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Stabilising virtues of central banks: (re)matching bank liquidity

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Stabilising virtues of central banks:
(re)matching bank liquidity

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Stabilising virtues of central banks: (re)matching bank liquidity[1]

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January 2017

Abstract

Central banks have been blamed for the negative side effects of the non-conventional monetary policy measures they have implemented since 2008. In this paper, we argue that central banks played a positive role in the money market and interbank liquidity recovery. Using novel, micro data of the French banking system on the pool of collateral eligible to ECB open market operations, we construct a "liquidity mismatch indicator (LMI)" for the aggregate banking sector that highlights the central bank influence on the bank liquidity condition. Our results show that central bank liquidity and haircut policies have indeed helped banks to reduce the mismatch of liquidity between their assets and their liabilities that had widened after the 2011 stress episode. Moreover, our bank liquidity measure can be useful as an early warning indicator for the macro-prudential purposes. It gives the "cash equivalent value" of the French banking sector and indicates the amount of the liquidity support that the ECB might have to provide in case of financial crisis. The LMI can also help identify the systematically important French institution in terms of their liquidity exposures.

Keywords: Bank liquidity, liquidity crises, unconventional monetary policy, macroprudential regulation.

JEL: E58, G21, G28.

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1. Introduction

With the advent of non-conventional monetary policy measures (NCMP), central banks have been blamed for the side effects of their policies. The bounded effectiveness of NCMP has also been underlined, as central banks managed to achieve only a limited shift in the portfolio structure of banks, while failing to restart bank credit to an extent that is commensurate with the boldness of monetary policy measures taken together.

But central banks that turned to NCMP have contributed to important improvement in money market and interbank liquidity conditions. In this paper, we look beyond the much researched impact of monetary policy on *market-wide* liquidity and concentrate on liquidity *within* banks' balance sheets. Using novel, micro data of the French banking system on the pool of eligible collateral in the ECB open market operations, we dissect the impact of NCMP on banks' liquidity and ask whether the ECB has indeed helped banks to manage the mismatch of liquidity between their assets and their liabilities. To do so we expand on Brunnermeier, Gorton and Krishnamurthy (2011) and construct a liquidity mismatch indicator (LMI) for the French banks. The novelty of our approach consists in taking into consideration the central bank's influence on the LMI and in particular the effects of the ECB collateral eligibility and its haircut policy.

Liquidity plays a central role in systemic crises and the LMI can be informative about systemic risks. We calculate the index for individual French banks in our sample and then aggregate it for the whole banking system. When the aggregate LMI is low, the banking sector is more susceptible to a liquidity stress. It gives the "cash equivalent value" of the French banking sector and indicates the amount of the liquidity support that the ECB might have to provide in case of financial crisis. Hence our measure can be useful as an early warning indicator for the macro-prudential purposes. The LMI can also help identify the systematically important French institution in terms of their liquidity exposures. Such a criterion constitutes an alternative with respect to the classification based on bank asset size. The LMI measure incorporates the ideas from the academic literature on liquidity. First, it jointly accounts for asset and liability liquidity. Second, asset and liability liquidity is evaluated conditional on given market conditions so the LMI explicitly accounts for liquidity risk. Therefore, the LMI provides a useful framework to implement liquidity stress tests.

Relative to existing tools, the LMI has a dual advantage as a real-time monitoring tool of funding conditions. It combines quantity-based measures (balance sheet items) and price-based measures (haircuts; spreads), while existing indicators are based either on prices or on quantities, but rarely both. In addition, it can be computed at a weekly frequency, allowing for a fairly high frequency monitoring relative to pure balance sheet based approaches. Therefore, the LMI could constitute a useful addition to the toolbox of market analysts, risk managers and central banks, in their assessment of banking system liquidity risk.

Our analysis of the LMI evolution indicates that despite a rapid worsening in systemic vulnerability following the stress episodes in 2011, the LMI never falls in negative territory, which demonstrates the resilience of the sector, in aggregate, to deteriorating funding conditions both on the asset and liability side. However, the resilience of the system taken as a whole hides heterogeneity across counterparties as some banks exhibit a lower LMI throughout the period with one bank falling into negative territory. The analysis also suggests that the ECB has alleviated banks' liquidity mismatch by a fair bit between 2011 and 2015. The recovery of the LMI between July 2011 and the beginning of

February 2012 coincides with important ECB unconventional monetary measures and indicates that the ECB measures played an important role in the bank liquidity mismatch decrease. Finally, the aggregated LMI of all banks in absolute terms stands at a higher level at the end of the period than before the 2011 liquidity shock. Most importantly, the aggregated LMI increases notably towards the end of the period, starting in end 2014, and manages to exceed its initial level. This could reflect the impact of the planned implementation of the liquidity regulation, and in particular the Liquidity Coverage Ratio, which observation period was scheduled to start in 2015.

2. Liquidity within the balance sheet of a bank: why does it matter?

Liquidity transformation is one of the main functions of financial intermediation. Banks provide liquidity by financing long-term projects or purchasing less liquid assets with liquid and often shorter-term liabilities. Liquidity transformation is essential for the financing of economic activity but at the same time it contributes to the fragility of financial system. Large amounts of illiquid assets along with short-term debt expose banks to liquidity risk and threaten their ability to meet their cash and collateral obligations. The liquidity risk is linked to both sides of bank balance sheets: the *market liquidity* of their assets and the *funding liquidity* of their liabilities. Market liquidity of assets refers to the ease to sell an asset without causing drastic changes in its price, while funding liquidity reflects the ability to settle obligations with immediacy.

The synergy between funding structure and asset choice is at the heart of modern commercial banking (Hanson et al. 2015). It is also essential for measuring the liquidity position of a bank. The banking literature suggests that liquidity mismatch emerges when market liquidity of banks' assets is smaller than funding liquidity of their liabilities (see for instance Brunnermeier, Gorton and Krishnamurthy, 2011).

Bank liquidity, and liquidity mismatch in particular, has been a central symptom of disruption preceding several financial crises. An important divergence between market liquidity of assets and funding liquidity of liabilities generates indeed a high liquidity risk for banks. They could mitigate this risk to some extent by holding liquid assets such as cash or short-term Treasury bonds and by issuing long-term debt claims. Yet, there exists several incentives for banks to build and maintain a significant asset-liabilities mismatch. Bhattacharya and Gale (1987) show that it is profitable for banks to invest only in illiquid assets and rely on other banks to obtain liquidity if a shock hits the system. In equilibrium, all banks invest excessively in illiquid assets, so that they are all affected when a liquidity shock occurs. Moreover, Brunnermeier and Oehmke (2013) argue that banks can dilute the claims of existing creditors by issuing new debt at shorter maturity. Creditors anticipate this behavior and opt for shorter maturity contracts as well. The outcome is a "maturity rat race" that leads all banks to rely excessively on short-term debt.

In turn, liquidity risk becomes of systemic importance when financial institutions are exposed to it in a correlated manner. Allen, Carletti, and Gale (2009) present a model where banks can stop trading due to aggregate liquidity risk and more specifically due to the fact that financial institutions hold similar rather than offsetting positions. One reason that explains the correlation of the financial system exposition to liquidity risk is the changing behavior of banks throughout the business cycle. Acharya et al. (2011) argue that the liquidity in banks' asset holdings is counter-cyclical: it is inefficiently low during the upturns and excessively high during downturns. Indeed, during economic

booms, all financial institutions tend to increase their holdings of illiquid assets and to issue short-term debt. A small shock can then generate the systemic crisis as banks' assets can only be sold at high discount and their funding cannot be rolled-over ("volatility paradox" in Brunnermeier and Sannikov, 2014). During crises, the probability of potential adverse shocks increases and all market participants desire to maintain high funding liquidity and to hold claims with high market liquidity. As a result there is an abnormal accumulation of safe assets in uncertain times.

3. From liquidity correlation to shock propagation: advantages of macro-prudential measures

Common asset and liquidity risk exposures in turn contribute to the propagation of the counterparty shocks, especially in the presence of asymmetric information (Heider et al., 2010). Many financial institutions finance their assets with short-term funding such as commercial paper or repo borrowing. In the context of increased counterparty risk, lenders increase haircuts on repo financing, limit eligibility of collateral, or stop rolling over short-term funding. The need to satisfy funding and collateral constraints forces banks to liquidate their assets, which in turn leads to further declines in asset prices (Shleifer and Vishny, 2011). With declining asset values and increasing haircuts, the banking system can become insolvent (Gorton and Metrick, 2012). Moreover, the losses incurred on fire sales deteriorate even more funding liquidity of the institutions. Market and funding liquidity are thus mutually reinforcing and under certain conditions lead to liquidity spirals (Brunnermeier and Pedersen, 2009).

Given that liquidity exposure is one of the key variables that drive systemic crises, it is essential that supervisors monitor the liquidity position of individual banks and of the financial sector as a whole. If the liquidity risk is not mitigated *ex ante* by financial regulation and supervision, then the central banks and governments must act *ex post* as lenders of last resort.

Yet, the concept of liquidity and liquidity risk is difficult to measure. It is especially complex to evaluate its systemic component as liquidity and solvency concerns are very much connected and overlap over a grey area. To address this measurability issue, several liquidity metrics have been recently developed.[2] An obvious one is of a regulatory nature. Basel III acknowledges the importance of liquidity by imposing liquidity ratios known as the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR), see box 1.

[2] We focus here on the liquidity measures related to the overall bank liquidity. Market liquidity measures such as bid-ask spreads, return-to-volume ratio or the composite indices developed by the ECB (2007) and the BoE (2007) are not discussed in this paper.

Box 1: Regulatory liquidity ratios under Basel III

Liquidity ratios developed under the Basel III framework are known as the Liquidity Coverage Ratio (LCR)[3] and Net Stable Funding Ratio (NSFR)[4]. The objective of the LCR is to promote the short-term resilience of the liquidity risk profile of banks. It requires that banks hold sufficient amount of unencumbered High Quality Liquid Assets (that consists of cash or assets that can be converted into cash at little or no loss of value in private markets) to meet their liquidity needs for at least a thirty calendar-day stress scenario. European regulation 2013/575 requires that institutions report their LCR at 1 October 2015 and that it be at least 60% in 2015 and 100% in 2018.

The NSFR on the other hand aims at monitoring bank maturity mismatch risk over a time horizon that extends to one year. It is intended to limit overreliance on short-term wholesale funding and to promote longer-term resilience of a bank's liquidity risk profile. This ratio should be equal to at least 100% on an on-going basis. At the European level, European regulation 2013/575 introduces a reporting obligation for the NSFR without setting out more detailed requirements.

Such micro-prudential liquidity rules have shortcomings. While high ratios of NSFR and LCR diminish the chance of a systemic liquidity event for an individual institution, they do not prevent the build-up of a systemic liquidity risk. They can even make the whole financial system more risky when all banks have to meet a requirement at the same time (Claessens and Kodres, 2014). The Basel III liquidity ratios do not take into account the impact of a bank's failure on the financial system and are less likely to detect the events that affect multiple institutions simultaneously and might require central bank liquidity support. Thus, systemic rather than bank-centered approach is needed to prevent the initial shock, such as sudden dry-up of asset-backed commercial paper market, from turning into systemic crisis. Finally, current regulations are more aimed at addressing funding liquidity, but are less able to affect market liquidity, which can be an important trigger for collateral runs and fire sales mechanisms.

Current academic research on liquidity acknowledges these shortcomings. In recent years, macro-prudential liquidity indicators have been developed to measure systemic component of liquidity risk. They are based not only on the bank balance sheet items but also on the market data. Severo (2012)'s Systemic Liquidity Risk indicator assesses systemic liquidity stress level by measuring the breakdown of arbitrage conditions in international financial markets. Under normal conditions, price differentials for similar securities or portfolios tend to be relatively constant and small. However, significant differences in prices between instruments appear during the periods of financial stress and investors do not exploit them for relatively long periods. The magnitude of these non-exploited differences can be interpreted as indicators of stress in securities and funding markets. Jobst (2014)'s Systemic Risk-adjusted Liquidity model combines option pricing with market information and balance sheet data to generate a probabilistic measure of the frequency and severity of multiple institutions

[3] LCR = high-quality liquid assets/(cash outflows –cash inflows) at 30 days ≥ 100%. Assets are considered to be high-quality liquid if they can be easily and immediately converted into cash at little or no loss of value. There are three categories of high-quality liquid assets which under Basel III are subject to different haircuts: level 1 assets have no haircut, while level 2A and level 2B assets have a 15% and 50% haircut, respectively.

[4] NSFR = available amount of stable funding/required amount of stable funding ≥ 100%. "Available stable funding" is the portion of capital and liabilities expected to be reliable over a one-year horizon. "Required amount of stable funding" for a specific institution is a function of the liquidity characteristics and residual maturities of the various assets held by that institution as well as those of its off-balance sheet exposures.

experiencing a joint liquidity event, such as the one where banks jointly breach their NSFR ratio. Berger and Bouwman (2009)'s liquidity creation measure is the weighted sum of all asset-side, liability-side, and off-balance sheet activities. The authors attribute positive weights when the banks transform illiquid assets into liquid liabilities and negative weights when they transform liquid assets into illiquid liabilities.

The "Liquidity Mismatch Index (LMI)" recently proposed by Brunnermeier, Gorton and Krishnamurthy (2011) is particularly relevant for our paper. The LMI measures the mismatch between the market liquidity of assets and the funding liquidity of bank liabilities. To construct the indicator the authors use both balance sheet and market-based liquidity measures. On the one hand, they attribute to each asset class of bank balance sheet the liquidity weights that convert an asset into its cash-equivalent. On the other hand, each liability class is associated with time varying weights that represent its marginal contribution to the liquidity pressure of the bank. Their measure allows to compute how much cash the bank can raise against its balance sheet to withstand the cash withdrawals in case of a stress event. The authors propose to use LMI to identify the most systemically important financial institutions. They argue that banks with a very negative LMI will be forced to fire-sell assets and hence amplify the crisis. These institutions will also need the most the central bank liquidity. Unlike the Basel III micro-prudential measures, the LMI can also be meaningfully aggregated across the whole financial sector and provide an indicative amount of liquidity that the central bank might have to provide in case of a liquidity stress. Bai at al. (2016) implement this measure for the U.S. banking system. They argue that LMI is a useful tool for macro-prudential purposes as it measures liquidity imbalances in the financial system and can be used as an early indicator of financial crises. It also quantitatively describes the liquidity condition of the financial sector given that the negative LMI in 2007-2008 corresponds to the amount of the liquidity the Fed injected during the financial crisis.

Despite the advances that have been made by the policymakers and the academic literature, the ability of systemic risk measures to signal difficulties much ahead of the liquidity stress is still relatively untested. The lack of commonly accepted liquidity measure prevents not only the adequate regulation and supervision of the financial system. It also makes the investigation of many research and policy questions - such as the impact of the central bank policies on the bank liquidity - difficult. In this paper we present a measure that highlights the central bank influence on the bank liquidity mismatch.

4. Monetary Policy instruments affect bank liquidity through various channels

One of the ECB's main goals is to provide liquidity to the financial system so as to preserve its stability. Conventionally, open market operations are sufficient tools to attain this objective. However, at the onset of the subprime crisis significant tensions appeared on the euro-zone interbank market. An insufficient liquidity and solvency of the banking system impaired the transmission channel from the ECB policy rates to interbank rates and reduced the availability of credit flows to firms and households. The ECB reacted very promptly to the tensions on the interbank

market and implemented several unconventional monetary policy measures, such as exceptional liquidity provisions and collateral rules easing and haircut management.[5]

The exceptional liquidity measures have an important implication for the liquidity mismatch within banks' balance sheets. Liquidity-constrained banks may excessively hoard liquidity for precautionary reasons and at the same time are often compelled to proceed to fire sales of assets, affecting negatively their prices and the corresponding haircuts (Ewerhart and Valla (2007)). As a result, the liquidity position measured by the LMI of all banks exposed to these assets worsens. By ensuring *funding* liquidity, the ECB's unconventional measures diminish these adverse effects. While the full-allotment procedure allows in principle to satisfy all liquidity needs of the banks, the access to the central bank liquidity is in practice limited by the amount of the eligible collateral that the banks can provide. This is why the collateral rules easing was another important part of the ECB unconventional policy aimed at reducing the liquidity mismatch.

Central bank collateral and haircut policies have been key to bank liquidity during the post 2008 crisis

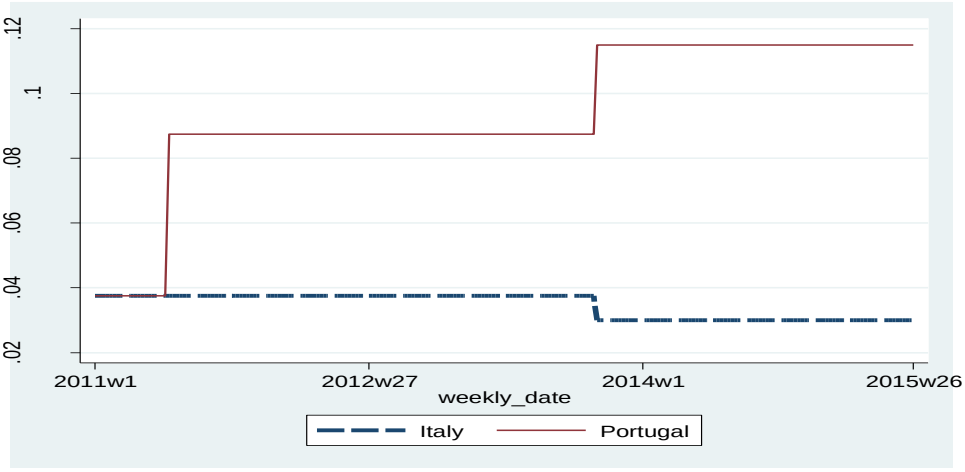
The ECB collateral and haircut policy is the most relevant for our liquidity mismatch indicator. Since the creation of the euro area the ECB had a collateral framework that was much less restrictive than the Fed and the Bank of England. Therefore, the loosening of the collateral rules was not as significant as it was in the US at the beginning of the crisis. However, after the Lehman Brothers collapse, the ECB significantly loosened its collateral rules while limiting its exposure to risky assets by applying adequate haircuts on the accepted securities.

In spring 2010 the sovereign debt crisis began and the ECB was obliged to ease further its collateral rules. In particular, it took several measures to ensure that the Greek banks would still be able to use Greek government bonds as a guarantee to obtain central bank funds. As the sovereign debt crisis spread to other euro-area countries in 2011, the ECB took the same decisions in favor of Irish and Portuguese government bonds. Moreover, in December 2011 the ECB decided to further reduce some ABS ratings thresholds and to accept for the first time the loans to small and medium-sized enterprises as collateral. In February 2012, another important innovation was announced: each national central bank would accept divergent types of collateral to accommodate the peculiarities of their national banking industries. Loosening of the collateral requirements can affect bank liquidity mismatch in several ways. First of all, it increases the volume of collateral that can be used as a guarantee in refinancing operations and therefore reinforces the liquidity provision channel. Furthermore, accepting lower-graded assets as collateral can contribute to lowering their interest rates in the same way as the asset purchases do.

[5] Since 2009, the ECB has also purchased bank covered bonds, ABS and euro-zone corporate and sovereign debt. The outright asset purchases have an impact on the liquidity mismatch as the ECB exchanges the less liquid assets for highly liquid central bank reserves and increases the value of assets often held by banks. However, these policies affect our liquidity mismatch indicator less directly. See Szczerbowicz (2015) for the detailed description of the unconventional monetary measures taken until 2013 and Marx et al. (2016) for the measures implemented later on.

In addition to collateral easing, the ECB significantly changed the level of haircuts and the way it applied them to riskier securities. In October 2008 it lowered the credit threshold that distinguishes between marketable and non-marketable assets from A- to BBB-.[6] In April 2010 the ECB decided to apply schedule of graduated valuation haircuts to the assets rated in the BBB+ to BBB- range. This graduated haircut schedule replaced the uniform haircut add-on of 5% that had been applied to these assets previously. Chart 1 depicts the haircut on Italian and Portuguese sovereign bonds of maturity between five and ten years in the period between 2011 and 2015. In October 2013 the ECB raised the haircuts on low quality assets (BBB+ to BBB-) while reducing them for the high quality assets (AAA to A-). In this way, the central bank allowed banks to obtain more liquidity with high-quality assets, such as Italian sovereign bonds, and diminished further the amount of liquidity that could be raised with low-quality assets, such as Portuguese bonds. Indeed, in May 2011, the Portuguese sovereign bonds changed the credit category from high-credit to low-credit quality, which raised the haircut applied to these assets by 5 percentage points. The Italian bonds on the other hand were classified as high credit quality bonds in the open market operations over the whole period.[7] The changes in haircut schedule had an immediate impact on the amount of liquidity that the banks could claim against their collateral. Moreover, the ECB decisions whether to maintain an asset within its actual credit category, downgrade it or suspend it from the OMO eligibility have also direct implications for the banks' liquidity mismatch.

Chart 1: Haircuts applied by the ECB to Italian sovereign bonds (bleu dashed line) and Portuguese sovereign bonds (red solid line) of maturity comprised between 5 and 10 years.



5. Data

Our data cover the period from 2011:Q1 to 2015:Q3 for a sample of eight French banks that represent around 87% of the country's banking system total assets. The period covered encompasses the funding stress of 2011 that hit European banks, and the subsequent improvement in funding

[6] This rule did not apply to asset backed securities.

[7] On January13, 2017, the DBRS downgraded Italy's sovereign credit rating to BBB (high). Of the four agencies used by the ECB to determine collateral requirements, DBRS was the only one that gave Italy an A-band rating so the downgrade means that the banks will be able to claim smaller amount of funds against the Italian bonds they hold. For instance, Italian bonds with the residual maturity between 7 and 10 years will be subject to 11,5% haircut compared to 3% applied previously.

conditions following the implementation of very Long Term Refinancing Operations. The period 2013-2015 also provides an example of a relatively benign period in terms of funding conditions, in contrast to the preceding stress period.

We use a confidential data on the pool of eligible collateral in the ECB open market operations. These data contain the following information: operation date (weekly OMO), ISIN code of the asset mobilized as collateral, the nominal value of the asset, the value before and after the ECB haircut and the identity of the borrower. The information on haircut on tradable assets comes from the ECB website. Table 1A in appendix shows the average haircut rates applied across the collateral types in our sample. EBA data from 2011:9, 2011:12, 2012:6 and 2014:01 served, when available, to derive sovereign debt holdings at the bank level.

The other relevant balance sheet data – including the maturity structure of the banks liabilities - that we use is obtained from Bloomberg and is available on quarterly, semi-annual or annual bases since 2011. Finally, the OIS-German T-Bill spread is obtained from Bloomberg.

6. A liquidity mismatch indicator for central bank instruments

In this section we construct a liquidity mismatch indicator that takes into account the role of the central bank collateral and haircut policy. To that end, we follow the approach of Brunnermeier, Gorton and Krishnamurthy (2011) who propose a theoretical measure called "Liquidity Mismatch Index (LMI)". They argue that the liquidity mismatch, defined as the difference between market liquidity on the asset side of the balance sheet and the funding liquidity on the liability side of the balance sheet, is the determining factor for assessing the financial system liquidity position. Bai et al. (2015) implement the LMI to gauge the liquidity mismatch of the US bank holding companies during 2002 - 2014.

The contribution of this paper is twofold. First, it applies a novel macro-prudential liquidity indicator to a new, micro, dataset on the French banking sector. Second, it takes into account specifically the impact of the haircut scheme implemented by the central bank on the liquidity of the banking sector as a whole.

LMI evaluates the liquidity of a given bank under a liquidity stress event that is parameterized by time-varying market-implied liquidity weights. The index is constructed from both asset and liability side of the balance sheet but is also dependent on market indicators of liquidity premia. Each asset and liability category contributes to the liquidity position of the bank. They are assigned respectively positive or negative weights. The asset-side liquidity weights are partly calibrated and partly driven by the ECB haircuts of underlying securities and loans, while the liability-side weights are determined by liabilities' maturity structure and by the expected stress duration, which is pinned down by market liquidity premium. The LMI assumes that in a liquidity stress episode, all contractual claimants on the bank act to maximally extract cash from the bank. This means that overnight debt holders refuse to rollover debt and the bank has to cover the cash shortfall from this loss of funding.

As an example, let us consider a bank with an ABS worth €50, to which a 20% haircut is applied at the ECB open market operations (asset liquidity weight =0.8) and a Portuguese sovereign bond worth €50 with the corresponding haircut of 10%. The market liquidity of these assets is €85, i.e. the bank

can raise 85€ at the ECB with its assets worth 100€. On the liability side, the ABS and the Portuguese bond are funded by very short term repo of €100 (liability liquidity weight=-1) such that the liability index is – €100. As a result, we obtain a net liquidity mismatch index of €–15. If the ECB increases the haircut on Portuguese bond to 20%, the bank can raise less money against the Portuguese bond in the ECB open market operations and the liability index goes to €–20. Such time-varying market conditions are not captured by the Basel liquidity ratios.

More formally, the LMI for a bank *i* at a given time *t* is the net of the asset and liability liquidity, given by

$$LMI_t^i = \sum_k \lambda_{t,a_k} a_{t,k}^i + \sum_{k'} \lambda_{t,l_{k'}} l_{t,k'}^i$$

where $a_{t,k}^i$ and $l_{t,k'}^i$ represent respectively the value of class *k* asset and class *k'* liability in bank *i*. λ_{t,a_k} and $\lambda_{t,l_{k'}}$ are corresponding liability-side and asset-side liquidity weights.

We compute the liability-side weights as an exponential function of the expected duration of the stress event and the liability's time to maturity:

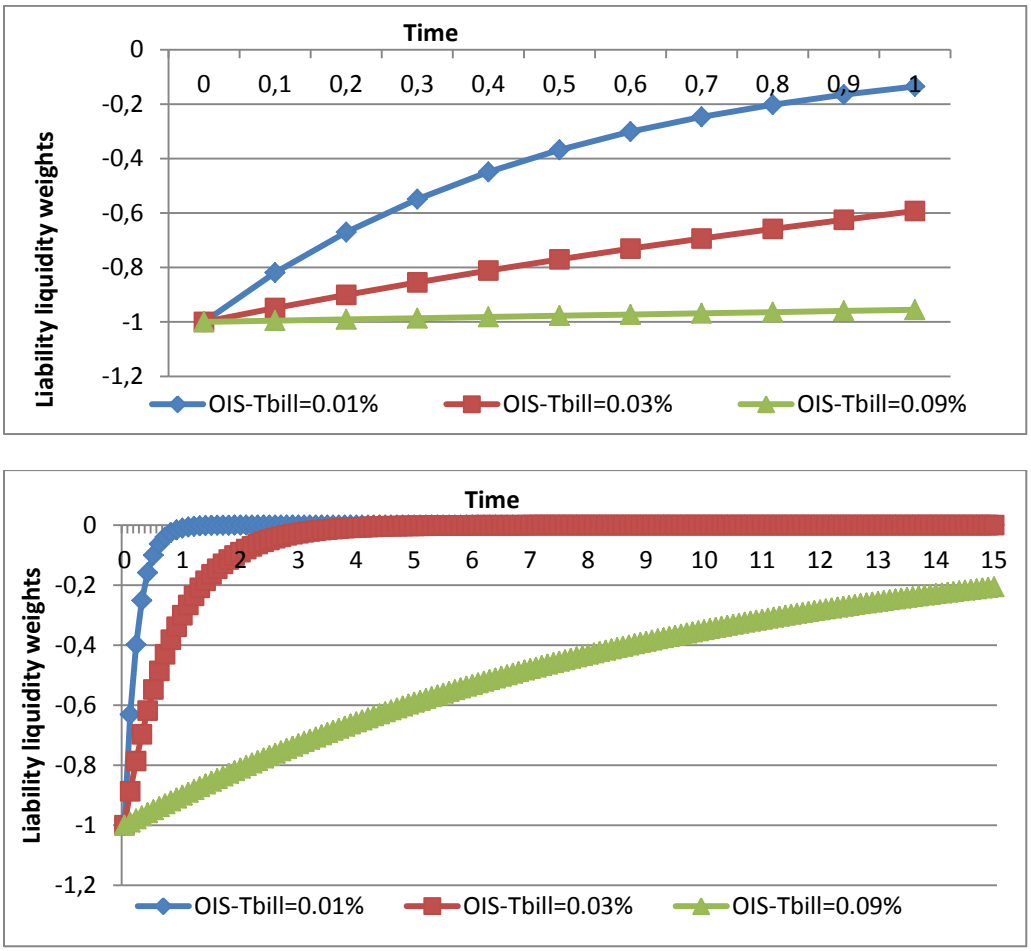
$$\lambda_{t,l_{k'}} = -\exp(-\mu_t T_{k'})$$

where $T_{k'}$ stands for maturity of the liability class *k* and μ_t is an expected duration of the stress event.

We use the OIS-German Treasury Bill spread as an approximation of the expected duration of the stress event, μ_t. Bai et al. (2015) indeed show that there is a relation between μ_t and the liquidity premium that the bank earns on its liabilities. They also argue that the bank liquidity premium can be approximated by the term structure of the OIS-TBill spread.[8] Under the assumption that OIS - TBill spread is a pure measure of the liquidity premium, as it is not contaminated by credit risk premium, μ_t is proportional to ln(OIS - TBill)/T. In normal times the OIS-German TBill spread is small and therefore only the very short-term liabilities have high weights (Chart 2). In a liquidity crisis, when the OIS-German TBill spread is high, many types of liabilities have large weights except for the very long-duration securities such as equity.

[8] Indeed, when the market's desire for liquidity is high, as reflected in high OIS German T-Bill spread, the financial intermediaries that can issue a liquid liability can earn a premium on this liquidity. Nagel (2014) shows that there is a positive relation between the liquidity premium on bank liabilities and market measures of liquidity premium.

Chart 2: Liability liquidity weights for maturities up to one year and up to fifteen years.



The parameter $T_{k'}$ indicates the maturity of a liability of a class *k'*. The balance sheet data that we obtain from Bloomberg allow us to distinguish the following classes of bank liabilities: deposits, short-term borrowing, long-term borrowing, other liabilities, equity, and off-balance items. The maturity structure of long-term and short-term debt for each bank is taken from Bloomberg. For other liability classes, we use the calibrated maturities in a spirit of Bai et al. (2015). In particular, deposits have a maturity of five years (T=5), equity of thirty years (T=30), other liabilities of seven years (T=7) and off-balance positions of five years (T=5).

The time-varying asset-side liquidity weights are given by

$$\lambda_{t,a_k} = 1 - m_{t,k}$$

with $m_{t,k}$ corresponding to the ECB haircut applied to the bank's *i* class of asset *k* posted as collateral.

The balance sheet data obtained from Bloomberg allow us to distinguish the following classes of assets: cash and near cash items, interbank assets, short-term and long-term investments, net loans, net fixed assets, and other assets. Moreover, we obtain from EBA the quantities of sovereign bonds held by each banks. The asset liquidity weights define the amount of cash that a bank can raise over

a short-term horizon for a given asset. As in Bai et al. (2015) we calibrate the weights for some categories of assets. For cash and near cash items, interbank assets, which are very liquid, we set $\lambda_{t,a_k} = 1$. For net fixed assets and other assets, which are difficult or time-consuming to convert into liquid funds, we set $\lambda_{t,a_k} = 0$.

Bai et al. (2015) use repo market haircuts as a proxy for the time-varying liquidity weights for the securities held by banks and they measure the loan haircuts based on the average bid price as a percentage of par in the secondary loan market. The novelty of our approach consists in the use of the ECB haircuts to construct the weights for the bank loans and the bank short-term and long-term security investments, including sovereign bond holdings. Using the ECB haircuts as a proxy for the asset-side liquidity weights we can measure $\lambda_{t,a_k} a^i_{t,k}$ as the amount of cash the bank can immediately rise using $a^i_{t,k}$ as collateral at the ECB open market operations. The bank can use these assets to cover the liquidity outflows. The weights for these asset categories, just as liability weights, vary over time given that the ECB haircuts schedule and the credit quality of an asset change with market conditions.

There are several reasons that make the ECB haircuts relevant for the banks liquidity mismatch. First, in the fixed-rate full-allotment framework, the access to the ECB liquidity is limited only by the amount of eligible collateral that the bank holds. Second, the haircuts applied by the ECB are sometimes smaller than these applied by the private repo market giving the banks incentives to use their assets as collateral at OMO rather than in the private repo markets. As a result, the banks mainly used the Eurosystem OMO operations to exchange their illiquid assets for the highly liquid central bank money. Consistently, the amounts exchanged at the private repo market diminished after the crisis, while the amounts distributed by the ECB increased significantly.

Liquidity plays a central role in systemic crises and the LMI can be informative about systemic risks. We calculate the index for individual French banks in our sample and then aggregate it for the whole banking system. When the aggregate LMI is low, the banking sector is more susceptible to a liquidity stress. Hence our measure should be useful as an early warning indicator for the macro-prudential purposes. It gives the “cash equivalent value” of the French banking sector and indicates the amount of the liquidity support that the ECB might have to provide in case of financial crisis. The LMI can also help identify the systematically important French institution in terms of their liquidity exposures. Such a criterion constitutes an alternative with respect to the classification based on bank asset size.

Moreover, contrary to the LCR, it does not limit the liquidity horizon to 30 days which is an advantage given that there were many periods in recent years where the liquidity stress lasted for several months. During a financial crisis when liquidity premium is high, the LMI is computed under a longer-lasting liquidity scenario. LCR just as LMI underlines importance of both market and funding liquidity. However, the definition of high quality liquid assets is fixed whereas in reality these assets can quickly become illiquid (Greek government bonds). LMI implements time-varying asset weights (haircuts) which account for the changing market conditions.

The LMI measure incorporates the ideas from the academic literature on liquidity. First, it jointly accounts for asset and liability liquidity.[9] Second, asset and liability liquidity is evaluated conditional on given market conditions so the LMI explicitly accounts for liquidity risk. Therefore, the LMI provides a useful framework to implement liquidity stress tests. The LMI that we propose can be further developed with more detailed balance sheet data.

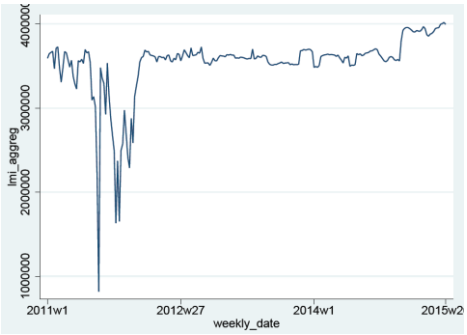
7. Results

The evolution of the banking system's liquidity mismatch over 2011-2015 is displayed on Charts 3 and 4. It provides a number of important results relevant for policy.

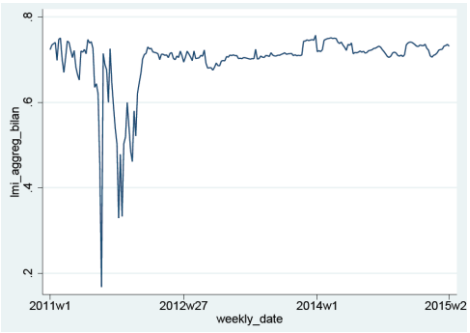
First, the French banking system was still "afloat" prior to the 2011 central bank intervention. Its liquidity mismatch (for the system as a whole) shows a drastic decline in the second half of 2011, suggesting a rapid worsening in systemic vulnerability following the stress episodes at the beginning of the year. Yet, our LMI indicator never falls in negative territory (Chart 3), which demonstrates the resilience of the sector, in aggregate, to deteriorating funding conditions both on the asset and liability side. During the period that precedes the intervention of the central bank, the LMI varied between 18% and 70% of total assets. This in turn suggests that, in aggregate, the French banking sector has remained fairly resilient to the 2011 liquidity shock, or at least its immediate impact, even prior to the central bank intervention.

Chart 3: Liquidity mismatch (LMI) of the French banking system

(a) Liquidity Mismatch Index



(b) LMI scaled by total bank assets



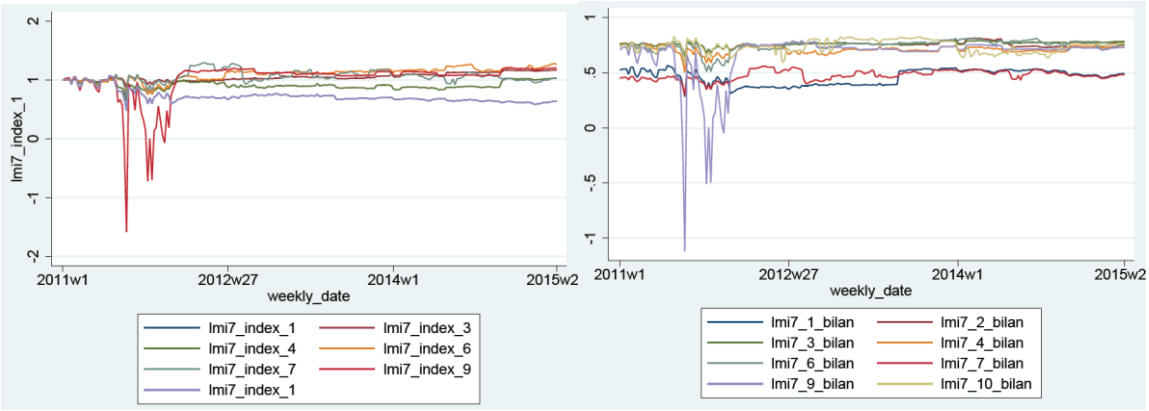
Source: authors. A decrease in the LMI depicts a deterioration of the liquidity situation of the sector, i.e., an increase in the liquidity mismatch between assets and liabilities.

Second, the resilience of the system taken as a whole hides heterogeneity across counterparties (Chart 4). Some banks exhibit a lower LMI throughout the period and one bank stands out as an outlier, experiencing a dramatic fall of its LMI in 2011, to a very negative level, with a strong subsequent recovery bringing its LMI in line with that of the bulk of the sample, around 70% of total assets. This outlier bank is not large enough to drive the aggregated LMI for all banks into negative territory, but demonstrates that the sector-level resilience does not imply that every bank would have coped with the liquidity stress on a stand-alone basis.

[9] Berger and Bouwman (2009)'s aggregate liquidity measure is similar with this respect. However, our liquidity weights incorporate market-based liquidity information and are hence time-varying while Berger and Bouwman's liquidity weights are constant.

Chart 4: Heterogeneous dynamics of individual liquidity mismatch

(a) Rebased (2011:1=100) (b) LMI scaled by total bank assets



Source: Authors.

Third, the deterioration of liquidity proves very inertial. The speedy decline in the LMI in the second half of 2011 occurs in just one or two weeks, while the return to the initial pre-shock liquidity situation takes as long as 6 months. This asymmetry between the pace of the fall and that of the rebound illustrate the vulnerability of banks to liquidity shocks and the necessity of a credible central bank backstop.

Fourth, the LMI goes back slowly to its pre-fall level from the end of July 2011 until the beginning of February 2012 and this period coincides with numerous ECB unconventional monetary policies described earlier, namely restart of sovereign bond purchase in August 2011, announcement of covered bond purchase program in October 2011 along with additional one-year LTROs and finally the announcement of three-year LTROS in December 2011. Moreover, the collateral requirements were relaxed in September and December 2011 and then again in February 2012.[10] The recovery of the LMI during this period suggests the ECB measures played an important role in the bank liquidity mismatch decrease.

Finally, the aggregated LMI of all banks in absolute terms (graph 3A) stands at a higher level at the end of the period than before the 2011 liquidity shock. Most importantly, the aggregated LMI increases notably towards the end of the period, starting in end 2014, and manages to exceed its initial level. This could reflect the impact of the planned implementation of the liquidity regulation, and in particular the LCR, which observation period was scheduled to start in 2015. The end-of-period increase is less pronounced when the aggregated LMI is scaled to total assets, perhaps reflecting that the improvement in the liquidity position in euro terms in was used by banks to originate additional (less liquid) lending, which in turn translated into a stable LMI in percentage of total assets.

[10] On 21/09/2011 the ECB increases the pool of assets accepted as collateral, to include for example instruments issued by credit institutions and traded on non-regulated markets, but tightens its rules on banks using their own unsecured bonds as collateral; on 08/12/2011 the ECB reduces the rating threshold for some ABS and allows national central banks to accept credit claims as collateral; On 09/02/2012 ECB allows the collateral regulations to vary by country.

8. An additional tool to monitor liquidity

What can be the usefulness of an LMI for policy purposes? Relative to existing tools, the LMI has a dual advantage as a real-time monitoring tool of funding conditions. It combines quantity-based measures (balance sheet items) and price-based measures (haircuts; spreads), while existing indicators are based either on prices or on quantities, but rarely both. In addition, it can be computed at a weekly frequency, allowing for a fairly high frequency monitoring relative to pure balance sheet based approaches. Therefore, the LMI could constitute a useful addition to the toolbox of market analysts, risk managers and central banks, in their assessment of banking system liquidity risk.

An additional usefulness of the LMI is for stress-testing. The LMI could lend itself to stress testing approaches, for instance by applying a shock to the level of market haircuts or by assuming a sudden shortening of the maturity of liabilities.

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Appendix: Constructing our central bank induced liquidity mismatch indicator

Table 1A: Haircuts by collateral type in our sample

Collateral	Mean	Std
A. Sovereign bonds	**0.039**	**0.028**
B. Investment securities	**0.071**	**0.038**
Agency & Supra National securities	0.033	0.020
Asset-backed securities	0.148	0.034
OBE	0.109	0.093
OBNS	0.087	0.042
OBS	0.046	0.052
C. Loans	**0.290**	**0.064**

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