights purchased by all banks is F. We assume that CLF rights are allocated in a competitive fashion, meaning that each bank takes the fee ϕ as given when choosing the quantity of rights to purchase. Our model can be generalised to allow for non-competitive allocation rules or for pricing rules in which each bank faces an increasing fee schedule depending on the amount borrowed, but we restrict our attention to the simpler, linear case here.

We focus on two specific designs for the CLF. The first is a fixed-price standing facility in which each bank can purchase as many CLF rights as it wants at a given price $\bar{\phi}$; this design corresponds to setting $\phi(F) = \bar{\phi}$ for all F. The second design we consider is a fixed-quantity auction, where the central bank offers a quantity $\bar{F}$ of CLF rights and is willing to accept whatever fee emerges from the auction. In the analysis below, we show that these two designs lead to equivalent outcomes in our model.

4. Optimal Portfolio Choices

In this Section, we derive a typical bank's demand for each of the three assets and for CLF rights. We begin with Stage IV in the time line in Figure 1, where each bank determines how much to borrow from the central bank's standing facility at the end

of the period. This borrowing rule allows us to derive a bank's expected profit before the payment shock is realised, which is the objective the bank seeks to maximise when making its decisions in Stages I and II.

4.1 Borrowing from the central bank

Borrowing from the central bank is costly and, therefore, each bank will choose to borrow the minimum amount needed to meet its regulatory requirements. Let X_K^i denote the minimum amount bank i must borrow from the central bank to fulfill the reserve requirement in Equation (2):

$$X_K^i \equiv \max\{\varepsilon^i - R^i, 0\}. \tag{7}$$

Let X_C^i denote the minimum amount bank i must borrow to fulfill the LCR requirement in Equation (3):

$$x_C^i \equiv \max\{(1-\theta)\varepsilon^i + \theta\bar{D} - B^i - R^i - F^i, 0\}. \tag{8}$$

Bank i's total borrowing from the central bank X^i will be the minimum amount needed to fulfill both of these requirements, that is:

$$X^i = \max\{X_K^i, X_C^i\}. \tag{9}$$

Figure 3 depicts X^i as a function of the realised payment shock ε^i together with a density function g for this shock. The blue curve in each panel represents Equation (7), the borrowing needed to satisfy the reserve requirement, which is positive whenever ε^i is larger than

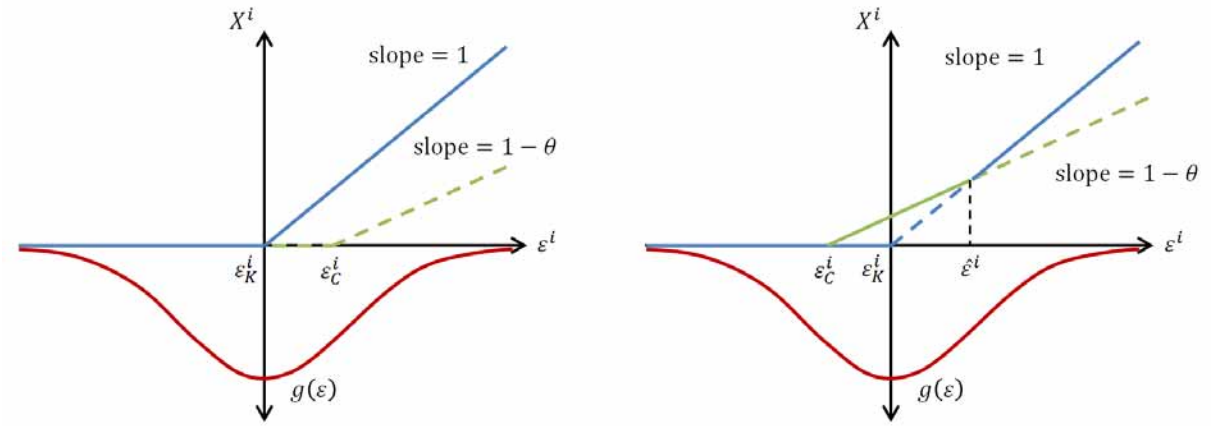
$$\varepsilon_K^i \equiv R^i. \tag{10}$$

The green curve represents Equation (8), the borrowing needed to satisfy the LCR requirement, which is positive for values of ε^i larger than

$$\varepsilon_C^i \equiv \frac{B^i + R^i + F^i - \theta\bar{D}}{1-\theta}. \tag{11}$$

The bank's borrowing X^i is the upper envelope of these two curves.

Bank i 's borrowing from the central bank lending facility Figure 3



As Figure 3 shows, two distinct cases arise. In panel (a) of Figure 3, the elements of the bank's balance sheet are such that $\varepsilon_K^i < \varepsilon_C^i$. In this case, the borrowing needed to satisfy the bank's reserve requirement is always sufficient to ensure that the bank also satisfies its LCR requirement, even when ε^i is larger than ε_C^i. In other words, the amount borrowed from the central bank's lending facility is determined solely by the bank's need to meet its reserve requirement in this case; the LCR requirement is never a binding concern. In contrast, panel (b) of Figure 3 depicts a situation where the balance sheet is such that $\varepsilon_K^i > \varepsilon_C^i$ holds. In this case, the amount borrowed from the central bank is determined by the need to meet the LCR requirement if ε^i falls in the interval $(\varepsilon_C^i, \hat{\varepsilon}^i)$, where

$$\hat{\varepsilon}^i \equiv \frac{\theta\bar{D}^i - B^i - F^i}{\theta}, \tag{12}$$

and by the need to meet the reserve requirement when ε^i is larger than $\hat{\varepsilon}^i$.

4.2 Expected profit

The expected value of bank i 's profit defined in Equation (4) can, using $E[\varepsilon^i] = 0$ and rearranging terms, be written as

$$E[\pi^i] = (r_L - \tau)L^i + r_B B^i - r_D\bar{D} - \phi F^i + r_R R^i - (r_X - r_R)E[X^i]$$

Using the definition of X^i in Equation (9), we can rewrite this expression as

$$\begin{aligned} E[\pi^i] = {} & (r_L - \tau)L^i + r_B B^i - r_D\bar{D} - \phi F^i + r_R R^i \\ & -(r_X - r_R)\left\{\begin{array}{l} \mathbb{I}_{\{\varepsilon_C^i < \varepsilon_K^i\}} \int_{\varepsilon_C^i}^{\hat{\varepsilon}^i} \left((1-\theta)\varepsilon^i + \theta\bar{D} - B^i - R^i - F^i\right) dG\left[\varepsilon^i\right] \\ + \int_{\max\{\varepsilon_K^i, \hat{\varepsilon}^i\}}^{\infty} (\varepsilon^i - R^i) dG\left[\varepsilon^i\right] \end{array}\right\}, \end{aligned} \tag{13}$$

where the indicator function $\mathbb{I}_{\{\cdot\}}$ takes the value one if the expression in curly brackets is true and zero otherwise. In making its decisions in Stages I and II of

Figure 1, bank i will aim to maximise the value of (13). We derive the optimal choices in each of these Stages below.

4.3 The demand for bonds and reserves

In Stage I, bank i divides its initial resources from deposits and equity between loans, bonds and reserves, subject to the balance sheet constraint

$$L^i + B^i + R^i \leq \bar{D} + \bar{E} \tag{14}$$

We use this constraint to replace L^i in Equation (13) and focus on the choices of B^i and R^i. To account for the indicator function in this objective function, we look at the first-order conditions separately in two distinct regions of the feasible set.

First, consider values of (B^i, R^i) such that $\varepsilon_C^i < \varepsilon_K^i$, which corresponds to the situation in panel (b) of Figure 3. In this region, the indicator function is one, we have $\max\{\varepsilon_K^i, \hat{\varepsilon}^i\} = \hat{\varepsilon}^i$, and the first-order conditions that characterise a solution are[10]

$$\frac{\partial E[\pi^i]}{\partial B^i} = -(r_L - \tau) + r_B + (r_X - r_R)\left(G[\hat{\varepsilon}^i] - G[\varepsilon_C^i]\right) = 0 \tag{15}$$

and

$$\frac{\partial E[\pi^i]}{\partial R^i} = -(r_L - \tau) + r_R + (r_X - r_R)\left(1 - G[\varepsilon_C^i]\right) = 0\,. \tag{16}$$

Equation (15) says the marginal income lost from holding bonds instead of loans, $r_L - \tau - r_B$, must equal the marginal benefit bonds provide in meeting the LCR requirement. When ε^i falls in the interval $(\varepsilon_C^i, \hat{\varepsilon}^i)$, holding an extra dollar's worth of bonds allows the bank to borrow one dollar less from the central bank, saving it the net cost $(r_X - r_R)$. Similarly, Equation (16) states that the marginal income lost from holding reserves, $r_L - \tau - r_R$, is equal to the marginal benefit reserves provide in terms of meeting both the LCR requirement and the reserve requirement. As shown in panel (b) of Figure 3, holding an additional dollar of reserves allows the bank to borrow one dollar less from the central bank whenever the payment shock is larger than ε_C^i.

Next, consider the region where $\varepsilon_C^i \geq \varepsilon_K^i$, which corresponds to panel (a) of Figure 3. In this case, the value of the indicator function is zero, we have $\max\{\varepsilon_K^i, \hat{\varepsilon}^i\} = \varepsilon_K^i$, and the first-order conditions are

$$\frac{\partial E[\pi^i]}{\partial B^i} = -(r_L - \tau) + r_B = 0 \tag{17}$$

and

$$\frac{\partial E[\pi^i]}{\partial R^i} = -(r_L - \tau) + r_R - (r_X - r_R)\left(1 - G[\varepsilon_K^i]\right) = 0\,. \tag{18}$$

[10] To simplify the presentation, we allow banks to short sell both loans and bonds and to run overdrafts in their reserve accounts in this stage, which implies there are no non-negativity constraints on this choice problem. In equilibrium, interest rates will be such that banks always choose to hold non-negative amounts of each asset.

Notice that Equation (17) implies $r_L - \tau = r_B$ must hold for the solution of the bank's problem to fall in this region. Since the LCR requirement is never a binding concern in this region, Equation (18) implies that the lost income from holding reserves instead of loans, $r_L - \tau = r_R$, must equal the marginal benefit reserves provide simply in terms of meeting the reserve requirement. The following proposition combines these two cases and characterises the bank's optimal portfolio choice in Stage I of Figure 1.

Proposition 1. Bank i will choose (B^i, R^i) so that the critical values $(\varepsilon_K^i, \varepsilon_C^i, \hat{\varepsilon}^i)$ defined in Equations (10) to (12) satisfy

$$r_B = r_R + (r_X - r_R)\left(1 - G[\max\{\hat{\varepsilon}^i, \varepsilon_K^i\}]\right) \tag{19}$$

and

$$r_L = r_R + (r_X - r_R)\left(1 - G[\min\{\varepsilon_C^i, \varepsilon_K^i\}]\right) + \tau\,. \tag{20}$$

4.4 The demand for CLF rights

In Stage II of Figure 1, bank i will choose to purchase a quantity $F^i \geq 0$ of CLF rights, again with the objective of maximising Equation (13). In the region where $\varepsilon_C^i < \varepsilon_K^i$, the first-order condition characterising the optimal choice is

$$\frac{\partial E[\pi^i]}{\partial F^i} = -\phi + (r_X - r_R)\left(G[\hat{\varepsilon}^i] - G[\varepsilon_C^i]\right) \leq 0\,,$$

with equality if $F^i > 0$. In this region, which again corresponds to panel (b) in Figure 3, purchasing CLF rights helps mitigate the bank's LCR shortfall when the realisation of the payment shock is between ε_C^i and $\hat{\varepsilon}^i$. Notice the similarity between this condition and Equation (15), which reflects the fact that holding bonds and purchasing CLF rights offer the same benefit in terms of increasing the bank's LCR. The bank will choose to purchase CLF rights only if the fee ϕ is no larger than the income loss associated with holding bonds, $r_L - \tau - r_B$.

In the region where $\varepsilon_C^i \geq \varepsilon_K^i$, the marginal benefit of CLF rights is given by

$$\frac{\partial E[\pi^i]}{\partial F^i} = -\phi\,,$$

which is always negative. This region again corresponds to panel (a) in Figure 3, where the LCR is never a binding concern and, as a result, CLF rights have no value for the bank. If the solution to the bank's optimisation problem lies in this region, it will necessarily have $F^i = 0$. The following proposition formalises these results.

Proposition 2. Bank i 's demand for CLF rights is given by

$$F^i = \left\{\begin{array}{c} 0 \\ \in [0, \infty) \\ \infty \end{array}\right\} \text{ if } \phi \left\{\begin{array}{c} > \\ = \\ < \end{array}\right\} r_l - \tau - r_B\,.$$

This result shows a tight relationship between the CLF fee ϕ and the opportunity cost of holding bonds, $r_L - \tau - r_B$. If purchasing CLF rights is more expensive than holding bonds, banks will not use the CLF. If purchasing CLF rights is cheaper than

holding bonds, banks will demand as many CLF rights as possible, selling bonds to compensate. In the middle case, banks are indifferent at the margin between holding bonds and purchasing CLF rights for the purpose of satisfying the LCR requirement.

5. Equilibrium

In this Section, we derive the equilibrium interest rates and portfolio choices. After providing a formal definition of equilibrium, we analyse outcomes in a benchmark setting with no liquidity regulation, then in a setting with an LCR requirement but no CLF, and finally in a setting where a CLF is introduced.

5.1 Definition

Since there is a unit measure of banks, all of whom face the same decision problem, the aggregate demand for loans, bonds, reserves and CLF rights are the same as the individual demands derived above. Equilibrium requires that each of these demands equals the corresponding supply of the asset to the banking system, as specified in the following definition.

Definition: An equilibrium consists of a portfolio choice for banks (L^*, B^*, R^*, F^*) together with interest rates (r_L^*, r_B^*) and a CLF fee ϕ^* such that:

(i) each bank's choices (L^*, B^*, R^*, F^*) maximise its expected profit (Equation (13)) subject to the balance sheet constraint in Equation (14), taking the interest rates and CLF fee as given

(ii) markets clear, that is

$$B^* = \mu^{-1}(r_B^*) \text{ and } R^* = \bar{R} = 0 \tag{21}$$

(iii) CLF rights are priced according to the central bank's rule,

$$\phi^* = \phi(F^*).$$

Using the market-clearing conditions in Equation (21), we can write the equilibrium values of the critical points for the payment shock defined in Equations (10) to (12) as

$$\varepsilon_K^* = 0,\ \varepsilon_C^*(B^* + F^*) = \frac{B^* + F^* - \theta\bar{D}}{1-\theta} \text{ and } \hat{\varepsilon}^*(B^* + F^*) = -\frac{B^* + F^* - \theta\bar{D}}{\theta}. \tag{22}$$

Note that ε_K^* depends only on the central bank's choice for the quantity of excess reserves, which we have assumed to be zero. In contrast, both ε_C^* and $\hat{\varepsilon}^*$ are functions of the sum of banks' bond holdings and CLF rights, $B^* + F^*$, which is determined as part of the equilibrium.

5.2 Equilibrium with no liquidity regulation

We begin by studying the properties of equilibrium in a benchmark case where there is no liquidity regulation, which corresponds to setting the run-off rate θ in our model to zero. In this case, the critical values in Equation (22) will always satisfy

$\varepsilon_C^* \geq \varepsilon_K^* = 0$ and, hence, the configuration is always like that in panel (a) of Figure 3. In other words, when there is no LCR requirement, banks' only liquidity management concern in our model is satisfying the reserve requirement in Equation (2). The following proposition characterises the equilibrium outcome in this case.

Proposition 3. When there is no LCR requirement, equilibrium interest rates satisfy

$$r_L^* - \tau = r_B^* = \overline{r}\,.$$

When there is no liquidity regulation, the short-term, risk-free interest rate equals the midpoint of the central bank's corridor, $\overline{r}$, as in Whitesell (2006) and others. The interest rate on loans is given by $r_L^* = \overline{r} + \tau$, which implies that the premium τ can be interpreted as the market price of credit and liquidity risk.

Figure 4 illustrates this result. The blue line in Figure 4 corresponds to banks' demand for bonds from Equation (19). When there is no LCR requirement, this equation simply says that banks are willing to hold bonds only if the return they offer is at least equal to the risk-free rate. For this reason, the demand curve is flat at $\overline{r}$. Similarly, the red line represents banks' demand for loans from Equation (20). Since banks are willing to hold loans only if the net return $r_L - \tau$ is at least equal to the market risk-free rate, this demand curve is flat at $\overline{r} + \tau$. The green curve represents the supply of bonds to the banking system $\mu(B)$. Equilibrium occurs when this supply curve crosses the blue demand curve, which happens here at $B^* = 0$. In other words, given this particular function μ, banks will hold no bonds in equilibrium in the absence of liquidity regulation.[11]

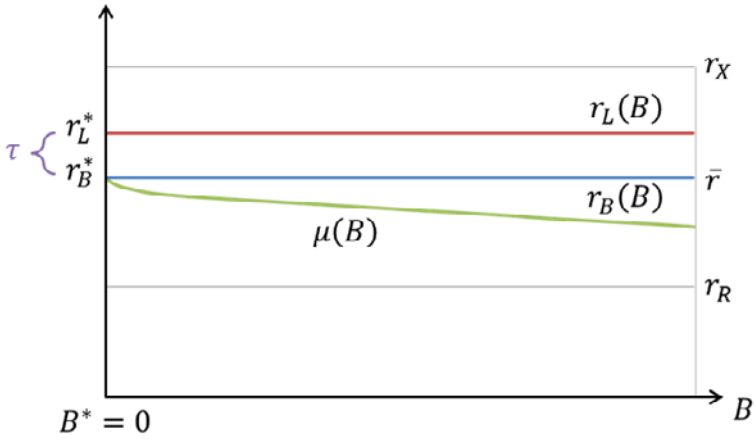
To the extent that holdings of liquid assets by banks provide external benefits, it might be desirable to introduce liquidity regulation to the situation depicted in Figure 4. One can think of the objective of such regulation as being twofold: (i) encouraging banks to hold a more liquid portfolio of assets; and (ii) correcting the possible underpricing of liquidity risk in markets. Stein (2013) puts it this way:

> [A]s the financial crisis made painfully clear, the business of liquidity provision inevitably exposes financial intermediaries to various forms of run risk ... [F]ire sales and bank failures – and the accompanying contractions in credit availability – can have spillover effects to other financial institutions and to the economy as a whole. Thus, while banks will naturally hold buffer stocks of liquid assets to handle unanticipated outflows, they may not hold enough because, although they bear all the costs of this buffer stocking, they do not capture all of the social benefits, in terms of enhanced financial stability and lower costs to taxpayers in the event of failure. It is this externality that creates a role for policy.

An LCR requirement is one policy tool that can be used to address these issues.

[11] The result that banks hold zero bonds in this situation arises, in part, because we have assumed that banks receive no liquidity or other services from holdings bonds, whereas non-bank entities do. Alternatively, one could interpret B^* as being banks' bond holdings beyond those used in its normal course of business, for example as collateral for settlement purposes.

Equilibrium with no liquidity regulation Figure 4



5.3 Equilibrium with an LCR requirement

We now study how the equilibrium changes when banks are subject to the LCR requirement in Equation (3) with a run-off rate on deposits of $\theta > 0$, but there is no CLF. The following proposition characterises the equilibrium outcome.

Proposition 4. When there is an LCR requirement but no CLF, equilibrium bond holdings B^* are implicitly defined by

$$\mu(B^*) = r_R + (r_X - r_R)\left(1 - G[\hat{\varepsilon}^*(B^*)]\right),$$

and equilibrium interest rates satisfy

$$r_L^* = r_R + (r_X - r_R)\left(1 - G[\varepsilon_c^*(B^*)]\right) + \tau$$

and

$$r_B^* = \mu(B^*).$$

This result and its implications are illustrated in Figure 5. The blue curve again corresponds to banks' demand for bonds from Equation (19), which we rewrite here as an explicit function of B using the equilibrium critical points in Equation (22) with F^* set to zero,

$$r_B = r_R + (r_X - r_R)\left(1 - G[\max\{\hat{\varepsilon}^*(B), 0\}]\right). \tag{23}$$

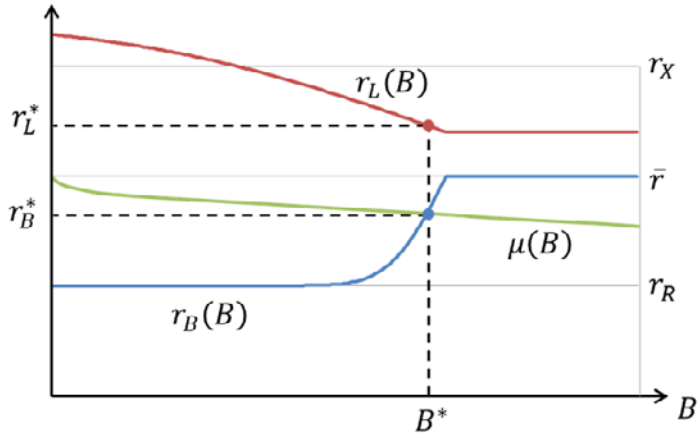
When banks' bond holdings are low, $\hat{\varepsilon}^*$ is positive and the curve is an increasing function of B. Once the level of bond holdings reaches $\theta\bar{D}$, however, banks are holding enough bonds to ensure that the LCR requirement is never a binding concern. Beyond this point, banks are willing to hold additional bonds only when the yield is at least $\bar{r}$. Similarly, using Equations (20) and (22), we can write the relationship between the loan rate r_L and the quantity of bonds held by banks as

$$r_L = r_R + (r_X - r_R)\left(1 - G[\min\{\varepsilon_C^*(B), 0\}]\right) + \tau. \tag{24}$$

This relationship corresponds to the red curve in Figure 5. When B is less than $\theta\bar{D}$, ε_C^* is negative and the curve lies above the rate $\bar{r}$. As B increases, the likelihood of an LCR deficiency falls and, therefore, the spread between the loan rate and $\bar{r}$ gradually declines, reaching τ at $B = \theta\bar{D}$.

Equilibrium with an LCR but no CLF

Figure 5



Equilibrium is determined by the intersection of the demand curve in Equation (23) with the supply curve for bonds $\mu(B)$, which is again represented by the green curve in Figure 5. Equilibrium bond holdings are denoted by B^* and the equilibrium interest rate on bonds by r_B^*. The equilibrium loan rate is determined by the corresponding point on the red curve, denoted r_L^*. Notice that once an LCR requirement is introduced, we have the strict ordering

$$r_L^* - \tau > \bar{r} > r_B^*.$$

In other words, the LCR requirement raises the equilibrium loan rate r_L^* while lowering the equilibrium interest rate on bonds r_B^*.[12] The spread $r_L^* - r_B^*$ now has two components: the original premium τ is augmented by a regulatory liquidity premium that reflects the equilibrium value banks place on bonds for the purposes of meeting the LCR requirement. Using Equations (23) and (24), we can write this spread as

$$r_L^* - r_B^* = \tau + (r_X - r_R)\left(G[\hat{\varepsilon}^*] - G[\varepsilon_C^*]\right) \equiv \tau + p^*. \qquad (25)$$

The regulatory liquidity premium, denoted p^*, equals the probability of the LCR being a binding concern for each bank (see panel (b) of Figure 3) multiplied by the net cost of borrowing an additional dollar from the central bank to meet this requirement. Note that while the additional premium raises the cost of credit – that is, loans in the economy – this outcome may be desirable if liquidity was thought to be underpriced before the regulation was put in place.

[12] These results mirror those in Bech and Keister (2013), which shows how an LCR requirement tends to raise the interest rate on interbank loans with maturities outside the 30-day LCR window, while lowering the rate on shorter maturity loans.

Equilibrium with no CLF and a small supply of bonds Figure 6

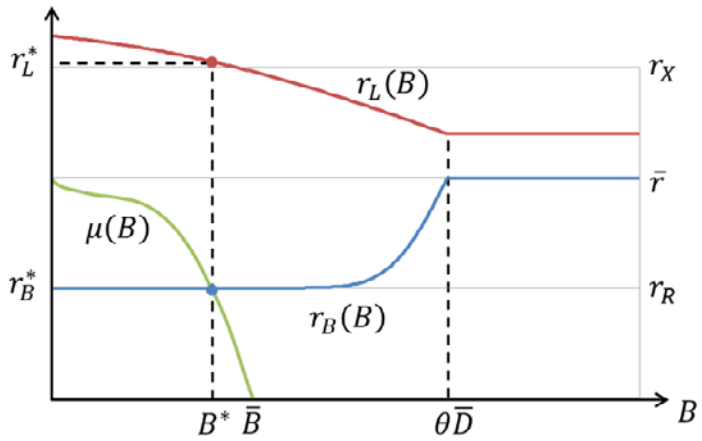


Figure 6 depicts the effects of an LCR requirement for an economy with a more limited supply of bonds. The increase in banks' bond holdings generated by the regulation is necessarily much smaller in this case than in Figure 5, while the increase in the spread $r_L^* - r_B^*$ is much larger. In fact, banks' demand to hold bonds for LCR purposes in this case pushes the equilibrium interest rate on bonds down to the floor of the central bank's corridor at r_R. The scarcity of bonds in the economy implies that banks will often find themselves facing an LCR deficiency and, hence, needing to borrow reserves from the central bank to meet this requirement. These borrowed reserves perform double duty in the sense that they count toward both a bank's LCR requirement and its reserve requirement. As a result of this borrowing, therefore, banks become virtually certain to over-satisfy their reserve requirements, which implies that bonds and reserves become near-perfect substitutes. In other words, introducing an LCR requirement in this economy causes the short-term interest rate to fall and thereby affects the implementation of monetary policy. In effect, the central bank in this scenario ends up operating a 'floor system' of monetary policy implementation.[13] Debelle (2011) discusses these concerns:

> [O]ne possible solution to the shortage of level 1 assets would be for banks to significantly increase the size of their [reserve holdings] to meet their liquidity needs. While this is possible, it would mean that the RBA's balance sheet would increase considerably. The RBA would have to determine what assets it would be willing to hold against the increase in its liabilities, and would be confronted by the same problem of the shortage of assets in Australia outside the banking system ... [T]his outcome would also significantly affect the ability to meet the cash rate target set by the Reserve Bank Board. That is, we do not want to impair the operational framework for monetary policy which has served us well for many years.

It is precisely to mitigate these problems that the LCR rules permit central banks in certain jurisdictions to operate a CLF.

[13] See Goodfriend (2002) and Keister, Martin and McAndrews (2008) for discussions of the floor system of monetary policy implementation.

5.4 Equilibrium with a CLF

We now ask how the equilibrium of the model changes when the central bank introduces a committed liquidity facility. The facility is characterised by a non-decreasing price function $\phi(F)$ as described in Section 3.3. We first show that if the fee for CLF rights is set sufficiently high, banks do not use the facility and the equilibrium outcome is the same as when there is no CLF.

Proposition 5. If $\phi(0) \geq p^*$, the CLF is not used in equilibrium, $F^* = 0$. Equilibrium bond holdings B^* and interest rates (r_L^*, r_B^*) are as given in Proposition 4.

Recall that p^*, as defined in Equation (25), represents the regulatory liquidity premium that arises in the absence of a CLF. If the fee for purchasing CLF rights is larger than this premium, it would be less expensive for a bank to increase its LCR by holding more bonds and fewer loans than by using the CLF. In such a situation, the CLF will see no activity. The next proposition characterises how the equilibrium allocation changes when the CLF is priced in a way that attracts usage.

Proposition 6. If $\phi(0) < p^*$, then the equilibrium quantities (B^*, F^*) are defined by

$$\mu(B^*) = r_R + (r_X - r_R)\left(1 - G[\hat{\varepsilon}^*(B^* + F^*)]\right) \tag{26}$$

and

$$\phi(F^*) = (r_X - r_R)\left(G[\hat{\varepsilon}^*(B^* + F^*)] - G[\varepsilon_C^*(B^* + F^*)]\right). \tag{27}$$

The equilibrium interest rates and CLF fee satisfy

$$r_L^* = r_R + (r_X - r_R)\left(1 - G[\varepsilon_C^*(B^* + F^*)]\right) + \tau, \tag{28}$$

$$r_B^* = \mu(B^*) \tag{29}$$

and

$$\phi^* = \phi(F^*). \tag{30}$$

Equation (26) requires that the supply of bonds to the banking system equal banks' demand for bonds, taking into account the fact that this demand depends on CLF usage F^*. Equation (27) requires that the CLF fee equals the size of the regulatory liquidity premium that arises in equilibrium, which ensures that banks are willing to use the facility.

As discussed above, banks can increase their stock of HQLA either by holding more bonds or by holding loans and purchasing CLF rights. The net yield from the latter approach is given by the net yield on loans, $r_L^* - \tau$, minus the CLF fee ϕ^*. Using Equations (27), (28) and (30), we can write this yield as

$$r_L^* - \tau - \phi^* = r_R + (r_X - r_R)\left(1 - G[\hat{\varepsilon}^*(B^* + F^*)]\right),$$

which, from Equations (26) and (29), is exactly r_B^*. In other words, these two ways of increasing a bank's HQLA must generate the same return. This result relates to the rules on CLF pricing, which state:

> ... the fee [should be] set so that banks which claim the facility line to meet the LCR, and banks which do not, have similar financial incentives to

> reduce their exposure to liquidity risk. That is, the fee should be set so that the net yield on the assets used to secure the facility should not be higher than the net yield on a representative portfolio of Level 1 and Level 2 assets, after adjusting for any material differences in credit risk. (BCBS 2013, paragraph 58)

Proposition 6 shows that, at least in our model environment, when the CLF is active the fee ϕ^* will *always* be such that these two net yields are equal, because the equilibrium returns on assets will necessarily adjust so that this relationship holds.

Next, we illustrate the results from Proposition 6 in more detail by studying particular forms of the CLF pricing function $\phi(F)$.

5.4.1 A fixed-price standing facility

Suppose the central bank sets $\phi(F) = \bar{\phi}$ for all F, thereby operating the CLF as a standing facility in which banks can purchase as many rights as they choose at a fixed per-unit fee. Figure 7 illustrates the equilibrium outcome under this type of facility. Recall from Equation (22) that the equilibrium critical values of the payment shock $(\varepsilon_C^*, \hat{\varepsilon}^*)$ – and hence the demand curve in Equation (23) – now depend on the *sum* of the bank's holdings of bonds and CLF rights,

$$r_B = r_R + (r_X - r_R)\left(1 - G[\max\{\hat{\varepsilon}^*\left(B+F\right), \varepsilon_K^*\}]\right).$$

The blue curve in Figure 7 is thus the same as in Figures 5 and 6, but the variable being measured on the horizontal axis is now $B+F$ rather than B alone. Similarly, the red curve has the same shape as in the earlier figures, but now relates the loan rate r_L to the sum $B+F$.

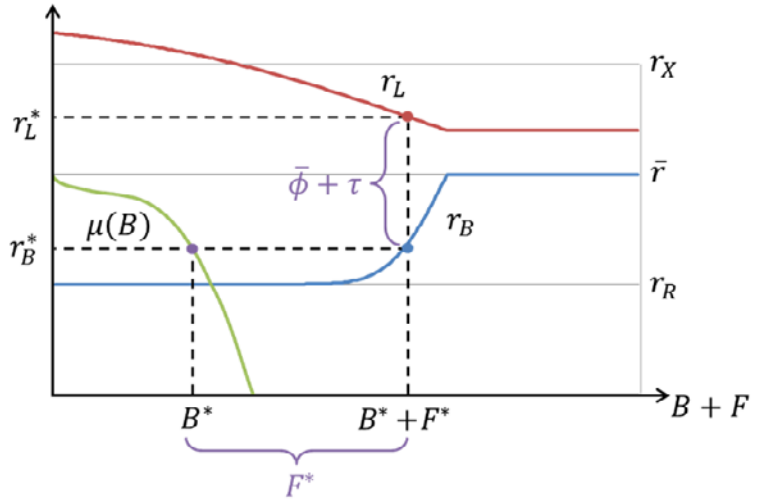
Combining Equations (26) to (30) shows that

$$\bar{\phi} + \tau = r_L^* - r_B^* \tag{31}$$

must hold in equilibrium. As shown in Figure 7, there is a unique value of $B+F$ such that the gap between the red and blue curves is exactly $\bar{\phi} + \tau$. Equation (31) thus determines the equilibrium sum $B^* + F^*$ and the equilibrium interest rates r_L^* and
r_B^*. The equilibrium quantity of bonds held by banks, B^*, is then determined by the supply of bonds $\mu(B)$ at the interest rate r_B^*, as required by Equation (29). The quantity of CLF rights purchased from the standing facility in equilibrium is equal to the difference between the demand for $B+F$ (the blue curve in Figure 7) and the supply of B (the green curve) at the interest rate r_B^*.

Equilibrium with a fixed-price CLF

Figure 7

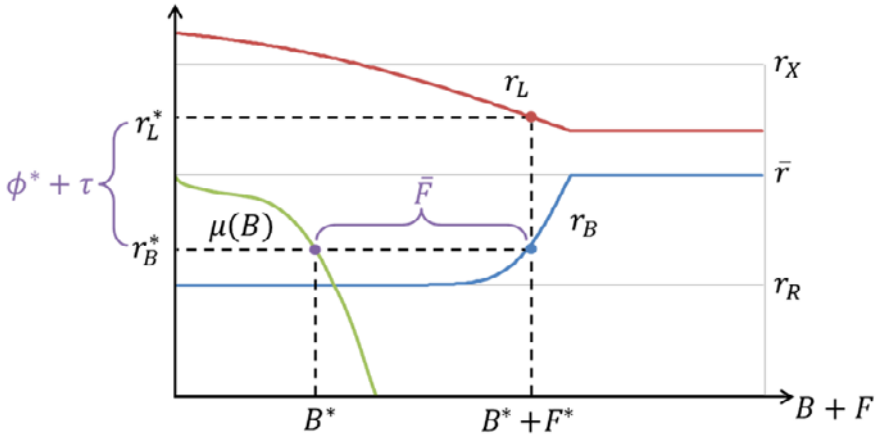


Several interesting results can be seen in Figure 7. First, setting the CLF fee allows the central bank to control the regulatory liquidity premium directly, regardless of the bond supply function μ. Even if the function μ were changing over time or unknown to the central bank, the chosen value of $\bar{\phi}$ would always determine this premium as shown in Equation (31). Second, Figure 7 shows there is a crowding out effect: when $\bar{\phi}$ is set lower, banks purchase more CLF rights but hold fewer bonds. The size of this effect is determined by the shape of the bond supply function μ. In regions where the supply of bonds is relatively elastic (i.e. the green curve is relatively flat), a small decrease in $\bar{\phi}$ will lead to a large decrease in B^*. Conversely, in regions where bond supply is inelastic, the crowding out effect will be small. More generally, Figure 7 shows how the bond supply function traces out the set of outcomes available to the central bank. Setting $\bar{\phi}$ higher implies that banks will hold more bonds in equilibrium, but the liquidity premium will also be larger. By choosing $\bar{\phi}$ appropriately, the central bank can pick out different points on this frontier, but the equilibrium pair (B^*, r_B^*) will always lie on the green curve. In this way, choosing the CLF fee allows the central bank to determine either the quantity of bonds held by banks or the equilibrium liquidity premium, but not both.

5.4.2 A fixed-quantity auction facility

Now suppose the central bank chooses to sell a fixed quantity $\bar{F}$ of CLF rights, possibly using an auction format. Figure 8 illustrates the outcome under this approach. For any $\bar{F} < \theta\bar{D}$, Figure 8 shows that there is a unique interest rate r_B such that the difference between the demand for bonds plus CLF rights (the blue curve) and the supply of bonds (the green curve) is exactly $\bar{F}$. The chosen quantity $\bar{F}$ thus determines the equilibrium interest rate on bonds r_B^* and the equilibrium quantity of bonds B^*. The equilibrium loan rate r_L^* is determined by the point on the red curve corresponding to the total quantity of bonds plus CLF rights, $B^* + \bar{F}$.

Equilibrium with a fixed-quantity CLF Figure 8



Comparing Figures 7 and 8, it is clear that the central bank in our model can achieve the same equilibrium outcome using either a fixed-price or a fixed-quantity CLF. In fact, this same outcome will obtain under *any* CLF pricing function ϕ that satisfies

$$\bar{\phi} = \phi(\bar{F}).$$

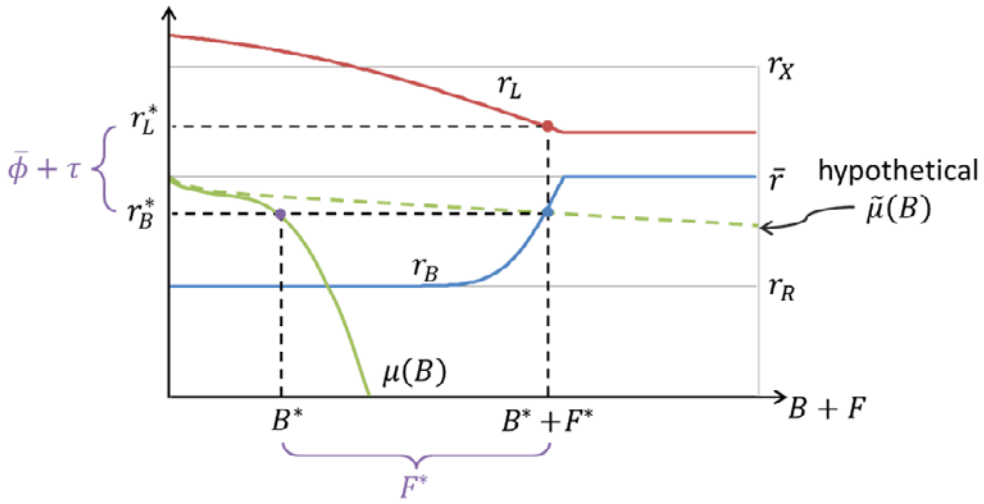
In reality, uncertainty about the positions of the (green) supply curve and the (blue) demand curve are likely to play an important role in determining the best design for the CLF. For example, the fixed-price design is likely to be appealing to a central bank that wishes to stabilise the interest rate spread $r_L^* - r_B^*$ and let the quantity of CLF usage vary depending on financial conditions. The fixed-quantity design, in contrast, would be attractive to a central bank that prefers to keep CLF usage predictable and allow interest rates to change in response to market conditions.

6. Pricing Committed Liquidity

Suppose a central bank has decided to create a CLF, which for ease of exposition we assume to be operated as a fixed-price standing facility. How should the price $\bar{\phi}$ be set? One possibility is to aim to replicate the equilibrium spread $r_L^* - r_B^*$ that would arise in an economy where HQLA is plentiful and there is no CLF. In the context of our model, this requires constructing a hypothetical supply function $\tilde{\mu}(B)$ that would apply if bonds were plentiful in this economy. This function is represented by the dashed green curve in Figure 9. The intersection of this hypothetical supply function with the actual demand curve in blue determines the interest rates (r_L^*, r_B^*) that would prevail in the hypothetical situation. The central bank would then substitute these interest rates into Equation (31) and set $\bar{\phi}$ accordingly. As shown in Figure 9, the actual bond supply function (in solid green) then determines the quantity of bonds held by banks, B^*, and the quantity of CLF rights purchased, F^*. One possible rationale for using this approach is that it equalises the effect of liquidity regulation on interest rates across jurisdictions, even when bond market conditions are very different.

Setting $\bar{\phi}$ based on a hypothetical bonds supply function

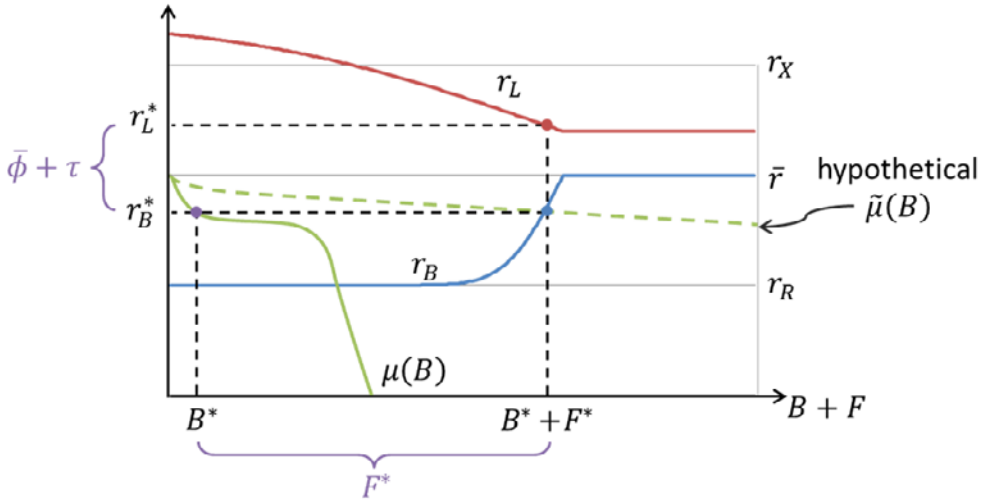
Figure 9



Notice, however, that the equilibrium allocations under the hypothetical supply curve $\tilde{\mu}$ and the actual supply curve μ are far from equivalent. In particular, banks' actual bond holdings B^* are much lower than they would be in the hypothetical situation, even though interest rates are the same. To the extent that one goal of liquidity regulation is to ensure that banks hold a more liquid portfolio of assets, it may be desirable to set the CLF price higher than indicated in Figure 9, which would lead banks to hold more bonds while increasing the interest rate spread $r_L^* - r_B^*$.

In general, the optimal pricing of the CLF is likely to depend critically on the shape of the bond supply function μ, which traces out the trade-off the central bank faces between two competing goals: encouraging banks to hold more bonds and maintaining spreads at reasonable levels. Figure 10 makes this point by assuming a very particular shape for the function μ. If the central bank were to follow the procedure described above of pricing the CLF according to the hypothetical supply function $\tilde{\mu}$, the resulting equilibrium would have banks holding a small quantity of bonds and meeting their LCR requirements almost entirely through the purchase of CLF rights. However, the true bond supply function μ is such that if the central bank were to increase $\bar{\phi}$ slightly, banks' bond holdings would rise substantially and reliance on the CLF would diminish. In such a situation, it seems likely that policymakers would prefer the latter outcome, where the spread between r_L^* and r_B^* is slightly wider but banks hold a substantially higher quantity of bonds.

The importance of the bond supply function for CLF pricing Figure 10



While the example in Figure 10 is in some ways extreme, it serves to make the general point that the optimal CLF pricing policy is likely to depend on the bond market conditions within each jurisdiction. In particular, policy makers will need to balance the costs associated with higher spreads against the benefits of having more liquid assets in the banking system. Doing so requires knowledge of how equilibrium interest rates and quantities respond to changes in the CLF pricing structure – that is, knowledge of the bond supply function μ. Estimating this relationship precisely is a difficult task, both ex ante and ex post. In light of this uncertainty, the RBA and SARB have taken a pragmatic approaches in setting their CLF fees and both jurisdictions place a cap on the amount of CLF rights available to a bank (see Table 1). Moreover, the reasoning laid out here suggests that it may be desirable to take a flexible approach to CLF pricing, possibly adjusting terms as more experience is gained with this new policy tool.

7. Conclusion

We have presented a stylised model that can be used to analyse the economic effects of liquidity regulation in the form of an LCR requirement and a CLF. We have shown how the LCR requirement can have significant side effects in a jurisdiction with a limited supply of HQLA, leading to a large regulatory liquidity premium and pushing the short-term interest rate to the floor of the central bank's rate corridor. Introducing a CLF allows the central bank to mitigate these effects, regardless of whether it is organised as a fixed-price standing facility or using a fixed-quantity auction format. By pricing the CLF appropriately, the central bank can control either the equilibrium liquidity premium or the quantity of bonds held by banks, but not both. We argue that the optimal pricing arrangement will need to balance the costs of higher interest rate spreads against the benefits of having more liquid assets in the banking system. Our analysis has shown how the appropriate balance is likely to depend on local bond market conditions and thus may vary across jurisdictions. Moreover, the uncertainty about equilibrium relationships in the new regulatory environment means means that central banks will likely take a flexible approach to CLF pricing, adjusting terms over time as experience with these facilities increases.

While CLFs may not be immediately necessary in jurisdictions outside of Australia, South Africa, and a few others, it is possible they will prove to be a useful policy tool in other situations as well. Stein (2013) argues that a CLF may be beneficial even in jurisdictions where HQLA are plentiful because it allows the central bank to place an upper bound on the costs of liquidity regulation. In addition, as shown in our analysis above, the CLF allows regulation to focus more directly on prices whereas the LCR requirement is focused on quantities. Another possibility is that a CLF could be used as part of a central bank's regular procedures for implementing monetary policy and providing liquidity to the banking system. The Winters (2012) review of the Bank of England's operational framework, for example, suggests that selling CLF rights for an up-front fee, followed by a lower-than-usual interest rate on amounts drawn down, could potentially reduce stigma and other non-price barriers that limited the usefulness of existing facilities during the crisis. The model we present here could potentially be extended to address these issues, which represent an interesting area for future research.

References

BCBS (Basel Committee on Banking Supervision) (2013), 'Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools', January 2013. Available at www.bis.org/publ/bcbs238.htm.

Bech ML and T Keister (2013), 'The Liquidity Coverage Ratio and Monetary Policy Implementation', BIS Working Paper No 432, October. Available at www.bis.org/publ/work432.htm.

Davis K (2011), 'Basel III Liquidity Options', Australian Centre for Financial Studies Discussion Paper 2011-02, 28 May.

Debelle G (2011), 'The Committed Liquidity Facility', Speech to the Australian Prudential Regulation Authority Basel III Implementation Workshop, Sydney, 23 November.

Debelle G (2013), 'The Impact of Payments System and Prudential Reforms on the RBA's Provision of Liquidity', Address to the Australian Financial Markets Association and Reserve Bank of Australia Briefing, Sydney, 16 August.

Goodfriend M (2002), 'Interest on Reserves and Monetary Policy', Federal Reserve Bank of New York, *Economic Policy Review*, 8(May), pp 13–29.

Heath A and M Manning (2012), 'Financial Regulation and Australian Dollar Liquid Assets', RBA *Bulletin*, September, pp 43–52.

Keister T, A Martin and J McAndrews (2008), 'Divorcing Money from Monetary Policy', Federal Reserve Bank of New York *Economic Policy Review* (September), 14(2), pp 41–56.

Poole W (1968), 'Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy', *Journal of Finance*, 23(5), pp 769–791.

RBA (Reserve Bank of Australia) (2011), 'The RBA Committed Liquidity Facility', Media Release No 2011-25, 16 November.

South African Reserve Bank (2012), 'Provision of a Committed Liquidity Facility and Utilisation of Statutory Cash Reserves in Terms of the Basel III Liquidity Framework', Guidance Note 5/2012. Available at www.resbank.co.za/Lists/News%20and%20 Publications/Attachments/5036/G5%20of%202012.pdf.

Stein JC (2013), 'Liquidity Regulation and Central Banking', Remarks at 'Finding the Right Balance', 2013 Credit Markets Symposium, Sponsored by the Federal Reserve Bank of Richmond, Charlotte, North Carolina, April 19. Available at http://www.federalreserve.gov/newsevents/speech/stein20130419a.pdf.

Whitesell W (2006), 'Interest Rate Corridors and Reserves,' *Journal of Monetary Economics*, 53(6), pp 1177–1195.

Winters B (2012), 'Review of the Bank of England's Framework for Providing Liquidity to the Banking System', October. Available at www.bankofengland.co.uk/publications/Documents/news/2012/cr2winters.pdf.