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Abstract

History suggests a conflict between current Basel III liquidity ratios and monetary policy, which we call the liquidity regulation dilemma. Although forgotten, liquidity ratios, named “securities-reserve requirements”, were widely used historically, but for monetary policy (not regulatory) reasons, as central bankers recognized the contractionary effects of these ratios. We build a model rationalizing historical policies: a tighter ratio reduces the quantity of assets that banks can pledge as collateral, thus increasing interest rates. Tighter liquidity regulation paradoxically increases the need for central bank’s interventions. Liquidity ratios were also used to keep yields on government bonds low when monetary policy tightened

JEL Classification: E43, E52, E58, G28, N10, N20

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1 Introduction

After the Global Financial Crisis, policy makers designed global standards to improve financial stability, under the name of Basel III banking regulations. These standards include liquidity regulations, whose explicit goal is to reduce the need for central bank's interventions when banks lose access to the money market.[1] It has become apparent, however, that there could be some tensions between this new regulation and the implementation of monetary policy.[2] As various liquidity ratios were phased-in, central bankers started to recognize that liquidity regulation raises permanently banks' demand for liquidity. This demand might have to be satisfied by central banks themselves. Otherwise, the price of liquidity (that is short-term interest rates) may increase, possibly out of sync with the monetary policy stance (Quarles (2018)). This problem became even more visible in the United States as the size of the Fed's balance sheet decreased. It culminated in September 2019, when liquidity regulation was believed to be responsible for a peak of short-term money market rates around 10% above the Fed target (Powel (2019)). The Fed responded to this spike by offering up to USD 490 bn in loans to the financial system on 31st December 2019.

This sequence of events shows the new dilemma that central bankers may face due to liquidity regulation: either they accept that monetary conditions tighten, or they expand their balance sheet to combat upward pressures on interest rates, which involves taking some degree of risk and goes precisely against the original goal of liquidity regulation.[3] This dilemma will reappear when central banks attempt to withdraw from accommodative policies. For this reason, it is key to understand precisely how and why liquidity regulations create this tension.

[1]For instance, Jeremy Stein, then Governor of the Federal Reserve Board stated: "The introduction of liquidity regulation after the crisis can be thought of as reflecting a desire to reduce dependence on the central bank." Stein (2013). The ECB printed in its monthly bulletin: "The objective of the liquidity regulation framework is to reduce the shortcomings of liquidity risk management [...] by ensuring that banks can rely more on their own liquidity resources." (ECB (2014)). The Basel Committee on Banking Supervision motivated the introduction of the LCR in the following way: "[During the GFC] The banking system came under severe stress, which necessitated central bank action to support both the functioning of money markets and, in some cases, individual institutions" (BCBS (2013))

[2]For instance Benoît Coeuré declared in 2013: "In my view, the interaction is expected to be complex and liquidity regulation may require adjustments to central banks' operational frameworks." (Coeuré (2013)). See also CGFS (2015).

[3]Increasing the size of the balance sheet, even without lending directly to financial institutions (e.g. by buying long-term Treasuries) implies that the central bank takes additional interest rate risk. This type of risks can be economically important (Bhattarai et al. (2015) and Greenwood et al. (2015)).

Our starting point is that, contrary to a common assumption, liquidity regulation is not new.[4] Based on detailed readings of historical central banks' reports and documents, this paper first documents that liquidity regulations – similar to the current Basel III Liquidity Coverage Ratio (LCR) – have been used from the 1930s to the 1980s in many countries as monetary policy tools. Lessons can be learned from their history. These ratios took the form of required deposits at the central bank ("cash-reserve requirements") or minimum holdings of liquid securities ("securities-reserve requirements"). As with modern liquidity ratios such as the LCR, these two types of liquidity requirements (cash and securities) were computed as a percentage of short-term deposits. While the history and theory of "cash-reserve requirements" are well known (Kashyap and Stein (2012), Carlson (2015), Bindseil (2004), and Romer (1985)), we are not aware of any study on "securities-reserve requirements". The existence of securities-reserve ratios is particularly important because they are closer to current Basel III liquidity ratios, than "cash-reserve requirements".

Second, we show that the mechanisms put forward by past central bankers can be rationalized with a simple model of the interbank market, considering that securities-reserve and cash-reserve requirements worked through different channels. Our model is in the tradition of Poole (1968) where banks experience a "late" deposit shock, after the interbank market has closed and may force them to borrow from the central bank. The novelty of our model is that we introduce a securities-reserve requirement, where banks have to hold a minimum amount of securities. A security cannot be pledged as collateral to borrow from the central bank at the same time as it is used to fulfill the liquidity ratio (i.e. it needs to be unencumbered). Thus, a higher liquidity ratio means that banks are more collateral constrained. The more likely the collateral constraint is to be binding, the higher the price of liquidity and thus the higher money market interest rates. Our effect is also at work when the liquidity ratio is fixed but the demand for liquidity increases because of an economic expansion (i.e the ratio works like an automatic stabilizer).[5]

[4]For instance: "Liquidity regulation is a relatively new, post-crisis addition to the financial stability toolkit" Stein (2013)

[5]Securities-reserve requirements operate through a different channel compared to cash-reserve requirements in our model. However, under certain conditions they are observationally equivalent. Another intuitive but important result of our model is that—contrary to standard cash-reserve requirements—securities-reserve requirements have no effects when the central bank acts fully as a lender of last resort.

The main historical lesson is that liquidity ratios were used to influence money market rates in order to stabilize output and inflation, a function that today would typically be assigned to monetary policy. In other words, the effects of liquidity ratios on money market rates were so obvious to past central bankers that they did not even try to use these liquidity ratios separately from other monetary policy instruments. Securities-reserve requirements also had the advantage of stimulating the demand for government debt, which was another objective of central banks in the post-war context. This potential "fiscal footprint of [modern] macroprudential policy" has been recently raised and discussed theoretically by Reis (2020). Our paper is the first to show that historical liquidity ratios were designed to increase the demand for government securities. Central banks increased liquidity ratios during times of restrictive monetary policy in order to prevent banks from selling government securities, which were the main type of asset eligible to fulfill the requirement. Liquidity ratios were akin to a collateral constraint. As such, banks were discouraged to shift their assets from government securities to corporate loans. This feature also explains why these ratios were phased out by central banks in the 1980s, as they had been associated with the so-called "financial repression" era (Reinhart and Sbrancia (2015)).

We contribute to several strands of literature that look at the interactions between monetary and macroprudential policies. Acknowledging that direct quantitative controls on bank lending or reserves were a key element of central banks' toolbox in the past, a growing literature has looked at historical experience to estimate their macroeconomic effects and discuss similarities with current macroprudential tools (Elliott et al. (2013), Monnet (2014), Kelber et al. (2014), Carlson (2015), Calomiris and Carlson (2017), Koch (2015), Aikman et al. (2016), and Richter et al. (2018)).[6] Being essentially empirical, this literature leaves aside a precise theoretical understanding of the mechanisms and channels of such a complex set of instruments. It follows that it is difficult to assess how context-specific these empirical results are. Contrary to this literature, we draw on historical experience of central banks to investigate theoretical mechanisms through which liquidity ratios interact with monetary policy.

[6] A precedent to this literature can be found in Romer and Romer (1993) which distinguished between credit actions and monetary policy measures of the United-States Federal Reserve.

Greenwood et al. (2016) argue that the LCR will fundamentally affect monetary policy. It will force central banks to maintain a large balance sheet to provide banks enough liquidity to comply with regulation, in direct contradiction with the initial goal of the LCR. In the only formal model of interaction between the LCR and monetary policy, Bech and Keister (2017) show that a binding LCR decreases the overnight interbank rate relative to term interest rates. Bonner, Clemens and Eijffinger, Sylvester C. W. (2016) and Fuhrer et al. (2017) present evidence of such an effect, based on the implementation of the LCR in the Netherlands and in Switzerland. Kandrac and Schlusche (2017) show that cash-reserve requirement had a contractionary effect before the crisis. None of these papers discuss the collateral constraint mechanism that our historical narrative and theoretical model put forward.

Recently, several theoretical paper have explored the benefits of liquidity regulation in terms of financial stability (Diamond and Kashyap (2016), Imhof et al. (2019) and Calomiris et al. (2015a)). While our paper is less interested in the financial stability aspect of liquidity ratios than in its monetary policy function, we note that there seems to be no paper modelling simultaneously liquidity regulation and the lender of last resort. From the theoretical standpoint, the debate remains open as to whether *ex-ante* regulation is really superior to the promise of *ex-post* central bank lending against sound collateral. This puts into question the original motivation of post-crisis liquidity regulation. For this reason, at least, it is key to understand the implication of new liquidity ratios for monetary policy implementation.

Section II provides the historical narrative of past reserve requirements. Section III develops the model and section IV concludes.

2 Cash and Securities-Reserve Requirements in History

The basic idea behind reserve requirements (also named “liquidity ratios”) is to require banks to hold a quantity X of liquid assets (central bank reserves or securities) for every unit of deposit (or any pre-defined liability or asset). X is then called the reserve requirement ratio. The central bank reserves or the reservable securities are called the “reservable assets” of any specific requirement.

The denominator of the ratio is called the " reserve base." There is a key conceptual and historical difference between two types of reserve requirements: "*cash-reserve requirements*", which are in fact what we usually call today "reserve requirements" (i.e. a minimum amount of bank balances at the central bank), and "*securities-reserve requirements*." This second category differs from the first because the liquid assets are not deposited with the central banks and they can include a broader set of assets (usually government securities). The current Basel III's Liquidity Coverage Ratio (LCR) is a form a securities-reserve requirement that also accepts central bank's liabilities as liquid assets. As such, when excess reserves at the central bank equal zero, the LCR is equivalent to securities-reserve requirements.

There is an extensive literature on the history and mechanics of cash-reserve requirements, and many central banks still officially use them for monetary policy implementation (O'Brien (2007) and Gray (2011)). The existing literature has identified four main functions of cash-reserve requirements:[7]

- Banking regulation: reserve requirements intend to force banks to keep a minimum amount of liquid assets to withstand bank runs (Feinman (1993) and Carlson (2015)).

- Monetary policy tool: reserve requirements can be used to constrain credit, and to control interest rates, either to control the demand of banks for central bank money or to stabilize interest rates (Huberto M. Ennis and Todd Keister (2008)).

- Tax: reserve requirements can be used as a direct tax on banks, for pure fiscal reasons (see Romer (1985) for an explicit tax and Reinhart and Sbrancia (2015) for an implicit tax under financial repression). The tax can also be used as a pigouvian tax on issuance of short-term deposits (Kashyap and Stein (2012)).

- Capital controls: a common form of cash-reserve requirement is to require banks to deposit with the central bank a percentage of the money they borrow from abroad (De Gregorio et al.

[7] For an alternative classification, see Bindseil (2004).

(2000) and Monnet (2018)). The purpose is to limit capital inflows or discourage currency risk.

By contrast, securities-reserve requirements have disappeared from the standard toolbox of central banks and their history have received little or no attention.[8]

As we shall see, securities-reserve requirements often had similar functions as cash-reserve requirements, although they work through different mechanisms. In some countries (prominently in the U.S. and Germany), central banks used cash-reserve requirements only. In many others, various securities-reserve requirements were in place from the 1950s to the 1980s, sometimes – but not always – combined with cash-reserve requirements. Among OECD countries, the central banks of Australia, Belgium, Canada, France, Italy, Netherlands, New-Zealand, Sweden, the United Kingdom were notable users of liquidity ratios taking the form of securities-reserve requirements and having an explicit monetary policy function (Fousek (1957), Goode and Thorn (1959), De Kock (1974) and additional references below). We rely on the writings of contemporary economists that described monetary policy tools, as well as on reports published by central bank themselves. Our goal is not to provide an exhaustive history of these tools; we cannot give a full account of the experience of each country that used them. Instead, our stylized presentation highlights the main reasons why they were introduced and – most of all – how contemporaries understood their effects. Each of the three following sub-sections highlight three important aspects of securities-reserve requirements: (i) cash and securities-reserve requirements were first introduced for regulatory purposes (in a limited number of countries), but were later incorporated into the central banks' monetary policy toolbox (in a large number of countries); (ii) the expected effect of securities-reserve requirements was to prevent banks from selling government securities (or using them as collateral to borrow more). These requirements therefore had a two-fold objective: it was a collateral constraint for banks, limiting credit to the private

[8] The use of securities-reserve requirements by central banks in OECD countries was abandoned in the 1980s (Bindseil (2004), Bisignano (1996), Jonung (1993), Monnet (2018), and Borio (1997)), mostly because of their complexity, because banks had found ways to circumvent them, and because central banks moved away from quantitative instruments. Today, few central banks in emerging markets (India, Philippines) still use them in order to control interest rates.

sector (by raising lending and money market rates) while maintaining the price of government securities; (iii) these tools were abandoned because of their complexity and criticisms of their distributional effects (prioritizing public debt over lending to private corporations).

2.1 From prudential to monetary policy functions

Cash-reserve requirements were first introduced in the United States in the 19th century as banking regulation tools, for prudential reasons (Goodfriend and Hargraves (1983), Calomiris (2012), Carlson (2015)). Then, the U.S did not have a central bank: cash-reserves had to be deposited in other banks, the "reserve city banks". Recurrent banking crises, and the failure of liquidity regulation alone (reserve requirements) to avoid them, led to the introduction of the lender of last resort, in the form of the Federal Reserve System in 1913 (Feinman (1993)). Contrary to the United States, other advanced economies had a central bank before 1913 but no banking regulation: banking regulation and central bank liquidity provision were perceived as substitutes.[9] In the interwar period, the U.S Federal Reserve started to use reserve requirements as monetary policy tools. It was a noted and influential shift that started in the early 1930s and was accomplished in 1936 (Friedman and Schwartz (1963), Meltzer (2010), and Carlson and Wheelock (2014)).[10]

This shift had been motivated by the recognition that cash-reserve requirements had an effect on credit and money creation and thus could no longer be deemed prudential tools only. The 1931 report of the Federal Reserve System Committee on Bank Reserves stated:

> "The committee takes the position that it is no longer the primary function of legal reserve requirements to assure or preserve the liquidity of the individual member bank. Since the establishment of the Federal Reserve System, the liquidity of an individual bank is more adequately safeguarded by the presence of the Federal Reserve banks,

[9] Only banks of issue – i.e. central banks – were regulated and had to keep reserves in function of their note issuance (Toniolo and White (2015)).

[10] Their effectiveness has however been challenged by Goodfriend and Hargraves (1983) and Calomiris et al. (2015b).

> which were organized for the purpose, among others, of increasing the liquidity of member banks by providing for the rediscount of their eligible paper, than by the possession of legal reserves." (quoted in Goodfriend and Hargraves (1983), p. 37 and Carlson and Wheelock (2014)).

Soon after, New Zealand and Sweden introduced similar cash-reserve requirements for monetary policy (in 1936 and 1937) to follow the U.S. innovation. The leading textbook on central banking during this period documented this important innovation:

> "In recent years a new method has been devised for the purpose of increasing or decreasing the available supply of bank cash [...]. This method was first introduced in the United States in 1933 and amended in 1935 [...] as an additional means of enabling the Reserve Banks to control the money market and to contract or expand the credit-creating capacity of the member banks. It was brought into use for the first time in August 1936." (De Kock (1939), p. 266)

A visionary man, De Kock anticipated that "this method of changes in reserve requirements will probably tend to be more widely adopted and further developed" (De Kock (1939), p. 267). He was right: cash-reserve requirements became a major tool of monetary policy after the Second World War in most countries, together with open market operations, discount window lending and direct credit controls. It is only in the 1980s that open market operations displaced the others (Bindseil (2004), Borio (1997) and Monnet (2018)). The history of securities-reserve requirements started later, but it shows a similar shift, from prudential tools to monetary policy tools. As cash-reserve requirements in the U.S., securities-reserve requirements had been first introduced as prudential tools in the few other countries that adopted banking regulations before the mid-1930s, namely Sweden in 1911 and then Switzerland in 1934. Fixed liquidity ratios implemented for prudential purposes later became (or were complemented by) adjustable securities-reserve requirements and then were used for monetary policy purposes. Contrary to cash-reserve requirements, this shift did not occur in the 1930s but after the Second World War. A study written at the New York Fed in the 1950s on the "instruments of monetary policy" in countries outside the United States describes this development well:

> "Initially, minimum liquidity ratios [securities-reserve requirements] were established to safeguard bank liquidity and to protect bank depositors. Thus, in 1920's and 1930's, such ratios became a feature of commercial banking legislation in the Scandinavian countries and Switzerland." (Fousek (1957), p. 57)"

The United States never implemented securities-reserve requirements (although the proposal was discussed, as we shall see below). Their history and rationale as monetary policy tools after 1945 in other countries have received much less attention than the history of cash-reserve requirements. To this, we now turn our attention.

2.2 The rationale for securities-reserve requirements: collateral constraint and the price of government securities

Let's turn to the fourth edition of de Kock's book on central banking, published in 1974. Two differences with the 1st edition of 1939 are striking. First, as anticipated in 1939, reserve requirements indeed had become an instrument of first importance for central banks (De Kock (1974), p. 207).[11] Second, the definition of "reserve requirements" has widened. In 1974, it includes two types of instruments which De Kock names "cash-reserve requirement" and "liquid-asset requirement." The former is the same as the U.S. cash-reserve requirements presented in the 1939 edition: demand deposits at the central banks. The latter is what we call "securities-reserve requirements": a fixed proportion of total assets must be held in liquid assets (the definition of "liquid assets" being different across countries and periods). In other surveys of central banking practices in several countries, these two instruments were also viewed as two distinct types of "reserve requirement" (Fousek (1957), Goode and Thorn (1959), EEC (1962), EEC (1972), Tamagna (1963), Thurow (1971), Hodgman (1973), and OECD (1975)).

[11] They now deserved a full chapter, entitled "variable reserve requirements", alongside the three surviving chapters "discount-rate policy", "open-market operations" and "other methods of credit controls."

"Securities-reserve requirements" were clearly distinguished from "cash-reserve requirements", and alternatively called "liquid asset requirements" or "liquidity ratios." For example, Fousek (1957)'s international study on instruments of monetary policy devoted one separate chapter to each of them "Chapter IV: commercial bank cash-reserve requirements" and "Chapter V: commercial bank liquidity ratios". Another U.S economist, George Garvy, observed that, outside the U.S, cash-reserve requirements were sometimes introduced as monetary policy tools after securities-reserve requirements ("liquidity ratios") were already in use:

> "In several leading industrial countries where [cash] reserve requirements were introduced relatively recently, they have been integrated with the existing fairly complex systems of monetary control, notably liquidity ratios." (Garvy (1973), 1973, p. 256)

Some economists argued that securities-reserve requirements had a similar effects:

> "If the reserves take the form of government bonds or other securities than must be obtained from the central bank, their credit-limiting function is identical with that of cash-reserves." (Goode and Thorn, 1959, p. 10–13)

By contrast, others acknowledged that securities-reserve requirements had a specific effect which was different from the one of cash-reserve requirements. Economists and central bankers realized than cash and securities-reserve requirements were not substitutes but could be used to complement each other. More generally, securities-requirements were usually used to complement any quantitative instrument of monetary policy (credit controls, rediscount ceilings, cash-reserve requirements, etc.) because central banks wanted to avoid that banks circumvented restrictive measures by selling government securities to obtain additional liquidity. This argument was formulated explicitly in many central bank reports (EEC (1962), EEC (1972)) and was also at the core of the proposals to introduce securities-reserve requirements in the U.S., as we will see below. Fousek, among others, explained it very clearly:

> “Still another common problem arises in countries where banks hold large amounts of government securities and, by selling them or letting them run off, may be able to obtain additional reserves.” (Fousek (1957), p. 55)

Securities-reserve requirements could be used to avoid asset substitution in banks portfolio that would limit the effectiveness of cash-reserve requirements. This interaction is well described for instance in the case of Australia:

> “At times in Australia, however, the restraining effect of these [cash-reserve] requirements was largely nullified by the commercial banks’ liquidation of their government securities holdings in a market supported by the central bank. In 1954 such selling of government securities by the Australian banks prompted the central bank to propose that the banks observe a ratio of 25 percent between liquid assets (including government securities) and their total deposits; the central bank stated that this would make its monetary policy more effective.” (Fousek (1957), p. 58)

Similar mechanisms are described, for example, about French monetary policy and the interaction between securities-reserve requirements and other monetary policy tools (rediscount ceilings in this case, that is bank-by-bank quotas on borrowing from the central bank):

> “The fixing of rediscount ceilings would have lost its point if the banks, disposing as they did at the end of the war of a large portfolio of Treasury bills, had been left free to rediscount them with the central bank or not to renew them on their maturity. The banks were therefore called on at the same time to retain a minimum portfolio of Treasury bills. The imposition of “floors“ for government paper, [...] is an automatic restraint on the volume of loans the banks can make to their customers. “ (EEC (1962), p. 121)

In other words, central banks were afraid that the constraints they imposed on bank lending – i.e. contractionary monetary policy tools – would have led to banks selling their Treasury securities. Such strategy to circumvent the restrictive measures would have led to fall in the price of government securities (an increase in their yields). A careful observer of post-war U.S. monetary policy summarized these issues as follows, and thus argued for the introduction of securities-reserve requirements in the United States :

> "Banks can always sell securities to increase reserves and thus nullify [cash] reserve requirements. With its existing legal powers over reserve requirements the Federal Reserve is powerless to halt the process as long as it must stand ready to purchase government securities at prices which will keep yields and interest rates at their present low levels. (Burkhead (1947), p. 1)"

The conclusion for monetary implementation was straightforward: either the central bank imposed securities-reserve requirements as monetary policy tools, or it let the yield on government bonds rise. From this perspective, securities-reserve requirements were supposed to function as a collateral constraint: they prevented banks from increasing their short-term funding by selling Treasury securities. They were also means of securing government funding and maintaining a stable interest rate on government debt when money markets and lending rates increased. The U.S. is one of the only countries, with West Germany, that relied extensively on cash-reserve requirements for monetary control, without using securities-reserve requirements. The Bundesbank, however, used rediscount quotas (i.e. bank-by-bank ceilings limiting the amount borrowed at the discount window) which, as we show in our model of the next section, are equivalent to securities-reserve requirements. However, proposals to introduce securities-reserve requirements within the Fed policy instruments were made several times. First proposed by academics in 1940 (Riddle and Reierson (1946)), it was then endorsed by Fed officials in 1945 and 1948, under the names "special" or "secondary" reserve requirement (Federal Reserve Bulletin, January 1948, Willis (1948), Romer and Romer (1993), and Meltzer (2003) p. 645–650), but the U.S. Congress turned it down. Finally, such proposals emerged again in the late 1950s, especially motivated by European central banks experience with liquidity ratios

(Fousek (1957), Ascheim (1958), McLeod (1959)).[12] The objective of such tools was to control inflation through credit restrictions. As in foreign countries, the main rationale behind a U.S. securities-reserve requirement was to avoid that banks sold government securities to obtain additional liquidity and increase their loans to the rest of the economy:

> "This special requirement would make it possible for the Federal Reserve System to immobilize a portion of these assets. This immobilization, however, would be only for the purpose of preventing their use for the purpose of obtaining additional reserves ." (Federal Reserve Bulletin, January 1948, p. 10)

In the U.S debate, it was also clear that securities-reserve requirements could complement more traditional tools of the central bank (as opposed to the widespread credit controls measures introduced after the war, especially in Europe; see Monnet (2018)), such as the discount rate and open market operations:

> "From the monetary point of view the principal purpose of the proposed new requirement is to make possible the more effective use of the existing instruments in offsetting changes in bank reserves – particularly open market operations and discount rates – without seriously upsetting the Government securities market and unduly raising the interest cost on the public debt."(Federal Reserve Bulletin, January 1948, p. 18).

Securities-reserve requirements were deemed necessary because of the large holdings of government securities in banks' balance sheet (about 60 percent) during and after the war (Burkhead (1947)). Its proponents saw this as a key measure aiming at "reconciling monetary management and debt management policies" (Miller (1950)). Indeed, tightening liquidity ratios was a way to pursue a restrictive monetary policy stance without affecting the price of government debt:

[12] As in other countries, these proposals aimed to define a set of liquid assets (Treasury securities, certificates, or notes, balances with Federal Reserve Banks, cash, etc.) and impose a requirement of such liquid assets calculated as a percentage of the deposits of banks.

> "the view has been expressed that it would be both feasible and desirable to insulate government securities, in whole or in part, from the impact of restrictive monetary policies on the private credit market. One proposal commonly mentioned in this connection is to require government securities as part of the reserve to be held by commercial banks against their deposits, supplementary to the prevailing cash-reserve requirements." (Ascheim (1958))[13]

In many ways, today's situation (post 2007-2008 crisis) is reminiscent of the post WWII period, especially in the Euro Area, because of the large volume of government securities in banks' balance sheet and the commitment of central banks to purchase government bonds and keep their interest rates at low level. Furthermore, government bonds are treated generously in Basel III banking regulation framework. For instance, the Basel committee includes in the most liquid category of assets: "sovereign or central bank debt securities issued in domestic currencies by the sovereign or central bank in the country in which the liquidity risk is being taken or in the bank's home country" BCBS (2013). It implies that sovereign debt issued by a government in default could be counted as liquid assets (ESRB (2015)).[14]

2.3 Why these tools were abandoned

This section explores why liquidity ratios were phased-out. We highlight two main reasons: (i) the distributive effects of these tools on government financing were no longer accepted (ii) their complexity and the difficulties to assess their specific effects within a large set of quantitative instruments.

Reserve requirements – both cash and securities – performed several roles, beyond their function as monetary policy tools (Goode and Thorn (1959), Jonung (1993) and Monnet (2018)). As explained

[13] See also, for example: " Thus, soon after World War II, and again during the post-Korea inflation, a number of European countries turned to them [securities-reserve requirements] in an effort to halt the excessive expansion of bank credit; in certain cases, the ratios also resulted in channelling bank funds into the financing of budget deficits." (Fousek (1957), p. 57)

[14] The idea to tweak liquidity regulation to ensure a stable demand for some government asset can also be found in the current discussion around the creation of a European safe asset.

above, they were often born as banking regulation tools, and later were used to combat inflation and secure government financing. In most countries, however, they kept their banking stability function – although it was not their main objective anymore– since they acted on the riskiness of assets, or because a fixed ratio was kept in addition to the flexible liquidity requirements used for monetary policy. Their effect on the composition of assets was also used to allocate funds to the priority sectors or to act as capital controls (distinguishing between domestic and foreign assets). Depending on the objectives of the central bank and on the characteristics of the banking sector, all these functions could be combined in one instrument. For example, in France, securities-reserve requirements had well known distributive effects (beyond securing government financing) because reservable assets included long-term credit to priority sectors (Monnet (2018)). The Swedish case shows very clearly how liquidity ratios originally designed as banking regulation tools were later integrated into the set of monetary policy instruments aiming to fight inflation. It also provides an example of liquidity ratios that differed according to the size of the banks, since larger banks were more likely to hold government securities (Jonung (1993)). While some viewed the effect on public debt management and priority sectors as a positive by-product, others complained about such adverse distributive effects, and criticisms about "financial repression" became widespread from the 1970s onwards (Reinhart and Sbrancia (2015)).

Reserve requirements had to be binding to become effective monetary policy tools. It meant that they had to adapt to the characteristics of the banking system and to other policy instruments. Moreover, it was popular at the time to make monetary policy redistributive ("selective"), that is to offer advantageous credit conditions to some institutions or sectors. In practice, it meant that the securities of some important subsidized sectors, such as housing, could be legally defined as liquid assets. These two constraints (effectiveness and selectivity) made the use of liquidity requirements extremely complex and very diverse across countries. All contemporary economists noticed such a complexity and variety of tools (e.g., De Kock (1974), p. 223), and it has been restated in current studies of monetary policy and credit controls during the postwar era (Romer and Romer (1993), Elliott et al. (2013), Monnet (2018), Kelber et al. (2014), and Aikman et al. (2016)). Another important consequence of such features, especially discussed in Monnet (2014), is that it makes it impossible to measure the stance of monetary policy by simply looking at the value of the different ratios in place. The nominal value of the ratio (whether reserve requirement, discount ceilings or credit ceilings) is not informative in itself about the stance of monetary policy for two reasons. First, the ratios evolved over time in order to remain binding, so that their value had to adapt to the composition of banks' balance sheets, which may evolve over time for structural reasons. Second, the strength of these ratios depended on how they were combined together and with other tools (such as the discount rate or ceiling on credit growth). As explained in a 1975 studies about monetary policy from the Organisation for Economic Cooperation and Development (OECD):

> "the use of policy instruments is evolving constantly in the light of the experience gained, and there is always the danger of misinterpreting a temporary relaxation of policy as a more basic modification in the use of the instruments" (OECD (1975), p. 25).

A similar argument is expressed by Capie (2010), p. 274, in his masterful study of the Bank of England, about special deposits in the 1960s (i.e. cash-reserve requirements):

As a consequence, Romer and Romer (1993), Monnet (2014) and Aikman et al. (2016) provide a general assessment of the impact of monetary policy and credit controls during those years – for the U.S., France, and England respectively – based on a narrative approach or, when possible, a common component of instruments, but they cannot isolate the separate effect of each quantitative instruments on the macro-economy.[15]

For decades, central banks favored such tools that had a distributive impact, in order to direct credit to priority sectors and the government. This changed in the 1970s, and more so in the 1980s and 1990s, when central banks became independent and turned to market-oriented tools for monetary policy implementation, in particular open market operations (Borio (1997), Jonung (1993) and Monnet (2018)).

[15] Elliott et al. (2013), look at the effect of separate instruments (especially cash-reserve requirements) on credit, but for the reasons mentioned above, cannot find any robust effect.

The complexity and inherent difficulties associated with estimating the macroeconomic effect of liquidity requirements (contrary to the effect of interest rate changes) is probably one reason why we know so little about their effectiveness, and it added to the arguments for phasing them out.[16] Hence, we need better theory to identify the potential channels through which they could have monetary effects and be combined with other instruments.

3 A Model of Liquidity Ratios as Monetary Policy Tools

This section uses a simple theoretical model to clarify the precise mechanisms through which liquidity requirements affected interest rates on the money market.

As explained previously, liquidity requirements could take the form of cash-only reserve requirements or securities-reserve requirements. The channels through which these various ratios operated differed. Our model will show that binding liquidity ratios increase money market rates, which forces the central bank to choose between expanding its balance sheet to counteract this effect, or to accept to run a contractionary policy stance. This is what we call the liquidity regulation dilemma.

3.1 Securities-Reserve Requirements and the Money Market Rate

In this section, we discuss how securities-reserve requirements impact short-term money market rates. Our model is in the tradition of Poole (1968).[17] A key assumption of those models is that banks experience a “late” deposit shock. This assumption captures the fact that banks need to process payments at any time when they are open, and they might not know in advance about incoming or outgoing payments. These payment shocks may occur late in the day after the interbank market has closed. Another important assumption that we introduce is that securities can be pledged to borrow from the central bank, or be used to fulfill securities-reserve

[16] As shown in Monnet (2014) the effect of quantitative controls on money and credit could be disconnected from the effect of interest rates. In such context, interest rates cannot be used as a reliable proxy for the monetary policy stance.

[17] More recent papers in this tradition of modeling include Huberto M. Ennis and Todd Keister (2008), Bech and Keister (2017) or Vari (2020)

requirements like the LCR. But one unit of securities cannot be used for these two purposes at the same time. This reflect both historical experience and modalities of today's liquidity ratios, where liquid assets need to be "unencumbered". This dual role implies that an increase in securities-reserve requirements reduces the stock of collateral that banks can use to borrow at the central bank. To our knowledge we are the first ones to introduce liquidity regulation and collateral constraints in a model of the money market. By contrast Bech and Keister (2017) have modelled liquidity regulation in a context where there is no collateral constraint.

3.1.1 The Timing of the Model

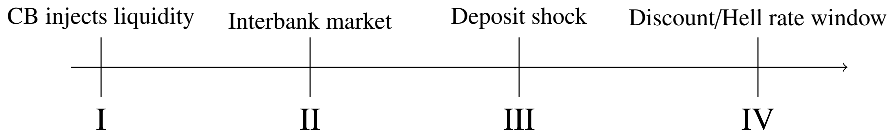
The model looks at banks' decisions during a typical trading day. The timeline of the model is the following: first, the central bank can inject liquidity.[18] Second, the market for interbank loans occurs. Third, once the interbank market is closed, banks experience a "late" deposit shock. Fourth, banks can go to the central bank to borrow overnight if they need to. They may either borrow at the discount window, up to a limit, which is dictated by the amount of collateral they have. When the limit is reached, banks can still borrow at the central bank, but at a penalty rate that is higher than the normal discount rate. Such penalty rates were common in most countries that relied on liquidity requirements (Garvy (1968)). Today, penalty rates are still a feature of central banks' discount window like at the US Federal Reserve System.[19] We call this penalty rate the "hell rate," as it was named by the Bank of France in the 1950s (Monnet (2014)). Finally, consistent with post-war central banking practices, we assume that required or excess balances of banks are not remunerated.[20]

[18]This assumption captures the fact the amount of central bank liquidity is known to banks at the beginning of the day. This assumption can easily be changed, and the central bank could inject liquidity at any time during the day as long as banks know when they trade and how much the central injected on the previous day.

[19]The Fed discount window offer several accesses for banks: primary and secondary credit. Secondary credit is available to depository institutions that are not eligible for primary credit. It is available at a rate 50 basis points above the primary credit rate.

[20]This assumption can easily be relaxed, but allow to simplify notations.

Diagram 1. Timing of the Model



3.1.2 The End of the Day: the Reserve Requirements Constraints

At the end of the day, banks need to satisfy their cash-reserve requirements. Cash-reserve requirements impose that the end-of-day balance of bank "i" is greater than some number K^i.[21] Thus, the constraint takes the following form:

$$R^i + B^i - \epsilon^i + X^i + H^i \geq K^i \tag{1}$$

Where R^i is the amount of central bank liquidity that bank "i" holds at the central bank before the interbank market starts (period I). B^i is the amount of interbank borrowings of bank i. ϵ^i is a random deposit shock with mean 0, to which bank "i" is subject to after the interbank market has closed (period III). X^i is the amount borrowed by bank "i" at the discount window. H^i is the amount of borrowings at the "hell rate" (i.e. a penalty rate). Borrowing at the hell rate and at the discount window both take place in period IV.

Banks need collateral in order to borrow at the discount window rate. If they do not have enough collateral they can only borrow at the "hell rate."[22]

Let C^i be the amount of collateral that bank i can pledge to borrow at the normal discount rate.

Banks have to fulfill a securities-reserve requirement T^i, such that the amount of securities held by bank "i" (denoted S^i), must be greater than T^i ($S^i > T^i$). The securities-reserve requirement has a

[21] Many central banks require banks to fulfill their reserve requirements obligations over a so-called "maintenance period" (Gray (2011)). As pointed by Bech and Keister (2017) this averaging provision complicates considerably the analysis (Bindseil (2004)) but does not change the results qualitatively. The reason is that these models can be thought as the last day of the maintenance period (when the averaging provision does not play a role). Interest rates on previous days should be aligned with the last day, by arbitrage.

[22] Our model is more general than a situation with a "hell rate." Our results would hold in a situation where banks, once they run out of collateral cannot borrow at any rate from the central bank triggering a reserve deficiency, that the central bank punishes by a fine. If the fine for each unit of currency of deficiency is equal to "r''_H, results in the two models are in fact identical.

direct impact on the capacity of banks to borrow from the central bank. The amount of collateral they can pledge is:

$$C^i = S^i - T^i \tag{2}$$

3.1.3 Period IV: Discount Window Borrowing

One can solve the bank's problem backward, starting with the demand for discount window loans and "hell rate" loans.

Using equation (1) implies that the demand for central bank facilities is as follows:

$$X = max\{0; min\{C^i; K^i - (R^i + B^i - \epsilon^i)\}\} \tag{3}$$

and

$$H = max\{0; K^i - (R^i + B^i - \epsilon^i) - C^i\} \tag{4}$$

That is, banks will borrow from the central bank discount window every unit of money needed to cover a cash-reserve requirement shortfall $K^i - (R^i + B^i - \epsilon^i)$, up to its stock of eligible collateral (C^i). If the shortfall is below zero, the bank does not borrow anything. Any shortfall in excess of the amount of collateral ($(R^i + B^i - \epsilon^i) - C^i$) needs to be borrowed from the hell window.

Given (3) and (4), the profit of bank "i" writes:

$$\Pi^i = Lr_L + r_s S^i - r_D(D^i - \epsilon^i) - r_B B^i - r_H H^i - r_X X^i \tag{5}$$

where r_L, r_s, r_D, r_B, r_X, r_H are respectively the interest rates on loans (L^i), government securities (S^i), bank deposits (D^i), interbank borrowings (B^i), discount window borrowings and finally the hell window borrowings (H^i). The first four rates are market rates. The two lasts are set by the central bank.

3.1.4 Period III: Profits for a given distribution of payment shocks

Profits of banks will vary as a function of the payment shock. The payment shock ϵ^i has mean 0, and its density function is denoted g(.). Its cumulative distribution function (cdf) is denoted G(.). Typically, G(.) can be thought as the cdf of the normal distribution or the uniform distribution. We assume that this function is identical for all banks.

Combining (3), (4), and (5), the expected profit function writes:

$$E(\Pi^i) = Lr_L + r_s S^i - r_D(D^i) - r_B B^i - r_H\Big(\int_{R^i-K^i+B^i+C^i}^{\infty} g(\epsilon^i)(\epsilon^i - (R^i - K^i + B^i + C^i))d\epsilon^i\Big)$$
$$- r_X\Big(\int_{R^i-K^i+B^i}^{R^i-K^i+B^i+C^i} g(\epsilon^i)(\epsilon^i - (R^i - K^i + B^i) + \int_{R^i-K^i+B^i+C^i}^{\infty} g(\epsilon^i)C^i d\epsilon^i\Big) \quad (6)$$

The term associated with r_H represents the expected value of H^i. It is positive only when the deposit shock is larger than the threshold $(R^i - K^i + B^i + C^i)$, meaning the shock has exhausted all the liquidity of the bank and its collateral. The term associated with r_X is the expected value of X^i and is non-zero, whenever the shock is moderately large, (i.e. whenever the shock is between $R^i - K^i + B^i$ and $R^i - K^i + B^i$).

3.1.5 Period II: Profit Maximization with respect to the amount of interbank loans

Profit maximization with respect to the amount of interbank loans (B^i) implies:

$$r_B = (1 - G(R^i + B^i - K^i + C^i))r_H + (G(R^i + B^i - K^i + C^i) - G(R^i + B^i - K^i))r_X \quad (7)$$

Banks will equate the marginal gain from lending one more unit of liquidity on the interbank market (interest rate r_B) with the marginal expected cost of having one less unit of liquidity. This cost is the interest paid on one more unit of liquidity in the state of the world where the deposit shock is so large that the bank's collateral is exhausted $(1 - G(R^i + B^i - K^i + C^i))$, times the hell rate, plus the probability that the shock is large, but not large enough to exhaust the bank's collateral

$G(R^i + B^i - K^i)$ times the discount window rate r_X

3.1.6 Period I: The central bank's injections

The central bank chooses R, the total amount of central bank reserves outstanding. We analyse in section 3.2 how exactly this is done. Note that the liquidity borrowed from the discount window or the hell window can only be used to cover end-of-day shortfalls. It is very different from R, in the sense that liquidity borrowed at the end of the day has to be paid back to the central bank before the following morning.

3.1.7 Equilibrium

At equilibrium, it must be the case that interbank loans are in zero net supply across the mass one of banks:

$$\int_0^1 B^i di = 0 \tag{8}$$

Variables, when aggregated across all banks are denoted without their index i. For instance, aggregate central bank reserves are denoted in the following way:

$$\int_0^1 R^i di = R \tag{9}$$

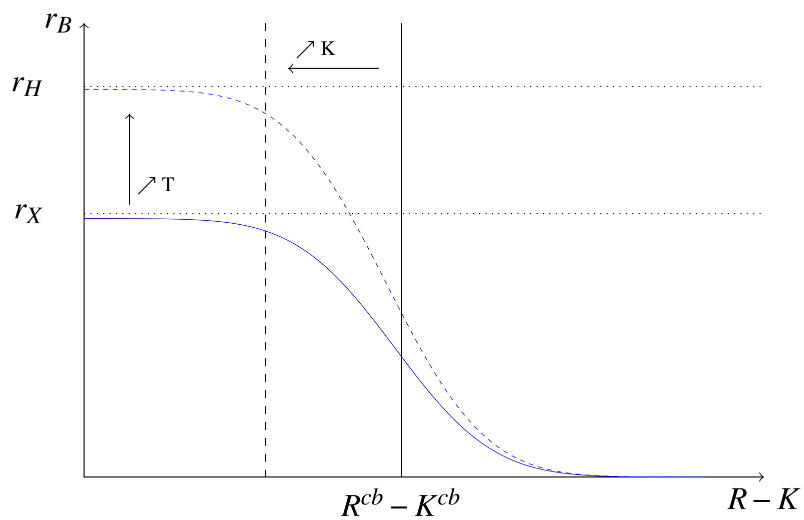
To find the equilibrium, we use (7) and sum the equation across the mass 1 of banks. Assuming that G(.) is linear (e.g. a uniform distribution function) and making use of (8) we find the following:[23]

$$r_B^\star = (1 - G(R - K))r_X + (1 - G(R - K + S - T))(r_H - r_X) \tag{10}$$

The equilibrium interbank rate depends on two components. The first term represents the traditional component that is present in most models of the money market: the interbank rate is

[23]Note that this result hold even if G(.) is not linear, if all banks are symmetric.

Figure 1: Changing money market rates through increases of reserve requirements



equal to the probability that the banking system becomes short of central bank liquidity $(1 - G(R - K))$ times the discount window rate. The second term represents our new collateral channel. It is the additional cost for banks to borrow "$r_H - r_X$" should they be short of collateral. Via this second term, the central bank can run a policy equivalent to quantity rationing, by indirectly restricting bank's access to the discount window.

3.2 Policy discussion

3.2.1 Liquidity ratios as quantity rationing

Equation (10) shows that cash-reserve requirements and securities-reserve requirements have similar effects on interest rates ($\frac{\partial r_B^\star}{\partial K}$ and $\frac{\partial r_B^\star}{\partial T}$ are both greater than 0), but they act through different channels.

These two channels can be represented graphically. Figure 1 plots (10) for different parameter values. The vertical bar represents the level at which the central bank sets the amount of excess reserves "R-K". One can see that when the amount of cash-reserve requirements K is increased, interest rates increase along the demand curve. When the amount of securities-reserve requirements (T) increases, the demand curve goes up, increasing interest rate for a given amount of excess reserves.

On the one hand, cash-reserve requirements increase directly the demand of banks for central bank liquidity. Banks need this liquidity to comply with the requirement, and excess liquidity on the money market is then reduced. It means that banks have a higher probability to borrow at one of the central bank penalty rates. This effect is a well-known feature of Poole-type models. Our model shows an additional effect of (securities) reserve requirements. In our model securities-reserve requirements restrict *de facto* the access of banks to the central bank discount window - through a decrease of available collateral ($C = S - T$) - and forces them to borrow at the hell rate.[24] In this sense, securities-reserve requirements have the same effects as so-called rediscount ceilings, whereby the central bank limits *de jure* the access of banks to the discount window (see Monnet (2014)). Securities-reserve requirements are equivalent to quantity rationing at the discount window.[25] In a discount ceiling system, the central bank controls C, the maximum amount of collateral that a bank can pledge from the discount window. In a world where the central bank provides unlimited access to its discount window (that is $r_H = r_X$), securities-reserve requirements have no effect. On the contrary, cash-reserve requirements still have an effect in this case (as in the standard models described previously).

3.2.2 How to counteract the effect of liquidity ratios?

The effect of (cash and securities) reserves requirements on interest rates can always be counteracted by increasing the amount of central bank reserves R. An increase in R can be achieved through various ways that expand the central bank balance sheet (quantitative easing, open discount window policy etc.). Whatever the tools used to expand R, our main conclusion is that an increase in (cash and securities) liquidity requirements pushes the central bank either to

[24] It is important to note that we have taken the amount of securities that banks hold as exogenous. We show in appendix A that if banks can endogenously choose their securities holdings, when the central bank increases T, they do increase their securities holdings but less than one for one. In other words, the central bank can decrease the amount of banks' collateral by increasing T.

[25] Interestingly, the Bundesbank never used securities-reserve requirements but relied on rediscount quotas. In France, securities-reserves requirements were used actively after 1960, once rediscount quotas were deemed less effective than in the 1950s because banks were less indebted towards the central bank.

accept a restrictive monetary policy stance, or to increase its balance sheet to nullify the restrictive effects of liquidity requirements. This second policy option is contradictory with the statements of central banks that recently adopted liquidity requirements in order to reduce banks' dependence on central bank liquidity. It is this tension that creates what we call the liquidity regulation dilemma. The opposite effects of reserve requirements and central bank liquidity was already visible during the post-war period that we studied in Section 1. The difference with contemporary policies is that past central banks did not intend to make a separation between monetary policy and liquidity requirements. Rather, they saw these two concepts as inseparable and were using the latter as instruments to implement the former.

3.2.3 Automatic stabilizers

Are the contractionary effects of liquidity requirements only at work when these requirements are tightened? Or does the mere existence of these requirements have an effect on interbank interest rates? Our partial equilibrium model provides an answer to this question. It might however be used with caution, keeping in mind that additional general equilibrium mechanisms be at work.

To answer this question, it is worth noting that if cash and securities-reserve requirements are set as a fraction of deposits, denoted respectively k and t (that is: $T = t.D$ and $K = k.D$). Equation (10) then becomes:

$$r_B^{\star} = (1 - G(R - kD))r_X + (1 - G(R - kD + S - tD))(r_H - r_X) \tag{11}$$

With :

$$\frac{\partial k r_B^{\star}}{\partial D} = k r_X g(R - K) + (k + t)(r_H - r_X)g(R - K + C) > 0 \tag{12}$$

If the central bank does not change the value of k, t, or R, liquidity requirements become akin to automatic stabilizers. When economic activity expands, loans (and therefore deposits) expand as well. For a given coefficient of reserve requirements, the total amount of required reserves increases. This leads to an increase in the interbank interest rate. This tightening of monetary conditions should in turn dampen economic activity. As discussed in Section 1, this is the main reason why, in the 1930s, a fixed ratio of securities (in Sweden and Switzerland) or cash (in the United States) reserve requirement was recognized as having a monetary policy effect, and central banks then decided to use adjustable reserve requirements as a policy tool. Put differently, as long as aggregate deposits fluctuate, a fixed reserve requirement has an effect on money market rates.[26]. This conclusion is in fact already well-known and documented for cash-reserve requirements, as it is akin to the money multiplier model that prevails in undergraduate macroeconomic textbook whereby the credit-creation capacity of banks is limited by bank deposits with the central banks. In our model however, the adjustment works through interest rates and - most of all - is also true for securities-reserve requirements. Note that the money multiplier model (whereby the adjustment works through quantities) usually called upon to describe the effect of cash-reserve requirements has been most likely inoperative in industrialized countries in recent years.[27]

3.2.4 Banks' holding of government securities

As explained in our historical narrative, securities-reserve requirements have an additional advantage over cash-reserve requirements in avoiding that banks sell their government bonds to the central bank to obtain the liquidity required to fulfill cash-reserve requirements. We show formally in appendix A that securities-reserve requirements increase banks' holding of government securities. Past central banks usually supported government bonds by buying (or discounting) them from banks at a pre-determined price, any bank selling its bonds created

[26]Central bankers recognized that an expansion of credit would be associated with an increase of required reserves at the central bank: "However, changes in the country's official gold and foreign exchange reserves need not necessarily lead to offsetting changes in the reserve requirements. The bank has stated that there would, for instance, be no ground for a reduction in the requirements if a fall in the gold and foreign exchange reserves were linked with credit expansion" (Fousek (1957), p. 54)

[27]There are indeed at least two conditions for the money multiplier mechanism to be operative. First, it must be the case that the level of central bank liquidity is fixed. However, since the shift to inflation targeting, central banks have accommodated movements in the required reserves to ensure that interest rates remain at some chosen level. In other words, when deposits were increasing and the amount of required reserves expanding, central banks were providing more liquidity, preventing the money multiplier to be exert any restraint. Second, for a low level of reserve requirements or when reserve requirements can be avoided by banks using other types of liabilities, there might be other constraints preventing the expansion of loans, such as the amount of loan demand or other regulatory constrains such as capital requirements (Martin et al. (2016)).

additional central bank liquidity.[28] Cash- reserve requirements could also be used to sterilize the interventions of central banks on the foreign exchange market or interventions on the domestic government bond market. Overall, many of the channels we have discussed using our partial equilibrium model are relevant for today's monetary policy. Like securities-reserve requirements, today's Basel III regulation reduces the stock of collateral that banks can use to borrow from the central bank (BCBS (2013)). Similarly, today's government might find it convenient that regulation increases demand for their debt.

[28]This mechanism is different from the one when reserve requirements are used to prevent banks to sell their securities to the non-banks.

4 Conclusion

This paper has explained how and why liquidity ratios were used in the past as monetary policy tools. It was the case not only for cash-reserve requirements but also for securities-reserve requirements. Whereas the history of the former was already well known (especially in the United States) the history of the latter (and the interactions between both types of instruments) had received no attention in the recent literature.

Central banks used securities-reserve requirements as a monetary policy tool to avoid that banks borrow during phases of restrictive monetary policy. When the liquidity ratio was binding, banks had no longer available collateral to borrow at the central bank discount window. As our model has shown, this was a quantity rationing effect, akin to imposing borrowing limits. An alternative option for the central bank would have been to sell government securities (the typical liquid asset) or to refuse to purchase them from banks. But this would have increased the interest rates on government debt. Hence, as recognized by contemporaries, the use of liquidity ratios was a way to run contractionary monetary policy while maintaining low interest rates on government debt.

The use of liquidity ratios as monetary policy tools shows that modern central banks may not be able to escape the dilemma of liquidity regulation, and will have to choose between expanding their balance sheet (which involves taking some degree of risks) or accept a tightening of monetary policy.

A Endogenous portfolio choice between loans and securities

To endogenize the portfolio choice of banks, it is necessary to add an additional period to the model, where banks can chose how much securities and loans they wish to hold. Let's call it period 0.

Banks maximize their profits with respect to the amount of securities they hold. They take as given quantity of deposits (D^i) and use any additional deposit to invest either in loans (L^i) or in securities (S^i), such that:

$$D^i = S^i + L^i \tag{13}$$

In other words, we assume that banks decide on their loan supply according to the amount of deposits they receive, and allocate their deposits between different types of assets. We assume that banks use overnight loans only to cover short-term liquidity needs, and decide on their portfolio allocation between loans an securities on a longer term basis. Thus banks do not use overnight loans to make up for the differentials between their deposits and their long-term assets such as loans and securities. Such assumption can be rationalized either by prudent risk management constraints or by regulation such as the Net Stable Funding Ratio (NSFR).

Replacing L^i by $D^i - S^i$ in the profit function, and maximizing it with respect to collateral holdings (C^i) yields a second FOC:

$$r_L - r_S = (r_H - r_X)(1 - G(R^i - K^i + B^i + S^i - T^i)) \tag{14}$$

Banks will equate the expected benefit of granting an additional loan over holding securities ($r_L - r_S$) and the expected potential cost of having less collateral to pledge. This expected cost is the probability that the shock is larger that the bank's liquidity and its collateral holdings ($1 - G(R^i - K^i + B^i + C^i)$), times the penalty for being short of collateral $r_H - r_X$.

Using (14) and aggregating across a mass one of symmetric banks yield:

$$r_L^\star = r_S + (r_H - r_X)(1 - G(R - K + S - T)) \tag{15}$$

The equilibrium loan market rate is equal to the interest rate on securities plus a spread that is decreasing in the securities holdings of the banking system (S) and increasing in securities-reserve requirements (T).

Assuming that yields on securities are the same as the interbank market rate: $r_S = r_B$, yields:[29]

$$r_L^\star = 2(r_H - r_X)(1 - G(R - K + S - T)) + r_X(1 - G(R - K) \tag{16}$$

To find the equilibrium amount of securities and Loans, it is necessary to assume a linear loan demand function:

$$L = L^{max} - Ar_L \tag{17}$$

Where, L^{max} is a shifter that represents the quantity of loans demanded when interest rate are at zero, and parameter A represent the sensitivity of loan demand to interest rates.

Combining the two previous equations yields:

$$L = L^{max} - A(2(r_H - r_X)(1 - G(R - K + C)) + r_X(1 - G(R - K)) \tag{18}$$

To obtain a closed-form solution, we assume that $G(.)$ is a uniform distribution over $[P; -P]$, where P is the maximum value of the shock.

This implies:

$$L^\star = \frac{PL^{max} + A[(r_H - r_X)(D - T) + (R - K - P)(r_H - \frac{r_X}{2})]}{P + A(r_H - r_X)} \tag{19}$$

Using equation (13), one can find the amount of securities banks hold:

[29]This assumption could be explicitly derived in equilibrium if we were to model explicitly the portfolios choices of non-banks. They would then arbitrage between the return on securities and deposits. The rate offered by banks on deposits under perfect competition is equal to the interbank market rate. Thus $r_B = r_D = r_S$.

$$S^{\star} = \frac{P(D - L^{max}) + A[(r_H - r_X)T + (K - R + P)(r_H - \frac{r_X}{2})]}{P + A(r_H - r_X)} \tag{20}$$

The collateral banks own is then:

$$C^{\star} = \frac{P(D - L^{max} - T) + A(K - R + P)(r_H - \frac{r_X}{2})}{P + A(r_H - r_X)} \tag{21}$$

As can be seen in equations (20) and (21), when the central bank increases T, banks increase their securities holdings (S), but less than one-for-one. Thus, the amount of collateral that can be pledged at the discount window (C) decreases.

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