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LIQUIDITY (RISK) CONCEPTS

DEFINITIONS AND INTERACTIONS

by Kleopatra Nikolaou

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DEFINITIONS AND INTERACTIONS[1]

by Kleopatra Nikolaou[2]

In 2009 all ECB publications feature a motif taken from the €200 banknote.

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2 European Central Bank, Kaiserstrasse 29, D-60311 Frankfurt am Main, Germany; email: kleopatra.nikolaou@ecb.europa.eu

Address
Kaiserstrasse 29
60311 Frankfurt am Main, Germany

Postal address
Postfach 16 03 19
60066 Frankfurt am Main, Germany

Telephone
+49 69 1344 0

Website
http://www.ecb.europa.eu

Fax
+49 69 1344 6000

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CONTENTS

Abstract

We discuss the notion of liquidity and liquidity risk within the financial system. We distinguish between three different liquidity types, central bank liquidity, funding and market liquidity and their relevant risks. In order to understand the workings of financial system liquidity, as well as the role of the central bank, we bring together relevant literature from different areas and review liquidity linkages among these three types in normal and turbulent times. We stress that the root of liquidity risk lies in information asymmetries and the existence of incomplete markets. The role of central bank liquidity can be important in managing a liquidity crisis, yet it is not a panacea. It can act as an immediate but temporary buffer to liquidity shocks, thereby allowing time for supervision and regulation to confront the causes of liquidity risk.

JEL classification: G10, G20.
Keywords: liquidity, risk, central bank, LLR

Non-technical summary

Financial liquidity is an elusive notion, yet of paramount importance for the well-functioning of the financial system. In fact, the events in financial markets since August 2007 bear all the hallmarks of increased funding liquidity risk, but also reveal how this type of risk can contaminate market liquidity and necessitate reactions from central banks. This project combines literature on liquidity from various fields of research in a schematic and holistic way in order to provide a unified and consistent account of financial system liquidity and liquidity risk. The outcome of this effort reveals the following:

Three main liquidity notions, namely central bank liquidity, market liquidity and funding liquidity are defined and discussed. Their complex and dynamic linkages can give us a good understanding of the liquidity workings in the financial system and reveal positive or negative effects for financial stability, depending on the levels of liquidity risk prevailing.

The causes of liquidity risk lie on departures from the complete markets and symmetric information paradigm, which can lead to moral hazard and adverse selection. To the extent that such conditions persist, liquidity risk is endemic in the financial system and can cause a vicious link between funding and market liquidity, prompting systemic liquidity risk. It is exactly this type of market risk that typically alerts policy makers, because of its potential to destabilise the financial system. In such cases emergency liquidity provisions can be a tool to restore balance.

The central bank has the ability and the obligation to minimise the real costs of liquidations and the probability of a financial system meltdown. However, the role of central bank liquidity in such turbulent periods does not have guaranteed success, as it cannot tackle the roots of liquidity risk. In fact, the potential benefits are limited by the fact that the central bank cannot distinguish between illiquid and insolvent banks with certainty. Therefore, it should only focus on halting (temporarily) the vicious circle between funding and market liquidity. The tradeoff

between the benefits and costs of intervention should be taken into account when the central bank has to decide on its liquidity providing strategy. This task is not easy and there is no established rule of thumb.

In order to eliminate systemic liquidity risk, greater transparency of liquidity management practices in needed. Supervision and regulation are the fundamental weapons against systemic liquidity risk. These practices can tackle the root of liquidity risk by minimising asymmetric information and moral hazard through effective monitoring mechanisms of the financial system. In this way it is easier to distinguish between solvent and illiquid agents and therefore impose liquidity cushions to the ones most in need. This would also help markets become more complete. However, such mechanisms can be costly, due to the amount of information that needs to be gathered. They should, therefore, be run by the most cost efficient and result-effective agent.

1 Introduction

"The word liquidity has so many facets that is often counter-productive to use it without further and closer definition"

Charles Goodhart (BdF, 2008)

Financial liquidity is an elusive notion, yet of paramount importance for the well-functioning of the financial system. Indeed a quick view into the financial market tensions since August 2007 stress this point. These tensions appeared as liquidity in money markets declined significantly (see Figure 1), following credit rationing in the interbank markets. This was due to the fact that banks refused to lend to each other because of funding liquidity problems relating to uncertainty over their exposure to structured products. The amount of exposure was a significant consideration because market liquidity of these structured assets had declined significantly, thereby reinforcing difficulties in valuing such products. As a result, central banks intervened and injected liquidity into the markets. This short exposition reveals important insights. To begin with, financial markets liquidity can take many different facets - such as market liquidity (interbank and asset market), funding liquidity and central bank liquidity. More importantly, in order to understand financial system liquidity, one needs to look closer at the various forms of liquidity in the financial system and the linkages among them.

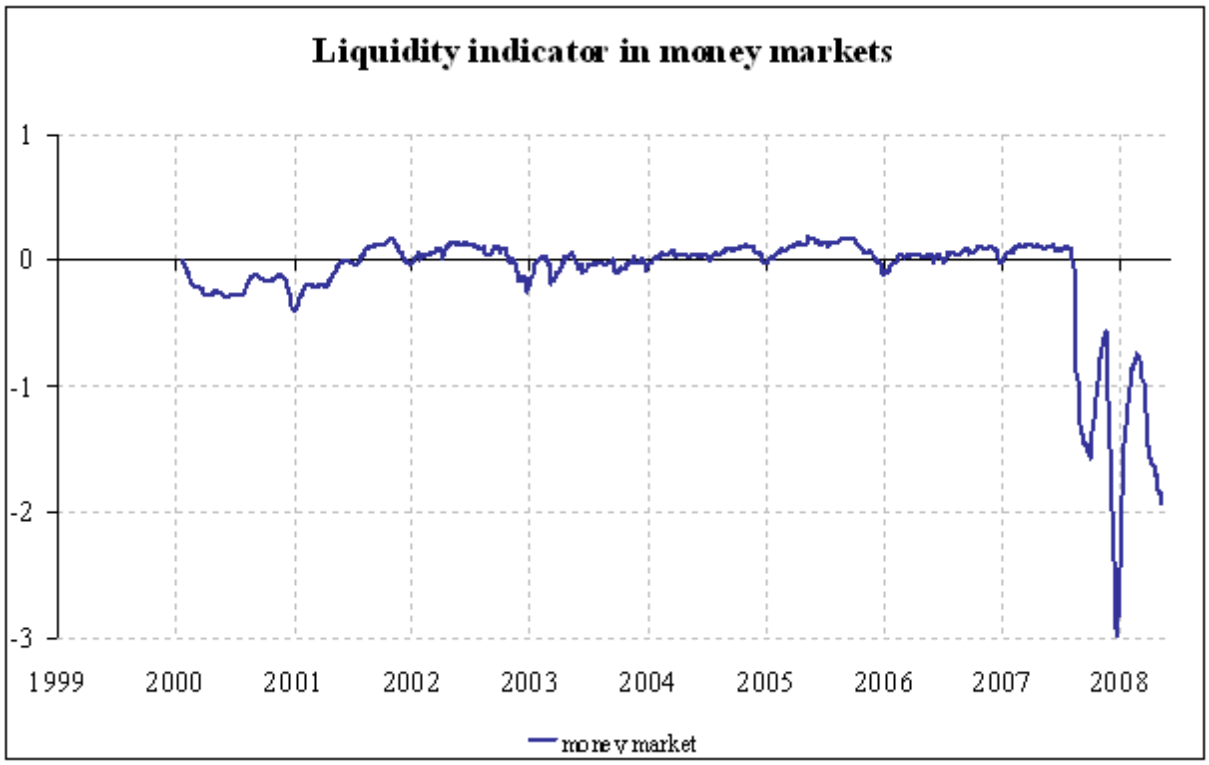

Figure 1: Liquidity in the euro area money markets (source: ECB)

This project differs from the current literature on liquidity. The academic literature up-to-date has looked at various liquidity types and has recorded broad linkages between them. However, it mainly treated the different concepts of liquidity in a rather fragmented way, because it aimed at explaining issues not necessarily related to financial liquidity and liquidity linkages[1]. In other words, it mainly used various notions of liquidity and fragmented parts of their linkages as input for the analysis of various other issues. As a result, it has yet to provide an analysis of the various liquidity types into a context focused only on liquidity. This project

[1]For example central bank liquidity is typically discussed in the context of monetary policy implementation, but also enters into the lender of last resort literature. Market liquidity is typically seen separately in the asset pricing literature, and funding liquidity is usually discussed in the context of liquidity management. More recently, links between funding and market liquidity have been recorded in the theoretical and empirical literature (Brunnemeier and Pedersen, 2007; Drehmann and Nikolaou, 2008).

addresses this gap. It provides a structured and coherent approach of financial liquidity (risk) by concentrating, condensing and re-interpreting a broad spectrum of available literature results.

More specifically this project presents a coherent liquidity framework where it differentiates between the various liquidity types, appropriately defines them and brings forward the linkages among them (i.e. describe the transmission channels and spill-over directions among these types). Namely, it describes liquidity flows in the financial system by examining the linkages between three broad liquidity types: central bank liquidity, market liquidity and funding liquidity. The first relates to the liquidity provided by the central bank, the second to the ability of trading in the markets, and the third to the ability of banks to fund their positions. It then discusses the definitions and properties of each liquidity (risk) type and integrates theoretical findings and empirical evidence in the up-to-date literature to present a structured view of the liquidity flows among these three types under smooth and under turbulent times. In so doing, it explains how these linkages and liquidity transmission channels are affected by liquidity risk and exposes the causes of the latter.

This project suggests two important policy implications. Liquidity linkages among the various liquidity types are strong. In normal times (times of low liquidity risk) such linkages promote a virtuous circle in the financial system liquidity, guaranteeing the smooth functioning of the financial system. In turbulent times (times of high liquidity risk) the linkages remain strong, but now become propagation channels of liquidity risk in the financial system, leading to a vicious circle which might end up destabilising the financial system. The role of central bank liquidity together with supervision and regulation are of paramount importance in restoring stability to the system. Finally, this project explains how departures from the classical economy paradigm, i.e. asymmetric information and incomplete markets, create liquidity risk, how liquidity risk is endemic in the financial system and

how the central bank (liquidity) has an important, albeit limited role in mitigating liquidity risk.

The current project is structured as follows: Section 2 introduces the definitions and discusses the three types of liquidity and liquidity risk. Section 3 discusses the linkages among the various liquidity types in normal periods and in turbulent periods. Section 4 describes the current turmoil and evaluates the relevance of the academic literature based on what was actually observed and Section 5 draws implications for policy makers and briefly concludes.

2 Definitions

In this section we identify and define three main types of liquidity pertaining to the liquidity analysis of the financial system and their respective risks. The three main types are central bank liquidity, market liquidity and funding liquidity. We analyse the properties and empirical behaviour of each liquidity (risk) type. We also present measures of liquidity risk and discuss the relation between liquidity and liquidity risk.

2.1 Liquidity

The notion of liquidity in the economic literature relates to the ability of an economic agent to exchange his or her existing wealth for goods and services or for other assets[2]. In this definition, two issues should be noted. First, liquidity can be understood in terms of flows (as opposed to stocks), in other words, it is a flow concept. In our framework, liquidity will refer to the unhindered flows among the agents of the financial system, with a particular focus on the flows among the central bank, commercial banks and markets. Second, liquidity refers to the "ability" of

[2]This remark draws heavily from Williamson's (2008) discussion of liquidity constraints. According to his discussion, such constraints "affect the ability of an economic agent to exchange his or her existing wealth for goods and services or for other assets".

realising these flows. Inability of doing so would render the financial entity illiquid. As will become obvious below, this ability can be hindered because of asymmetries in information and the existence of incomplete markets.

2.1.1 Central bank liquidity

Central bank liquidity is the ability of the central bank to supply the the liquidity needed to the financial system. It is typically measured as the liquidity supplied to the economy by the central bank, i.e. the flow of monetary base[3] from the central bank to the financial system. It relates to "central bank operations liquidity", which refers to the amount of liquidity provided through the central bank auctions to the money market according to the "monetary policy stance". The latter reflects the prevailing value of the operational target, i.e. the control variable of the central bank. In practice, the central bank strategy determines the monetary policy stance, that is, decides on the level of the operational target (usually the key policy rate). In order to implement this target, the central bank uses its monetary policy instruments (conducts open market operations) to affect the liquidity in the money markets so that the interbank rate is closely aligned to the operational target rate set by the prevailing monetary policy stance.

More technically, central bank liquidity, a synonym for the supply of base money, results from managing the central bank assets in its balance sheet, in accordance to the monetary policy stance[4]. Consider the balance sheet of a central bank (see Figure 2)[5]. In the liabilities side, the main components are the autonomous factors and the reserves. The autonomous factors contain transactions which are not controlled by the monetary policy function of the central bank[6]. The reserves

[3]The monetary base, otherwise known as base money or M-zero (M0) relates to the supply of money in the economy and comprises the currency (banknotes) in circulation and banks' reserves with the central bank.

[4]See ECB (2004) and Bindseil (2005).

[5]The view of the balance sheet presented here is very simple. For a detailed analysis see Bindseil (2004).

[6]In the euro system balance sheet the autonomous factor category contains banknotes in circu-

refer to balances owned by credit institutions and held with the central bank in order to meet settlement obligations from interbank transactions and to fulfil reserve requirements, i.e. the minimum balances that banks are required to hold with the central bank[7]. The need for banknotes and the obligations of banks to fulfil the reserve requirements create an aggregate liquidity deficit in the system, thereby making it reliant on refinancing from the central bank. The central bank, being the monopoly provider of the monetary base, provides liquidity to the financial system through its open market operations. Thus, these operations appear in the asset side of the central bank's balance sheet. The liquidity provided by the central bank through its operations, i.e. its assets, should balance the liquidity deficit of the system, i.e. its liabilities. Therefore, the central bank provides liquidity equal to the sum of the autonomous factors[8] plus the reserves. The central bank manages its market operations so that the inter-bank short-term lending rates remain closely aligned to the target policy rate[9].

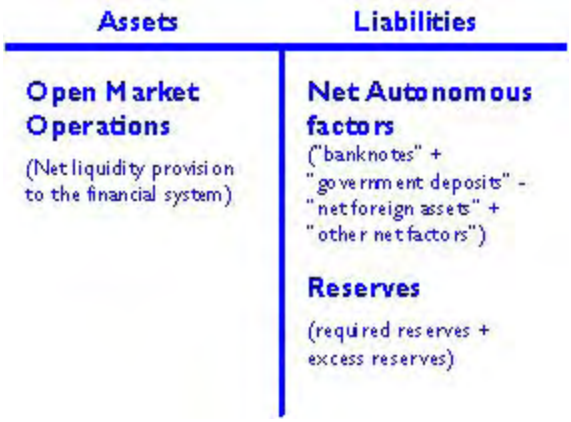

Figure 2: The balance sheet of the central bank

lation, government deposits, net foreign assets and "other net factors" (see ECB, 2004).

[7]Usually, the amount of reserve requirements is close to the amount of total reserves. A potential reason might be - among others- that excess reserve requirements are not remunerated.

[8]In practice the actual size of autonomous factors is not known and a forecast of them is used to determine the liquidity allotment. See ECB (2004) for details on this issue and for the properties of the autonomous factor forecasts.

[9]The short-term rates refer typically to the overnight rates, although in cases of some central banks, it can also be weekly or even three month money market rates.

At this point, a note should be made regarding the relationship of central bank liquidity and monetary or macroeconomic liquidity. The later refers to the growth of money, credit and aggregate savings[10]. Therefore, it includes broad monetary aggregates and in that sense includes central bank liquidity. Monetary liquidity is important for monetary policy decision making, however, we focus on central bank liquidity, because it is directly influenced by the central bank. It, thus, brings out the role of the central bank in financial liquidity in a clearer manner, which, from a policy making point of view, is more relevant.

2.1.2 Funding liquidity

The Basel Committee of Banking supervision defines funding liquidity as the ability of banks to meet their liabilities, unwind or settle their positions as they come due (BIS, 2008)[11]. Similarly, the IMF provides a definition of funding liquidity as the ability of solvent institutions to make agreed upon payments in a timely fashion. However, references to funding liquidity have also been made from the point of view of traders (Brunnemeier and Pedersen, 2007) or investors (Strahan, 2008), where funding liquidity relates to their ability to raise funding (capital or cash) in short notice. All definitions are compatible (see a relevant discussion in Drehmann and Nikolaou, 2008). This can be clearly seen in practice, where funding liquidity, being a flow concept, can be understood in terms of a budget constraint. Namely, an entity is liquid as long as inflows are bigger or at least equal to outflows. This can hold for firms, banks, investors and traders. This paper mainly focuses on the funding liquidity of banks, given their importance in distributing liquidity in the financial system.

It is therefore useful to consider the liquidity sources for banks. A first one is,

[10] See Ferguson et al. (2007) in Geneva Report on the World Economy for a definition of macroeconomic liquidity. The Report presents a similar distinction of liquid types, namely macroeconomic liquidity, funding liquidity and market liquidity (pp. 9 and 10). Moreover, it mentions that these notions are inter-related and are important for financial stability.

[11] Basel Committee on Banking Supervision (2008), paragraph 1.

as already seen, the depositors, who entrust their money to the bank. A second is the market. A bank can always go to the asset market and sell its assets or generate liquidity through securitisation, loan syndication and the secondary market for loans, in its role as "originator and distributor"[12]. Moreover, the bank can get liquidity from the interbank market[13], arguably the most important source of liquidity. Finally, a bank can also choose to get funding liquidity directly from the central bank. In the euro system, this is possible by bidding in the open market operations of the ECB (see Drehmann and Nikolaou, 2008 for an extended analysis of the sources and their importance). Knowledge of these sources is important in order to better understand the liquidity linkages (described in Section 3).

2.1.3 Market liquidity

The notion of market liquidity has been around at least since Keynes (1930). It took a long time, however, until a consensus definition became available. A number of recent studies define market liquidity as the ability to trade an asset at short notice, at low cost and with little impact on its price. It therefore becomes obvious that market liquidity should be judged on several grounds. The most obvious would be the ability to trade. Moreover, Fernandez (1999) points out that "(market) liquidity, as Keynes noted [...] incorporates key elements of volume, time and transaction costs. Liquidity then may be defined by three dimensions which incorporate these elements: depth, breadth (or tightness) and resiliency"[14]. These dimensions ensure

[12] In doing so, banks also create market liquidity, because they create a credit market with the bank being the market maker (Strahan, 2008). This is an important insight, which helps to understand the linkages between funding and market liquidity.

[13] The interbank market is the market where banks can trade with each other loans of very short horizons (over-night) secured or unsecured.

[14] A market is deep, when a large number of transactions can occur without affecting the price, or when a large amount of orders lies in the order-books of market-makers at a given time, i.e. the number of available buyers and sellers is large. A tight market is a market where transaction prices do not diverge from mid-market prices. Finally, in a resilient market price fluctuations from trades are quickly dissipated and imbalances in order flows are quickly adjusted. According to Liu (2006), they can be summarised into four characteristics of liquidity: Trading quantity, trading speed, trading cost and price impact.

that any amount of assets can be sold anytime within market hours, rapidly, with minimum loss of value and at competitive prices.

Academic interest has been broad regarding the properties of market liquidity and its importance on the functioning of markets. An interesting finding is the remarkable commonalities in market liquidity. There is a positive covariance between individual stock liquidity and overall market liquidity. Moreover, Chordia et al. (2000, 2005) have documented that liquidity is correlated across markets, namely across stocks and across stocks and bonds (see papers for a relevant literature review). In fact, Brunnemeier and Pedersen (2005) provide a theoretical framework which rationalises commonality of liquidity across assets and markets in general through the microstructure analysis of the behaviour of traders. Moreover, Stahel (2005) points to the existence of a global (market) liquidity factor. Finally, the literature also records a negative (positive) relation between liquidity and asset prices (returns) (Acharya and Pedersen, 2005).

For the purpose of this project we are going to focus on two types of market liquidity. The liquidity in the interbank market, where liquidity is being traded among banks and the liquidity in the asset market, where assets are being traded among financial agents. These two types, as already seen, are the main sources for a bank to acquire funding liquidity from the markets and therefore can help us explain interactions between the various liquidity types.

2.2 Liquidity risk

Risk relates to the probability of having a realisation of a random variable different to the realisation preferred by the economic agent[15]. In our context the economic agent would have a preference over liquidity. In that sense, the probability of not being liquid would suggest that there is liquidity risk. The higher the probability,

[15]Machina and Rotschild (1987) suggest that the notion of risk is related to the probability distribution of the underlying random variable, where economic agents have well-defined preferences over the realizations of the random variable of interest.

the higher the liquidity risk. When the probability equals unity (i.e. the possibility becomes a certainty) liquidity risk reaches a maximum and illiquidity materialises. In that sense, there is a inverse relationship between (il)liquidity and liquidity risk, given that the higher the liquidity risk, the higher the probability of becoming illiquid, and therefore, the lower the liquidity.

2.2.1 Central bank liquidity risk

A definition for central bank liquidity risk was, to the best of our knowledge, not possible to come up with in the literature. This is mainly because of the widespread view that central bank liquidity risk is non-existent, as the central bank is always able to supply base money and, therefore, can never be illiquid. Typically the central bank, being the monopoly provider of liquidity, i.e. the originator of the monetary base, can dispense liquidity as and when it deems needed, so as to satisfy the equilibrium demand for liquidity in the banking system (avoiding cases of excess liquidity or liquidity deficits) according to its policy stance. A central bank can only be illiquid to the extent that there is no demand for domestic currency, and therefore the supply of base money from the central bank could not materialise. This could happen in cases of hyperinflation or an exchange rate crisis. However, based on conventional wisdom such a scenario could be safely regarded as unlikely, at least in developed, industrialised countries and, therefore, it is not considered in the literature.

It would also be useful to stress that a central bank can incur costs in its role as a liquidity provider, but these costs do not necessarily reflect liquidity risk. Such costs can involve central bank specific risks (e.g. counterparty credit risk related to collateral value), monetary policy related risks (e.g. risks of wrong signalling) or wider risks to financial stability (i.e. the moral hazard issue that relates to emergency liquidity assistance in turbulent periods). Nevertheless, these risks do not affect the ability of the central bank to provide liquidity.

2.2.2 Funding liquidity risk

At least since Bagehot (1873) it was known that banks are subject to funding liquidity risk. According to the IMF (2008) funding liquidity risk captures the inability of a financial intermediary to service their liabilities as they fall due. Other definitions of funding liquidity risk usually involve a time horizon, that is, the probability of becoming illiquid is typically measured for a given period ahead and can differ significantly according to the length of the period (Matz and Neu, 2006; Drehmann and Nikolaou, 2008). Typically, funding liquidity risk depends on the availability of the four liquidity sources, as described in Section 2.1.2, and the ability to satisfy the budget constraint over the respective period of time.

Measuring funding liquidity risk is not trivial. In most cases practitioners construct various funding liquidity ratios, which reveal different aspects of the availability of funds within a certain time horizon ahead and use them as proxies for funding liquidity risk[16]. Such measures can be produced either by static balance sheet analysis or by dynamic stress testing techniques and scenario analysis. The latter is more cumbersome to calculate if only because it relies on complicated calculations and a wider set of information and hypotheses[17]. Recently, Drehmann and Nikolaou (2008) suggest a simple and more straightforward proxy, based on the role of the central bank as a potential funding liquidity source. They argue that bidding behaviour in central bank auctions can reveal the funding liquidity risk of banks over a one week horizon and construct proxies of funding liquidity risk from bidding data.

[16] Matz and Neu (2006) and Banks (2005) provide a list of funding ratios and liquidity ratios that are frequently used at a firm level as liquidity risk proxies (for example the funding ratio, which is the ratio of total available funding over the total available assets above a number of periods).

[17] Static balance-sheet analysis provides a simple, "point in time" liquidity index, which is based on a static and often backward looking impression of the liquidity condition. It does not contain any information about the horizon within which positions can be liquidated or become due (see Banks, 2005). The dynamic analysis is essentially based on a more detailed break down of inflows and outflows. In this type of analysis the respective paths of in- and outflows of assets and liabilities are being considered per time period. Banks then analyse the flow constraint under several scenarios or stress tests.

Academic evidence on the properties of funding liquidity risk is scant. Drehmann and Nikolaou (2008) find that funding liquidity risk bears similarities to market liquidity risk, in the sense that it is low and stable most of the times, but subject to occasional spikes (e.g. funding liquidity risk appears elevated during the current turmoil period). This finding is supported by Matz and Neu, (2006), who view liquidity risk as a consequential risk, because it increases following one or more spikes in other financial risks (i.e. market liquidity risk). Brunnemeier and Pedersen (2007) provide further theoretical support, and rationalise linkages between market and funding liquidity risk (for traders), which are validated empirically by Drehmann and Nikolaou (2008).

2.2.3 Market liquidity risk

Market liquidity risk relates to the inability of trading at a fair price with immediacy. It is the systematic, non-diversifiable component of liquidity risk. This has two important implications. First, it suggests commonalities in liquidity risk across markets. Such commonalities have been grounded theoretically (Brunnemeier and Pedersen, 2005 and 2007) and recorded empirically across stocks and across bonds and equity markets (Chordia et al., 2005 - see discussion in Section 2.1.3). More extensive propagation mechanisms can also transfer liquidity risk across interbank and asset markets (see discussion in Section 3.2).

The second implication of systemic risk is that it should be priced. Namely, market liquidity risk has been typically regarded as a cost or premium in the asset pricing literature, which affects the price of an asset in a positive way[18] (Bangia et al., 1999; Holmström and Tirole, 2001; Pastor and Stambaugh, 2003; Acharya and Pedersen, 2005; Chordia et al., 2005) thereby influencing market decisions (i.e. optimal portfolio allocation as in Longstaf, 1998) and market practices (i.e. transaction costs as in Jarrow and Subramanian, 1997). The larger the premium, the higher

[18] In fact, the relationship between liquidity risk and prices can be endogenous, in the sense that there is a two-way causality (Acharya and Pedersen, 2005).

the market liquidity risk. In practical terms, starting with the liquidity-based asset pricing model of Holmström and Tirole (2001), asset pricing models typically measure liquidity risk as the covariance (commonality) between a measure of liquidity (innovations) and market returns (Pastor and Staumbaugh, 2003; Acharya and Pedersen, 2005; Liu, 2006). Liquidity risk commoves with contemporaneous returns, but it is also possible to predict future returns based on current liquidity risk estimates (Chordia et al., 2001; Acharya and Pedersen, 2005; Liu, 2006). Overall, the related literature suggests that asset prices reflect liquidity costs, which are linked to the existence of liquidity risk.

The behaviour of market liquidity risk (i.e. of the market liquidity premium) has also been recorded. Liquidity risk is in most cases low and stable. Elevated liquidity risk is rare and episodic (see empirical evidence in equity market in Pastor and Staumbaugh, 2003). The episodic nature can result from downward liquidity spirals due to mutually reinforcing funding and market illiquidity (Brunnemeier and Pedersen, 2005 and 2007) and is rare because of benefits from cooperation in trading (Carlin et al., 2007). On this latter point, Brusco and Castiglinesi (2007) further argue that financial links are established only when the benefits are greater than the costs, that is, when the possibility of a financial crisis (and therefore elevated liquidity risk) is limited. As a consequence, crises and financial contagion are rare events. Given this behaviour of market liquidity risk, it is possible to understand why liquidity is time varying and persistent in smooth periods (Amihud, 2002; Chordia et al., 2000,2001,2002; Pastor and Staumbaugh, 2003).

Finally, the implications of market (systemic) liquidity risk are important from a financial stability point of view. In fact, individual liquidity risk (leading to single or few bank failures) might not be of consequence, and indeed might even be a helpful mechanism to restore financial health in certain parts of the system (Diamond and Dybvig, 1983; Allen and Gale, 1998). However, systemic (market) liquidity risk can have serious repercussions for the financial system as a whole. Notably, it

can lead to financial crises, which damage financial stability, disrupt the allocation of resources and ultimately, affect the real economy (Hoggarth and Saporta, 2001; Ferguson et al., 2007). Given the importance of market liquidity risk (i.e. systemic risk) to financial stability, it is the type of liquidity risk that immediately alerts policy makers. Nevertheless, given the intense linkages among the various liquidity types, a general view of the liquidity flows in the system is also needed to examine market liquidity risk.

3 Liquidity linkages

In this section we argue that the three distinct types of liquidity are intensively interconnected. To validate this claim, we analyse linkages among them based on two alternative scenarios. The first is under normal periods and the second under turbulent periods. Normal periods refer to periods of low liquidity risk. In such periods the system a virtuous circle would be established between the three liquidity types, fostering stability of the system. The turbulent periods would refer to periods of high liquidity risk. In such periods the linkages between the three liquidity types would remain strong, however, they would prompt a vicious circle among the three liquidity types which could ultimately destabilise the financial system. We describe the liquidity linkages under these two scenarios in an attempt to analyse the causes of liquidity risk, bring forward the mechanisms and transmission channels among the different liquidity types and discuss the role of central bank liquidity in such situations.

3.1 Liquidity linkages in normal times

In normal periods liquidity flows easily among the three liquidity types, establishing a virtuous liquidity circle that stimulates stability in the financial system. The central bank, who has the responsibility to supply aggregate liquidity (Friedman and

Schwarz, 1963), would provide the "neutral" amount of liquidity[19] to the financial system. This would cover the liquidity deficit of the financial system on aggregate. This amount of liquidity would be received by the banks and, through the various markets (interbank[20] and asset markets) it would be re-distributed to the liquidity needing agents of the financial system and recycled within the system. Each agent who is liquidity constrained would ask for the amount of liquidity that would satisfy her funding liquidity needs. After this (aggregate) re-distribution, the central bank would observe the new demand for liquidity and supply it, so that a similar liquidity circle start again (see ECB, 2004). In that sense, each liquidity type performs a very specific role. The central bank would provide the "neutral" amount of liquidity, markets would ensure its re-distribution and recycling and funding needs its efficient allocation among the agents (See Figure 3).

Liquidity type	Role
Central bank liquidity	Provision of amount of liquidity that balances demand and supply
Market liquidity	(Re)distribution and recycling of liquidity
Funding liquidity	Efficient allocation of liquidity resources

Figure 3: The role of the different liquidity types

From this simple outline it becomes obvious that each liquidity type depends on the other two types (see Figure 4). This is because, the role of each liquidity type is unique in the financial system, therefore each liquidity type should perform its

[19]The neutral or equilibrium demand for liquidity is the amount of liquidity that would satisfy the liquidity demand of the financial system, to the extent that the interbank rates are in line with the policy rates.

[20]Note that not all banks are eligible to take part in open market operations or are successful in their bidding behaviour. Therefore, the interbank market is responsible for redistributing the amount of liquidity allocated by the central bank to all banks needing liquidity, though inter-bank lending.

role and rely on the good functioning of the other two for the system to be overall liquid. Namely, the "neutral" amount of liquidity provided by the central bank should flow unencumbered among the agents as long as market liquidity effectively recycles it and funding liquidity allocates it within the system in an efficient and effective way. Markets should be liquid provided that there is enough liquidity in the financial system on aggregate (i.e. there are no liquidity deficits) and each counterparty demands liquidity according to their funding needs. Finally, funding liquidity depends on the availability of the funding liquidity sources. For example, in this scenario, a bank would always be liquid as long as it an get enough liquidity to satisfy its funding needs from the markets[21] or the central bank.

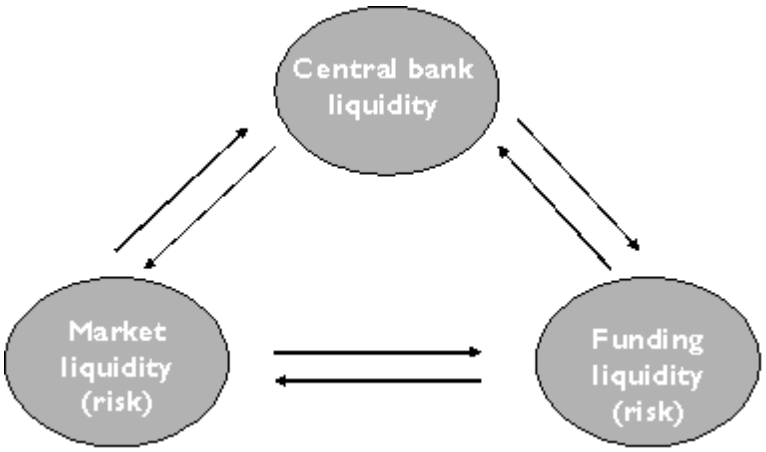

Figure 4: The three liquidity nodes of the financial system

This base-line scenario could generate a virtuous circle in the economy (see Figure 4) and foster financial stability. The system overall would be liquid, because there would be enough liquidity in the system on aggregate. This liquidity would be effectively distributed to the agents they need it most, according to their funding liquidity needs. Overall, liquidity would flow easily and unobstructed in the system

[21] Funding liquidity sources, as seen in Section 2.1.2 include both the central bank and the market. A bank can get liquidity directly from the central bank, or through the markets. The interbank market can be one option, but asset markets can further generate (funding and market) liquidity through assets sales (part of which might be related to banks' securitised assets).

and banks could have recourse to any of the liquidity options available. In fact, if markets are efficient, the choice of alternative liquidity providers will only be based on price considerations (Ayuso and Repullo, 2003; Ewerhart et al., 2007; Drehmann and Nikolaou, 2008), i.e. they will be able to choose the most cost-efficient funding option. Under these circumstances, there will always be enough liquidity so as to smooth out any frictions[22]. That would suggest minimal systemic risks in the financial system and much reduced possibility of financial crisis, therefore robust financial stability.

3.2 Liquidity linkages in turbulent times

As liquidity risk creeps into the system, the links described above can be distorted and in fact produce a vicious illiquidity spiral in the financial system. In what follows we are going to focus on two main issues. First, discuss the origins of liquidity risk in the financial system, so as to show that liquidity risk is in fact endogenous to the system. This implies the possibility of reverting from a virtuous to a vicious circle in the economy. Second, we are going to analyse how this vicious circle might work and what measures could be taken to halt it and restore the virtous one.

More specifically, we show that the cause of liquidity risk lies in coordination failures among depositors, banks or traders, which ultimately feed and are being fed by asymmetric information and incomplete markets. We also explain how interactions between the three main liquidity types (funding, market and central bank liquidity) can be affected by liquidity risk. Notably, the strong linkages remain, but in turbulent times they rather serve as risk propagation channels and destabilise the financial system. Central bank liquidity policies can halt it temporarily, but

[22]In fact, in the extreme case of no liquidity risk, banks will have no reason to plan their liquidity (or for that matter to engage in liquidity management to avoid bad surprises in their liquidity position): they can just return to the capital market as needs arise (Tirole, 2008). In essence, liquidity management will not matter as banks or markets will never be illiquid.

restructuring of the system based on efficient supervision and effective regulation could fight the source of liquidity risk and restore the virtous circle. In our analysis we pick an arbitrary starting point, e.g. a situation of elevated funding liquidity risk in a bank and discuss how it can spread through market liquidity risk and what is the role of central bank liquidity in such cases (see Figure 5). In so doing, we stress the existence of asymmetric information and incomplete markets as sources of liquidity risk. We choose to depict such a situation also due to the resemblance it bears to the current turmoil period.

3.2.1 From (bank) funding liquidity risk

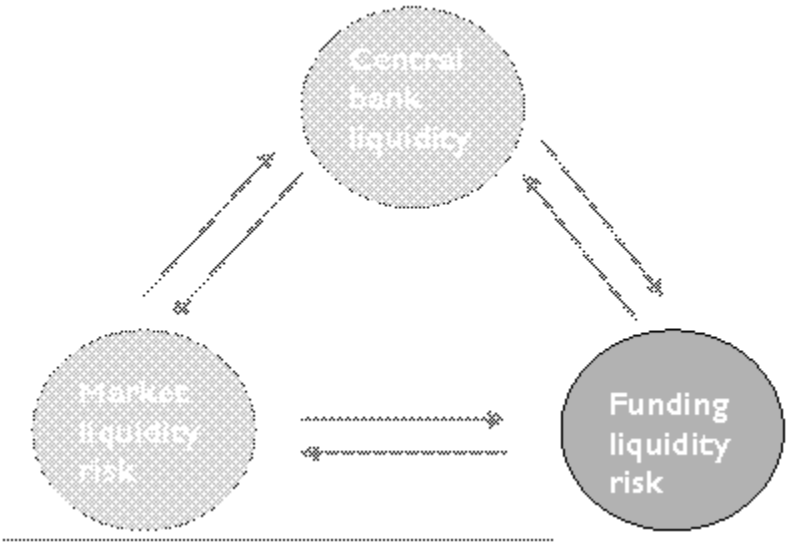

Figure 5: Funding liquidity risk

Funding liquidity risk lies in the heart of banking. Banks are considered by construction fragile due to the maturity transformations they undertake (liquid short-term deposits to illiquid long-term loans). More specifically, the main role of banks in the financial system is to provide liquidity through intermediation. Banks intermediate between depositors and investors and provide illiquid loans to the latter,

which are funded with liquid deposits from the former [23],[24],[25]. In so doing, banks transform short maturities (deposits) into longer maturities (investments) in order to create funding liquidity for investors (Strahan, 2008) and to promote the efficient allocation of resources in the system[26]. This leaves the banks exposed to an inherent maturity mismatch. This mismatch can cause instability in the bank in its role as provider of liquidity upon demand to depositors (through deposit transactions), or borrowers (through committed lines of credit). Holding enough liquid assets at any point would minimise their exposure to risk, but this is not optimal for them because these assets are yielding low returns. Banks, therefore face a trade off between holding (short-term) low-yield liquid assets and using them to invest in (long-term) high-yield illiquid assets[27] (Strahan, 2008).

This fragile construction of banks subjects them to funding liquidity risk. Given

[23] A number of papers investigate the role of banks as liquidity providers and more specifically why banks have a comparative advantage over other financial institutions to provide both deposit taking and lending. Kashyap, Rajan and Stein (2002) put forth the idea of important synergies between deposit taking and lending, which allow banks to provide liquidity in the most cost-efficient manner. That is, under particular conditions, the coexistence of these two functions creates an economy of scale that conserves on the amount of costly liquid assets that are needed to support loan commitments. The synergy exists as long as deposit withdrawals are not too highly correlated with commitment take-downs. Gatev and Strahan (2006) and Gatev et al. (2006) provide empirical evidence of negative covariance, which enables them to further suggest that deposits can be viewed as a natural hedges against systematic liquidity risk exposures stemming from issuing loan commitments and lines of credit. This mechanism is possible given the liability guarantees (i.e. deposit insurance, central bank liquidity and targeted liquidity assistance) of the banking system. For example, Pennachi (2006) shows that before the introduction of deposit insurance, such synergies did not appear to be in place.

[24] The traditional banking environment of asset transformation through "originate and hold", would suggest that banks hold the illiquid loans provided in their balance sheets. In the new banking environment, of "originate and distribute", banks transform illiquid loans into more liquid assets through securitisation, loan syndication and the secondary market for loans. (See Strahan (2008) and ECB (2008) for a discussion on securitisation).

[25] Banks rely on the presence of asymmetric information between depositors and investors and rationalise their role via their ability to monitor investors better (Diamond and Dybvig, 1983). Their superior information on loans granted can only partly safeguard them from funding liquidity risk.

[26] A similar logic can stimulate a liquidity creation mechanism between market makers or traders and financial market investors.

[27] Illiquid investments might include loans to households and businesses, as well as assets generated through securitisation.

this inherent fragility, incomplete markets and asymmetric information could prompt coordination failures between agents (depositors) demanding liquidity from the bank, resulting to bank runs, the extreme form of funding liquidity risk[28]. Typically a bank run is modelled as a situation (possible equilibrium) where depositors decide to liquidate their deposits before the maturity of the investment, leading to increased demand for liquidity that the bank cannot satisfy (see e.g. the seminal work on bank runs of Diamond and Dybvig, 1983). This can materialise if depositors believe that other depositors will run. In that case, even a perfectly sound and solvent bank, can fail. According to Diamond and Dybvig (1983, 2000), the reason propelling such coordination failures is bad expectations leading to self-fulfilling prophecies (sunspot equilibria or exogenously determined). Alternatively it may relate to fundamental worries, i.e. rational concerns, which may be linked to departures from the classical economic paradigm. Namely, imperfect information may lead to bank runs. As argued by Morris and Shin (1999) if the soundness of the borrower is uncertain, runs may occur when a commonly observed signal about the borrower increases uncertainty among depositors, because it is optimal to pre-empt withdrawals of others by borrowing first. On the other hand, bank runs may result from incomplete markets, as aggregate risk cannot be hedged away (Allen and Gale, 1998)[29]. Such concerns are empirically more likely to motivate demand shocks by depositors than self-fulfilling prophesies according to Gorton, (1988)[30]. Overall,

[28] However, note that bank runs may not always be costly as was originally suggested by Diamond and Dybvig (1983). For example, Allen and Gale (1998) investigate cases where allowing for bank runs can achieve an optimal allocation of resources in the economy.

[29] In a relevant model by Allen and Gale (1998) bank runs are a result of a natural out-growth of the business cycle (elevated aggregate risk). The impact of the business cycle on the bank's assets is captured by uncertainty about asset returns. An economic downturn will reduce the value of bank assets, raising the possibility that banks are unable to meet their commitments. Concerns about the solvency of the bank increase and, because markets are incomplete and therefore agents are not able to hedge against such downturns, funding liquidity risk is raised (see Allen and Gale (1998) for a formal exposition and a related literature review).

[30] A combination of panic and fundamental views of crises that generates runs is also described by Rochet and Vives (2004) in a theoretical model that links the probability of occurrence of a crisis to the fundamentals.

funding liquidity risk is endogenous in a bank and results from departures from the classical economy[31].

3.2.2 To market liquidity risk

Funding liquidity risk in a single bank (i.e. individual liquidity risk) is *per se* not a cause of concern for policy makers. The problem arises when funding liquidity risk is transmitted to more than one bank, i.e. when liquidity risk becomes systemic (market liquidity risk). In what follows we are going to see how individual funding liquidity risk can propagate to other banks and generate liquidity risk to the inter-bank and the asset market. We first explore the transmission channel from funding to market liquidity (see Figure 6).

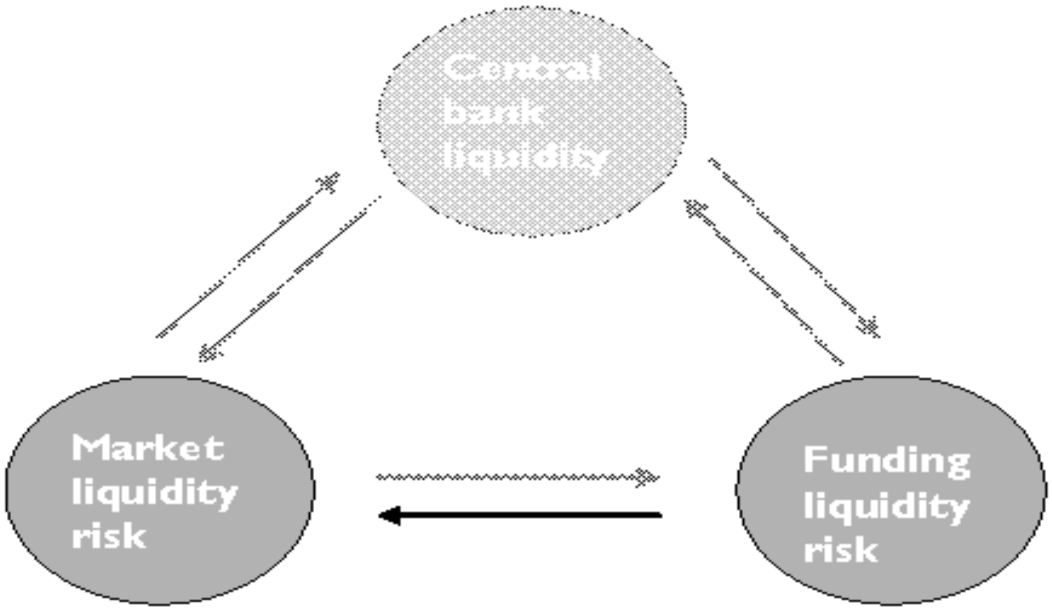

Figure 6: The link from funding liquidity (risk) to market liquidity (risk)

[31] For a further analysis of the literature see Freixas et al. (1999) and De Brands and Hartmann (2002).

Interbank market: Focusing on the interbank market, funding liquidity risk is directly linked to interbank market liquidity risk. As Diamond and Rajan (2001, 2005) explain, banks are linked by a common market for liquidity. Individual bank failures can potentially shrink the common pool of liquidity which links all banks together and therefore propagate the liquidity shortage to other banks through excessive early restructuring, causing a contagion of failures until a complete meltdown of the system. Such propagation mechanisms can work through the extensive interlinkages among banks. The latter relate to the highly inter-connected bank payment systems (see Flannery, 1996 and Freixas et al., 1999 for further references), to balance sheet linkages (see Cifuentes et al., 2005 and references therein) or, more generally, cross-holdings of liabilities across banks (be it deposits, interbank loans and credit exposures, or committed credit lines). Moreover, they can take the form of informational spillovers to the interbank market, leading to generalised bank runs[32]. In this setting, individual illiquidity can lead to market illiquidity.

Such interlinkages can become crisis propagation channels in the presence of incomplete markets and asymmetric information. This is because in the face of such interlinkages the absence of a complete set of contingent securities (i.e. it is not possible to hedge against future liquidity outcomes) may combine with information asymmetries about the solvency of the banks (i.e. it is not possible distinguish whether a bank is illiquid or insolvent) and stimulate fears of counterparty credit risk (Allen and Gale, 2000; Drehmann et al., 2007; Brusco and Castiglinesi, 2007 and Strahan, 2008). Against this background, moral hazard may arise as insolvent banks may act as merely illiquid banks and decide to free-ride on the common pool of liquidity in the interbank market. These banks can then engage in risk prone behaviour by under-investing in liquid assets (Bhattacharya and Gale, 1987) and gambling for resurrection (Freixas et al., 2004). Ultimately, this can lead to adverse

[32] Aghion, Bolton, and Dewatripont (2000) show that, if banks are linked by the interbank market and aggregate liquidity shocks are sequentially correlated, a run on a single bank serves as a signal for depositors of other banks to withdraw, triggering the collapse of the entire banking system.

selection in lending, i.e. a situation where insolvent banks (mistaken for simply illiquid banks) will be granted liquidity, whereas solvent but illiquid banks will not. Adverse selection in lending can translate into limited commitment of future cash flows (as in Hart and Moore, 1994, and Diamond and Rajan, 2001) and uncertainty about future lending due to counterparty credit risk (Flannery, 1996). It may also take the form of liquidity hoarding, because of concerns about counterparty solvency (e.g. Rochet and Vives, 2004), or doubts about their own ability to borrow in the future (Freixas et al., 2004; Holmström and Tirole, 2001). Overall, some banks are rationed out of the system. The few remaining surplus banks may take advantage of their oligopoly power and strategically under-provide lending in order to exploit the others' failure (Acharya, Gromb and Yorulmazer, 2007) thereby aggravating the illiquidity in the interbank market, or short-squeeze the liquidity-thirsty banks, thereby increasing the cost of obtaining liquidity (Nyborg and Strebulaev, 2004).

Asset markets: Asset markets can be another propagation channel from funding liquidity risk to market liquidity risk. With the interbank market liquidity-providing channel severely impaired, liquidity risk might immigrate to the asset markets as banks may seek liquidity through fire-sales, which will impact on asset prices and asset market liquidity. The propagation runs through the asset side of banks' balance sheets, given that banks will need to restructure their portfolios and therefore will need to find buyers for their distressed assets in order to avoid costly project liquidation (Rochet and Vives, 2004). In an environment of incomplete markets, the supply of and demand for liquidity are likely to be inelastic in the short-run and financial markets may only have limited capacity to absorb assets sales (Allen and Gale, 2004, 2005; Gorton and Huang, 2002). This can result to increased volatility of asset prices (Allen and Gale, 2005), a reduction in market participation due to increased uncertainty (Easly and O'Hara, 2007), and distressed pricing, where the market for assets clears only at fire-sale prices as asset prices fall below their fundamental value in certain states (Allen and Gale, 1998).

3.2.3 The loop between market and funding liquidity

Up to know, we investigated the transmission channels from funding to market liquidity. However, it is easy to see that second round effects help create a loop between market and funding liquidity (from market liquidity back to funding liquidity and back again), leading to downward liquidity spirals (see Figure 7). In that sense, the final outcome can far outweight in magnitude the original shock.

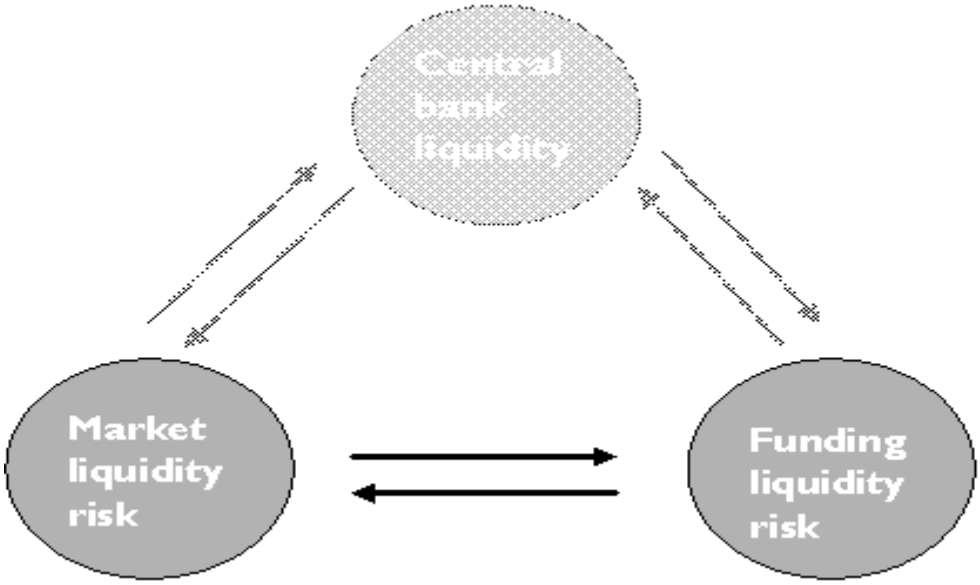

Figure 7: The interaction between funding and market liquidity (risk)

Second round effects: The strong linkages between market and funding liquidity can cause second round effects, which may deepen market illiquidity. This can happen in a financial system where assets and balance sheets are marked-to-market and subject to regulations. Asset price changes show up immediately in changes in net worth of the balance sheets and elicit responses from financial intermediaries who adjust the size of their balance sheets according to their leverage targets, thereby effectuating a speedy transmission of the feedback effect (Adrian and Shin, 2007). In the new prices, externally imposed solvency constraints, the internally imposed risk controls or regulatory considerations such as capital adequacy

ratios for banks may bind[33], thereby dictating further asset disposals (Cifuentes et al., 2005). Distressed pricing can become worse due to further frictions in trading, borne by trading regulations, limits to arbitrage and predatory trading renewing the circle and causing downward spirals in asset prices[34]. In this way, the combination of mark-to-market accounting and regulatory constraints has the potential to induce an endogenous response that far outweighs the initial shock. The loss and resulting funding liquidity risk in the single bank can be transmitted to its creditors, thereby leading to interbank liquidity risk, which could urge a new round of asset sales (Cifuentes et al., 2005) and further distress pricing. In that sense, the interaction between funding and market liquidity can lead to a dangerous downward liquidity spiral in the markets.

Furthermore, the new business model of credit, through an increase in securitisation, has strengthened linkages between market and funding liquidity, leading to more direct contagion channels and faster transmission of second round effects from asset markets to funding liquidity and vice-versa. The effects of securitisation can be twofold. On the one hand, it is an important source of funding for the bank and a broadly used tool to manage its funding liquidity risk (by transferring credit risk off its balance sheet). Moreover, it helps to complete markets, by creating a larger and more disperse pool of assets, which satisfy various risk appetites. On the other hand, it has reduced the fundamental role of liquidity transformation traditionally performed by banks. In the current design, banks originate assets and

[33]Bank capital regulation, especially when it is risk-based, has the drawback that requirements bite in recessions, when bank lending may need to be encouraged and tend to be slack in economic upturns when bank lending may need to be reined in.

[34]The relevant literature has recorded breakdowns in arbitrage when most needed (Schleifer and Vischny, 1997), while a breakdown in cooperation between traders can lead to predatory trading practices which aggravate illiquidity conditions in the short run (Brunnemeyer and Pedersen, 2005; Carlin, Lobo and Viswanathan, 2007). Such situations prevent prices from adjusting to their fundamental value. The uncertainty over the causes of deviations from fundamentals can unease traders who will react with raising margins. In so doing, initial liquidity shocks can be amplified because higher margins require further asset sales and result to illiquidity spirals (Brunnemeyer and Pedersen, 2007).

act as market-makers in order to distribute them. As a result, they have to adopt expertise on such things as pricing models, while becoming increasingly dependent to market institutional factors, such as credit rating agencies. Therefore, securitisation has made banks more dependent on market funding, market structures and workings. Notably, the banks' incentives and ability to lend are expected to depend on financial market conditions to a larger extent than in the past, when banks were overwhelmingly funded via bank deposits. The connection between funding liquidity (risk) and market liquidity (risk) is, therefore, tighter under this new design and risks are transferred in a more direct way (see ECB, 2008a; Ferguson et al., (2007) and Brunnemeier (2008) for an in depth analysis on the effects of securitisation). This makes the link between funding and market liquidity more tenuous and can therefore ease the evolution of downward liquidity spirals.

3.2.4 The role of the central bank

Up to now we have discussed that funding liquidity risk is endogenous in the banking system and that under incomplete markets and asymmetric information a vicious circle can be created between funding and market liquidity, potentially leading to systemic failures within the financial system. Such coordination failures and contagion effects have been shown to be potentially costly (Aharony and Swary, 1983; Herring and Vankudre, 1987; Saunders, 1987), lending support to the usefulness of supporting ailing institutions. The central bank should be in a position to tackle systemic liquidity risks in its role of guarantor of the entire economy (and not only for parts of the banking system) and in its capacity as the originator of the monetary base (see Section II). It is therefore charged with preventing panic-induced collapses of a banking system and minimising the costs of bank runs and forced liquidations through its interventions (for a discussion on the traditional role of a central bank see Thornton, 1802; Bagehot, 1873; and Humphrey and Keleher, 1984 in Goodhart and Illing, 2002). The role of the central bank is unique due to its

size and its immunity to bankruptcy (Flannery, 1996; Goddhart, 2008), but also because it is the only agent interested in maintaining aggregate welfare, having in its disposal the mechanisms to enable market stabilisation. These mechanisms are liquidity provision mechanisms, including emergency liquidity provision (i.e. acting as a Lender of Last Resort -LLR), complementary to which, they can also mobilise their supervisory and regulatory role. Overall, there is no doubt that the central bank has the ability and the right to provide emergency liquidity assistance (LLR).

However, there are certain limitations to central bank interventions, which make them an inadequate tool *per se* to tackle financial crises. To begin with, their role focuses on shock-absorbtion and not on shock-prevention. In other words, a central bank does not prevent all shocks to the financial system, but rather minimises the secondary repercussions of these shocks (avert contagion, spillover or domino effects). Moreover, it can be seen only as a short-run stabilisation function (see relevant discussion in Humphrey and Keleher, 1984)[35]. In terms of our simple illustration of liquidity linkages, this would suggest that central bank interventions can provide temporary injections of liquidity which would aim to break the loop between market and funding liquidity risk, so that downward liquidity spirals would fail to further distress markets (see Figure 7)[36].

The scope and the merits of emergency central bank liquidity assistance become murkier when one considers the conditions under which the bank should lend in

[35]Humphrey and Keleher (1984) review the role of central bank emergency liquidity aid. They view the role of the Lender of Last resort (LLR) as mainly to promote monetary stability, i.e. prevent credit/debt contraction from producing monetary contraction. They support the line of reasoning of Thorton and Bagehot, who suggested a policy of lending freely to the markets. It should be noted that this was equivalent to "unsterilised" interventions, which inevitably increased the amount of money in the economy. They therefore note that the LLR function can only act as a short-run stabilisation function which need not necessarily conflict with longer-run central bank objectives. In other words, the LLR actions should stop any crisis within a short period of time, before the supply of high powered money (central bank liquidity) strays far of its stable long-run path.

[36]Looking at Figure 6, this would suggest that central bank interventions aim to insulate the effects of liquidity risks within each node (funding liquidity and market liquidity) and break the link between the two nodes.

cases of crises, i.e. the optimal intervention policy. The basis of discussion goes back to the argument of Bagehot (1873) who expressed the fundamental, classical view on this issue. He argues that the central bank should **be known** to **be ready to lend** without limits **to any solvent bank against good collateral** and in **penalty rates**, so that banks do not use them to fund their current operations. However, a lot of research and experience have been accumulated since Bagehot and the points in his principle have been questioned and re-visited. A naive one-rule-fits-all intervention policy is no longer considered, rather, intervention policies appear in practice to be tailor-made. The Appendix of this project attempts to shortly review the debate on the Bagehot principle, address a few more relevant issues (such as the role of monetary policy and the issue of lending to the markets versus lending to individual institutions) and discuss the dilemma faced by policy makers with respect to intervention policies.

The crux of the problem faced in central bank interventions lies on information asymmetries that hamper the distinction between illiquid and insolvent banks. More specifically, the inability to distinguish between illiquid and insolvent borrowers can create bidirectional links from central bank liquidity to funding and to market liquidity, and also hurt the central bank itself. The link to funding liquidity is direct. By rescuing undeserving institutions (i.e. insolvent institutions) the central is implicitly penalising solvent but illiquid banks mainly because it increases their costs of funding. This could render them unable to borrow or to repay the loan, thereby enhancing their funding liquidity risk (For more information see Flannery (1996) and the argument of Goodfriend and King (1989) on "**Should a central bank lend only to solvent banks?**" in the Appendix). The link to market liquidity risk is also direct if we consider that the central bank provision can be seen as an insurance or safety net for institutions. A mis-allocation of central bank liquidity can promote excessive risk taking by banks and create moral hazard, as it would stimulate risk-prone behaviour by insolvent banks and the tendency

to gamble for resurrection with central bank money. As a result, it could favour current and stir future liquidity crises (through the adverse selection mechanism in lending already discussed in Section 3.2.3). Finally, lending to undeserving institutions could ultimately turn against the central bank's own stabilising role. This happens because the recovery of the financial system could be more uncertain, lengthy and costly and the central bank would be faced with increased costs of maintaining the financial safety-net. In a more practical level, liberal central bank liquidity intervention policies can increase credit risk in the central bank's portfolio (depending on the collateral that it accepts), and increase the risk of compromising its monetary policy objectives.

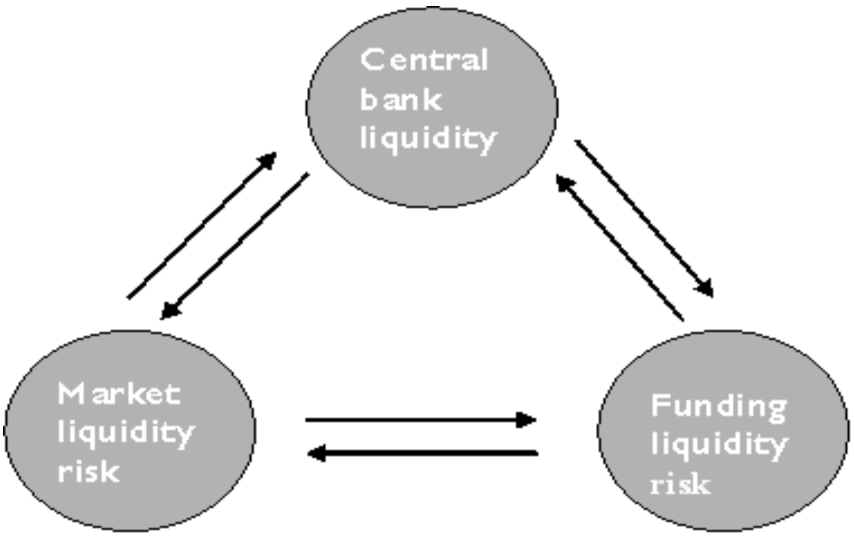

Figure 8: Liquidity (risk) linkages within the financial system

Overall, the role of central bank liquidity in situations of high liquidity risk is tedious. The central bank is not in a position to address the causes of liquidity risk, rather its function is itself hampered by incomplete information. In that sense, the role of central bank liquidity in cases of crises is not structural, rather it is a temporary support to the financial system, until the structural causes of liquidity risk can be dealt with. In essence central bank liquidity in turbulent times attempts

to break the vicious circle between funding and market liquidity through temporary liquidity injections to the system. This aid can be offered swiftly and promptly, until other more time-demanding tools (namely supervision and regulation) can be allowed the necessary time to focus against the causes of risk. This aid can be important, but it definitely is not a panacea. In fact, it is does not even offer guaranteed success, because the causes of liquidity risk can hurt the stabilising role of central bank liquidity and in fact produce the opposite effects, as already discussed. In this case, not only the vicious link between funding and market liquidity risk is not broken, but a full vicious circle is established in the financial system, that feeds from central bank liquidity (Figure 8).

3.2.5 The role of supervision and regulation

In turbulent times the role of supervision and regulation can be very important. Effective supervision (be it in the form of interbank peer-monitoring strategies[37] or official, centralised supervision) can balance information asymmetries because it facilitates the distinction between illiquid and insolvent banks (Freixas et al., 2004). Moreover, in the presence of effective regulation, the implementation of supervision can be safeguarded and supported and its effectiveness fostered (see for example Rochet and Tirole, 1996)[38]. In addition, efficient supervision and effective regulation can help the development of new financial products which would enlarge the pool of assets for various risk appetites and help to complete markets. In that sense, supervision and regulation can directly act against the causes of liquidity

[37] Peer monitoring among banks is considered important because of the large and unsecured nature of the inter-bank loans. Also, inter-bank lending relationships are perceived to help overcome agency problems. Failure of effective peer monitoring induces moral hazard and can lead to systematic illiquidity. Several papers in the literature focus on the role of peer monitoring in interbank markets (see Rochet and Tirole (1996) and Freixas and Holthausen (2005) for theoretical models based on this assumption, and Furfine (2001) for empirical analysis in support of the assumption).

[38] Rochet and Tirole (1996) show that the effective implementation of peer monitoring among banks may be difficult, due to commitment problems by governments. Liquidity requirements (regulation) may be a useful way to mitigate these commitment problems (See also Rochet and Vives, 2004).

risk[39].

With efficient supervision and effective regulation in the picture, the role of central bank liquidity can be recast in their shadow. Namely, central bank liquidity can act as a first buffer against the problems caused by liquidity risk and try to cope with breaking or halting the vicious circle between funding and market liquidity. In the mean time, supervision and regulation would tackle the sources of liquidity risk, namely asymmetric information and incomplete markets in order to both, quench the current crisis and also minimise the possibility of having future ones. To the extent that liquidity risk is endogenous in the financial system both the scope and the efficiency of central bank liquidity will always depend on the quality of supervision and regulation in the system. In the best case scenario, where supervision and regulation would minimise information asymmetries and enhance market completeness, the turbulent scenario described in this section would be avoided and the role of central bank liquidity intervention would be redundant.

Nevertheless, the implementation of efficient supervision and effective regulation is not a trivial issue. Among other reasons, this is because gathering information for supervision and establishing, implementing and monitoring regulation can be very costly. Market discipline can be imposed unofficially by peer monitoring of agents, as in the case of Goodfriend and King (1989), who suggest that deregulated markets can, through their financial instruments and practices successfully discipline themselves in order to provide well-functioning markets. In such cases, the central

[39]Note that ineffective regulation can lead to distorted outcomes. For example, it can increase systemic liquidity risk (as it can happen with the deposit insurance scheme, which can potentially encourage risky investments by banks). For example Pennachi (2006) argues that while a government deposit guarantee may produce risk-sharing benefits, the current methods for pricing this guarantee and for regulating banks are leading to new forms of moral hazard that kill off efficient private financial innovations. Moral hazard is created because insurance mis-pricing and capital regulations have the effect of subsidizing systematic risks. Moreover, regulation could cause problems when it becomes binding in turbulent periods where more lenience is needed (Cifuentes et al., 2005). Finally, the current market turmoil also reveals the frailty of certain regulatory measures, such as relying too much on market structures (i.e. rating agencies) for pricing instruments and risk (see footnote 44). It is, therefore, important to stress the need for effective supervision and efficient regulation.

bank intervention would be redundant and potentially disruptive for the incentive system developed. Rochet and Tirole (1996) have argued in favor of collateralising inter-bank lending and increasing the responsibility of banks, through insurance and transferring costs of failure to the originating banks (see also Goodhart, 2008). However, in cases where central bank intervention is deemed necessary (i.e. in cases of failures in the interbank markets) Rochet and Tirole (1996) are in favor of centralising liquidity management via the central bank. Other authors propose the establishment of official regulation and supervision, centralised in the hands of the central bank. This centralisation would promote better transparency and create economies of scale in acquiring information, which would lower the cost of monitoring banks, make it easier to distinguish illiquid from insolvent agents and therefore reduce the costs of central bank intervention. Moreover, it would, arguably, better insulate the financial system against coordination failures at early stages, therefore helping to eliminate systemic liquidity risk.

4 A description of the current turmoil

The whole discussion above could be merely academic, but recent events in financial markets seem to validate the theoretical reasoning presented. In what follows we are going to give a short description of the recent events and discuss them in the light of the literature presented above.

In order to understand the events, a simple snapshot of financial engineering workings in modern banking is needed. In the new banking environment of "originate and distribute", banks originated loans (in the forms of mortgages and other assets), repackaged the cash-flows generated by these loans in Mortgage Backed Securities (MBSs) and Asset Backed Securities (ABS)[40], and sold-on (distributed) these securities to investors. The selling in most cases was not direct, but via Special

[40] An ABS is essentially the same thing as a mortgage-backed security (MBS), except that the securities backing it are assets such as loans, leases, credit card debt, a company's receivables, royalties and so on, and not mortgage-based securities.

Purpose Vehicles (SPVs) (conduits or Special Investments Vehicles, SIVs)[41], thereby appearing as off-balance sheet liabilities of the bank. In their turn, the SPVs held the ABSs and issued (short-term) Asset-Backed Commercial Paper (ABCP)[42] to fund potentially illiquid longer-term securities. Given the maturity mismatch of this investment, sponsoring banks had undertaken to provide them with backstop liquidity via credit lines, if required. This highly complicated structure created liquidity by banks and satisfied various degrees of investor's risk appetites, but was sensitive, as proved, to stress in the economy (for an analytical exposition of the causes and events, see ECB, 2007).

Such stress originated with the sharp decline in the credit quality in US subprime mortgage markets, due to an increase in the number of delinquencies already from early 2007, which impacted on the fundamentals of structured credit instruments. The subsequent rating downgrades and the realisation that risk assessment and pricing methods for such complex instruments were inadequate, increased uncertainty related to the fundamentals of ABSs and created market (trading) frictions and translated to wide spreads up to the point where ABS markets dried-up. As a result there was a sharp decline in the issuance volumes of Collaterised Debt/Loan Obligations (CDOs/ LDOs), which, amid growing uncertainties towards such instruments, lead to widespread refusal by investors to maintain their ABCPs when they matured. This lead to refinancing problems of the SPVs, which had to draw on their committed credit lines from their sponsoring banks. Given the aggregate large exposures, emergency rescues from a number of other banks had to be arranged. As a consequence a number of credit institutions failed, large global palyers among them (IKB, Northern Rock, Sachsen LB, Bear Stearns, Lehmann Brothers), others well sold (Merryl Lynch), and others received large capital injections by governments (AIG, Citigroup, Fannie Mae, Freddy Mac, Indie Mac, Dexia, Fortis, HypoVere-

[41] A discussion of the differences between a conduit and an SIV can be found in ECB, 2007 (FSR, Dec 2007, Box 8).

[42] Asset-backed Commercial Paper (ABCP) is corporate debt that is due within a year, and is backed by assets.

insbank. Yet more credit institutions post profit warnings and record credit losses (UBS, Deutsche Bank. etc). Eventually, banks with liquid balances tended to hoard liquidity, for fear of counterparty credit risk and uncertainty about the amount of liquidity in their balance sheets. This situation caused a serious deadlock to the interbank (unsecured) market, with banks not being able to get funding for terms longer than one or two weeks. As a result, money market spreads shot up, which made central bank intermediation necessary[43].

Central banks around the globe reacted differently by changing their operational framework, or changing their monetary policy stance or both. Common reactions from major central banks (the ECB, the Fed and the BoE) included the provision of extraordinary amount of liquidity to the markets through a combination of long-term and short-term open market operations, as well as through internationally coordinated actions (i.e. currency swap agreements between the ECB and the Fed). In the case of the ECB, an active liquidity policy based on clear front loading of reserves via main refinancing operations gave way to the temporary introduction of fixed rate - full allotment liquidity in their main refinancing operations and a narrower corridor of standing facilities. The BoE, after an initial period of non-responding to the turmoil, was forced by the circumstances into intervention after the hit on Northern Rock (a solvent, but illiquid mortgage lender, who suffered a run). It responded by exploiting the flexibility of its operational reserve framework. The Fed's reaction was to slash interest rates, while providing ample liquidity both through changes in the discount window (TAs) and OMOs. Discussions about the stigma related to TAs (i.e. the use of the discount window or the marginal lending facilities) emerged, especially for the case of the US. Overall, this experience was effectively a stress testing on the liquidity management of the central banks, given their need to adjust their liquidity provision practices to rapidly and unexpectedly changing demand patterns.

[43]For a more intricate analysis of the causes and the development of the early stages of the turmoil, see ECB (2008).

It should be straightforward to recognise the mechanisms at work already described in the sections above. To begin with, the roots of liquidity risk stem from securitisation practices combined with the market's inability to keep up with them in terms of risk assessment, pricing and management. This combination ultimately enhanced rather than subdued information asymmetries concerning these instruments and their distribution of risks in the financial system (i.e. where do the risks in the financial system end up?). Moreover, although markets became deeper, serving wider and increasing investment risk appetites, they were still short of becoming more complete, as was clear from the downturn during the turmoil.

The link between funding and market liquidity risks in the new business model of banks become apparent. Funding liquidity risk, borne by incomplete markets and asymmetries in information relating to these new financial products, lead to moral hazard in investing, i.e. to a situation where banks economised on costly liquid assets, while investing on illiquid and riskier assets. This lead to coordination failure among both depositors (i.e. the bank run on Northern Rock) and, predominantly, among market participants (both interbank and the asset markets for structured products), resulting into market liquidity risk. Behind the deadlock in the money markets lie the already discussed adverse selection problem borne by uncertainties about counterparty credit risk and about their own exposure borne by market valuations. At the same time, asset markets experienced typical symptoms such as fire sales and trade frictions (due to margin calls, trader's risk limits, thinning of trading volumes etc.). This has facilitated second round and spiralling effects, which enhanced the fast propagation of risk between funding and market liquidity. Essentially, funding liquidity risk spread to the ABS market, from there to SPVs funding liquidity, which lead to ABCPs market liquidity risk. Then risk moved back to banks' funding liquidity, propagating itself to the interbank market liquidity. These multiple round effects were repeated and enhanced in each round, creating downward spirals in liquidity, which brought asset and interbank markets

to a deadlock, while drying up funding liquidity for many institutions.

Finally, the important role of central bank liquidity, as well as its limits were also highlighted. In the absence of a well-functioning interbank market central banks faced signs of increasing instability in the financial system and raising money market rates. Their reaction was to intervene by offering liquidity into the money market, although the aim, methods and effectiveness of the major central banks were quite different. Abstracting from criticising the decisions of each bank, their reactions showed that one rule cannot serve all, as indeed is the suggestion of the relevant literature. However, the limits of central bank intervention also sprung up. Namely, although the operating toolbox of banks was in many cases reshuffled and extended, it became clear that central bank interventions alone cannot stabilise the situation in an environment of such intense information asymmetry and adverse selection. More than a year after and the turmoil is not dented yet, while banks appear to be increasingly reliant on central bank money. The role of supervision and regulation is brought forward once more, and already, corrective actions in the regulatory and supervisory framework of financial markets and banks in particular are being discussed at a high (global) level in order to establish better transparency in the banking system in order to face the root of liquidity risk[44].

5 Policy recommendations and conclusions

The above analysis provides useful policy considerations:

- Within the financial system one can distinguish three broad liquidity types, the central bank liquidity, the funding liquidity and the market liquidity. These liquidity types sufficiently capture the workings of the financial system (at an aggregate level).

[44]It is nevertheless argued that ineffective regulation also played a role in the current turmoil. Basel III had arguably put a lot of weight on rating agencies in the risk assessment of innovative financial products. As already discussed, the rating agencies did not manage to keep up with the evolution of the products and their increasingly complicated nature, thereby enhancing mispricing and market illiquidity, when their mistake was realised. Therefore, the need for effective regulation should yet again be stressed.

The linkages among these liquidity types are complex, dynamic and strong and can have positive or negative effects on financial stability. In smooth financial periods the effects are positive and help to redistribute liquidity in the system in an efficient and unobstructed way, so that, overall, liquidity does not matter. It is merely the oil greasing the wheels of the financial system, so that they function frictionless and costless. Nevertheless, smooth periods do not last for ever.

- Turbulent periods, which relate to heightened liquidity risk, appear in a rare and episodic, yet intense manner and can destabilise the financial system. The causes of liquidity risk lie on departures from the complete markets and symmetric information paradigm, which can lead to moral hazard and adverse selection. To the extent that such conditions persist, liquidity risk is endemic in the financial system and can cause a vicious link between funding and market liquidity, prompting systemic liquidity risk. The latter is exactly this type of market risk that typically alerts policy makers, because of its potential to destabilise the financial system. In such cases emergency liquidity provisions can be a tool to restore balance.

-The central bank has the ability and the obligation to minimise the real costs of liquidations and the probability of a financial system meltdown. However, the role of central bank liquidity in such turbulent periods does not have guaranteed success, as it cannot tackle the roots of liquidity risk. In essence, it only focuses on halting (temporarily) the vicious circle between funding and market liquidity. However, its function can be hindered by the same causes of liquidity risk. The crux of the problem lies on the fact that the central bank cannot distinguish between illiquid and insolvent banks with certainty. Therefore, by providing liquidity to undeserving institutions it could potentially cause further damage to the system. This may happen because it actually hurts the funding liquidity of solvent but illiquid banks, the prospects of market liquidity (by risking to demoralise the financial system and thus increase systemic liquidity risk) and its own functions (i.e. by admitting counterparty credit risk in its portfolio or risk its monetary policy objectives). In

that case, a full vicious circle running through central bank liquidity is established in the financial system liquidity. The tradeoff between the benefits and costs of intervention should be taken into account when the central bank has to decide on its liquidity providing strategy. This task is not easy and there is no established rule of thumb.

- In order to eliminate systemic liquidity risk, greater transparency of liquidity management practices are needed. Supervision and regulation are the fundamental weapons against systemic liquidity crises. These practices can tackle the root of liquidity risks by minimising asymmetric information and moral hazard through effective monitoring mechanisms of the financial system. In this way it is easier to distinguish between solvent and illiquid agents and therefore impose liquidity cushions to the ones most in need. This would also help markets become more complete. In the best case scenario, when such mechanisms function effectively, the role of the central banks as a liquidity provider could be redundant (market discipline would be sufficient). However, such mechanisms can be costly, due to the amount of information that needs to be gathered. They should, therefore, be run by the most cost efficient and result-effective agent. If market discipline is not enough to install its own peer-monitoring rules and regulations at a lower cost, they should be managed by the central bank.

- Last, but not least, this project has demonstrated the importance of liquidity risk in the financial system stability. Liquidity risk can always be present and therefore should be clearly taken into consideration (priced) in policy relevant variables needed to draw conclusions on monetary policy strategy. The need to do that is most important during turbulent times, when liquidity premia increase and therefore the information from asset prices, relevant for the policy makers, is distorted if these premia are not properly accounted for. However, measuring such liquidity premia becomes even harder during such periods, due to the stochastic nature of feedback effects and amplification mechanisms at work during such periods, which increase the complexity of liquidity flows in the system.

Appendix

The scope of central bank liquidity intervention and the nature of optimal intervention policies has received considerable amount of attention in the literature. The basis of discussion goes back to the argument of Bagehot (1873) who expressed the fundamental, classical view on this issue. He argues that the central bank should **be known** to **be ready to lend** without limits **to any solvent bank against good collateral** and in **penalty rates**, so that banks do not use them to fund their current operations. In what follows we are going to review the opinions offered by the existing literature on each of the above issues in an effort to see where we currently stand[45].

Should a central bank be ready to lend? Goodfriend and King (1988) introduce a line of research suggesting that the central bank is by no means more effective in offering emergency liquidity assistance in the presence of a well functioning, deregulated, uncollateralised interbank market. Such a market can better cope with the issues of asymmetric information and moral hazard, because effective peer monitoring can introduce market discipline and accumulate information about the liquidity and solvency status of a bank in a more cost efficient way than central bank supervision. Widespread costly liquidations and systemic risk could rationalise intervention, however, it is not always clear ex-post whether disruption costs associated with costly liquidations are big enough. Moreover, intervention policies targeted at promoting financial market stability can encourage risk taking (moral hazard) and lead to the deterioration of private liquidity provision (adverse selection), when the central bank cannot distinguish between illiquid and insolvent banks. Under these conditions, the need of central bank intervention policies to avoid short term but widespread costly liquidations or in the face of systemic risk is not explicit.

[45] See Freixas et al. (1999) for an interesting literature review on issues related to the need, the role and the effects of the central bank as a LLR.

The reasoning of Goodfriend and King is valid, provided that interbank markets work effectively. Nevertheless, a long strand of research provided evidence that central bank intervention is needed when the interbank market fails to redistribute liquidity in the system (Flannery, 1996; Freixas et al., 1999; Freixas et al., 2004) and costly liquidation (costs of bank runs) is involved (Allen and Gale, 1998; Acharya et al., 2007). In such cases, the central bank should intervene despite the potential moral hazard and the credit risk that the central bank may assume.

Should a central bank *be known* to be ready to lend? Linked to the discussion of whether the central bank should intervene is the question of "constructive ambiguity" versus the intervention pre-commitment. The dichotomy between them is propelled by the feedback effect from liquidity provision to risk-taking incentives of financial intermediaries. The argument goes as follows: A pre-committed central bank emergency liquidity provision may act as a public insurance against aggregate risk in an incomplete market economy. In other words, it may increase expectations that the institution is insured against mismanagement of virtually all types of risk, including credit and market risk (Freixas et al., 1999). This could increase the incentives of financial intermediaries to free ride on liquidity by investing more on risky, high-yield investments (Repullo, 2005)[46]. Such investments could, on the one hand increase the capital stock and therefore the output of the economy in good states (Sauer, 2007), but could result to excessively low liquidity in the bad states due to dynamic consistency problems (Cao and Illing, 2007) and a deterioration of private liquidity provision (Goodfriend and King, 1988). "Constructive ambiguity" with respect to the conduct of the central bank in crisis situations should strengthen market discipline and mitigate the scope for moral hazard, in contrast to a committed bailout policy. It should be particularly effective in reducing moral hazard if coupled with procedures for punishing managers and shareholders for imprudent

[46]Indeed, the presence of a LLR is shown to influence the level of the optimal buffer of liquid assets. In fact, the share of safe assets in the bank's portfolio decreases with the introduction of a LLR. Gonzalez-Eiras (2003) provides empirical support for this line of reasoning.

management (Freixas et al., 1996)[47].

The literature provides mixed suggestions over the issue. A number of studies endorse the constructive ambiguity discipline (Freixas, 2000; Freixas et al., 2004), where the bank optimises ex-post, given the costs related to rescuing policies or the source of moral hazard[48]. However, Easly and O'Hara (2007) suggest that ambiguity is in fact not constructive, because uncertainty could reduce market participation and further exacerbate illiquidity. Flannery (1996) also supports pre-commitment but for different reasons. He argues that in the absence of well-functioning inter bank markets the central bank should be subsidising liquidity and should pre-commit to offer it. Finally, Rochet and Vives (2004) present a compromising view. They argue that in one type of equilibrium, the LLR policy is efficient if the central bank can commit. If it cannot and instead optimises ex-post, it will end up intervening too often.

In any case, the decision of pre-commitment is tightly linked to the decision of the lending rate, because the moral hazard could be overcome by lending at penalty rates (Bagehot, 1873). We are, therefore turning our attention to this question.

Should a central bank lend at penalty rates? This question would be irrelevant in the absence of moral hazard and adverse selection. Indeed, in such a situation central banks' help via the discount window lending should be at a very low rate whenever the bank is solvent. It avoids early closure and the central bank

[47] See Freixas et al. (1999) for a literature review on the sources and effects of moral hazard in central bank emergency lending and a more detailed discussion on the issue of constructive ambiguity versus precommittment.

[48] Freixas (2000) adopts a model where intervention is conditional on the amount of uninsured debt issued by the defaulting bank. Yet in equilibrium, because the rescue policy is costly, the central bank will not rescue all the banks that fulfill the uninsured debt requirement condition, but will follow a mixed strategy, thereby adhering to the creative ambiguity property.

Freixas et al. (2004) stress the importance of costly screening of loan applicants, which results at insolvent banks posing as illiquid banks and trying to "gamble for resurrection" (i.e. invests in projects of negative net present value). In such cases it may be desirable for the central bank to intervene as a Lender of Last Resort so as to appease the problems of insufficient supervision (i.e. limit the excessive liquidation of assets by illiquid banks). If the screening is successful (i.e. supervision is sufficient) then interbank market can efficiently peer-monitor borrowers and there is no role for an LLR.

loses no money because the loan can be repaid (Rochet and Vives, 2004). In the presence of moral hazard, however, insolvent banks may pose for merely illiquid banks. The argument goes that penalty rates would discourage insolvent banks from borrowing as if they were merely illiquid (Freixas et al., 2004). It therefore acts as a mechanism of discerning illiquid from insolvent banks. Nevertheless, there are arguments against lending at penalty rates. Goodfriend and King (1988) argue that it increases the cost of liquidity for illiquid but solvent banks, which can render these banks unable to repay (Flannery, 1996)[49]. This will increase the cost of intervention for the central bank (Flannery, 1996), but can also aggravate the bank's crisis: It can send a negative signal to the market, which may precipitate an untimely run or give managers the incentive to "gamble for resurrection" (Freixas et al., 1999). Such costs however depend on the ability of the central bank to discern illiquid from insolvent banks, an issue that lies in the heart of the optimal intervention policy discussion.

Should a central bank lend only to solvent banks? Lending to solvent banks would be optimal because it would minimise costs of intermediation and reduce moral hazard. However, Goodhart (1987) implies that this condition is difficult to satisfy, if only because it is difficult to discern illiquidity from insolvency. A number of reasons can make screening difficult, for example insufficient information on the bank in need, especially given the need for fast and timely action in crises periods, ineffective monitoring or uncertainty on the time horizon over which an illiquid bank can ultimately become insolvent (Freixas et al., 1999). Whatever the reason, the problem of screening is the crux of the central bank lending. As Goodfriend and King (1988) argue, in a world of perfect and costless information, illiquid banks would be distinguished from insolvent banks and would be able to borrow the present value of their expected income stream, discounted at a rate properly

[49] In fact, Flannery (1996) argues that in a crisis, when it may not be possible to discern solvent banks (i.e. even in the presence of moral hazard), the central bank must stand ready to subsidize credit, otherwise it may suffer a winner's curse, in the sense that solvent banks may not afford to repay, thereby increasing its cost of intervention.

adjusted for their individual risk. So any bank would be fully liquid, provided that it is solvent. However, with incomplete and costly information, it is only possible to lend to any bank at a pooled rate applying to all banks. This rate would entail a premium, related to liquidity risk due to asymmetric information. This could lead to adverse selection in lending, which would penalise solvent banks and induce further moral hazard related to risk-prone behaviour by banks. Therefore, screening loan applicants may not always be feasible and becomes a more severe problem in times of market distress, because of increased adverse selection (Flannery, 1996).

What should be the appropriate action in the absence of effective screening? Goodfriend and King (1988) suggest that the central bank should not intervene at all in such cases, leaving the interbank market to do the job. Freixas et al. (2004) argue that the interbank market may not be as efficient as Goodfriend and King suggests in screening loan applicants. In that case, there is a role for central bank emergency liquidity intervention, in order to appease problems of insufficient supervision (i.e. limit the excessive liquidation of assets by illiquid banks). Finally, Rochet and Vives (2004) argue that even if solvent banks cannot be distinguished, coordination failures in the interbank market can warrant the intervention of the central bank in ways that appear to contradict Bagehot's view, i.e. they identify cases when the central bank should be involved in early, corrective actions, even for insolvent banks and not at penalty rates. Along this line, Flannery (1996) also argues in favour of providing liquidity to all needy banks, as long as only very short-term, emergency loans are extended in cases of broad financial crises. In such cases, the potential benefits from the central bank loans far outweigh the likely damage to the banking system's risk-taking investments. Overall, the literature holds that, if illiquid banks cannot be distinguished form insolvent ones, it is better to lend to everyone, provided that social costs are high.

Should a central bank lend only against good collateral?

Lending only against good collateral could help screen insolvent from illiquid

banks, thereby reducing moral hazard in lending and minimise counterparty credit risk for the central bank. As Padoa-Schioppa (1999) mentioned, "the probability that a modern bank is solvent, but illiquid, and at the same time lacks sufficient collateral to obtain regular central bank funding is ...quite small." Indeed, the relevant literature seems to agree that central bank lending should be made against collateral, with only few exceptions[50]. However, there are issues pertaining to the composition and the market liquidity of the collateral.

Regarding the composition of the collateral, it is not clear whether central banks should only accept good collateral. Good collateral may not be abundant or available. In that case, accepting only good collateral or relatively simple and transparent instruments could ultimately come into conflict with the authorities' responsibility for financial stability, limiting their capacity to act as liquidity provider of last resort to the markets most in need (Eichengreen, 2008). The issue is, therefore, how far a central bank should widen the range of assets accepted as collateral[51]. It could be argued that the central bank can accept a wide range of collateral, because the central bank can rely on its outstanding currency liabilities to remain almost in perpetuity, therefore it can absorb market and liquidity risk (Goodhart, 2008). Moreover, allowing less liquid securities, or those denominated in other currencies, to be used as collateral at central bank lending facilities or in other contexts could also improve liquidity conditions (Caruana and Kodres, 2008), because the willingness of central banks to accept as collateral certain classes of assets will in turn affect the liquidity of such assets (Goodhart, 2008). The counter argument suggests that owing to asymmetric information, the central bank is likely to be offered the worst

[50] Flannery (1996) argues that a bank's decision to pledge collateral or sell assets can materially affect its unsecured creditor's ability to obtain repayment if the firm defaults, resulting to higher unsecured debt rates, which may depress banking firms values in other ways.

[51] A usual practice by banks is to cross pledge collateral. Such cross pledging is in general warranted, since it allows using diversification between different sources of risk for economizing on collateral. However, it requires sufficient independence between payment risks and other forms of liquidity risk, as well as a constant coordination between the Central Bank (who is sometimes in charge of monitoring the LVPSs) and the Banking Supervisors (Rochet, 2008)

such risk assets within the acceptable class held by the borrowing commercial bank. In that case, the central bank accepts credit risk, while allowing the bank to access the market with its better collateral (Goodhart, 2008). However, the general view holds that the central bank should be willing to accept some losses due to extended range of collateral, in order to address interbank market failures (i.e. hoarding of liquidity by a few market agents as described by Acharya, Gromb and Yorulmazer, 2008).

Moreover, the market liquidity of collateral may vary, which would affect the funding liquidity of banks. Regarding the market liquidity of collateral, in times of crises, collateral values tend to fall to only a fraction of their pre-crisis levels, when banks engage in fire-sales of their assets and collateral assets that back loans are marked to market. This makes collateral subject to systemic risk (Cifuentes et al., 2005). Changes in collateral values result to adjusted values for margin calls and haircuts (Brunnemeyer and Pedersen, 2007). Under such circumstances, banks are vulnerable to changes in the value and market liquidity of the underlying collateral, because they may have to provide additional collateral at short notice, which affects their funding liquidity risk (Flannery, 1996). The more widely collateralisation is used, the more significant this risk becomes, especially as market price movements result in changes in the size of counterparty credit exposures (IMF, 2008).

Should a central bank provide liquidity through targeted assistance (TA) or through Open Market Operations (OMOs)? By TA we mean liquidity support to individual institutions whereas OMOs refer to lending to the market as a whole. On a more technical level, TA refers to liquidity provision through the discount lending window (or marginal lending facilities), as opposed to a broad liquidity assistance though OMOs (or main refinancing operations -MROs- for the case of the ECB)[52]. Overall, both can induce moral hazard in different ways;

[52]There are substantial differences between the liquidity operational framework between the Fed and the ECB. In the Fed the discount window is distint as a monetary policy tool from open market operations. Only a few banks have access to it and the basic discount rate can be adjusted

however the choice between the two depends on the functioning of the interbank market and monetary policy goals of the central bank.

Starting with the arguments in favor of broad liquidity assistance, the main function of OMOs is the implementation of monetary policy, and they are alone sufficient for this purpose (Goodfriend and King, 1989). Therefore, OMOs make sense when the central bank needs to control market rates. This can be particularly important in cases of liquidity crunches when the elevated market rate increases liquidation costs (Rochet and Vives, 2004)[53]. It can also be rationalised in cases of generalised liquidity shortages, where support should be provided to the market as a whole (Freixas et al., 1999). Furthermore, broad liquidity provision can minimise the social costs borne from moral hazard, i.e. the risk-prone behaviour of banks that are inherent in TAs, when the central bank ends up supporting insolvent institutions (Kaufman, 1991 and Schwartz, 1992) or institutions which rely on TAs on the grounds that they are Too-Big-To-Fail (Rochet and Tirole, 1996; Freixas, 1999)[54]. Finally, it is interesting to note that Furfine (2001) provides empirical evidence of banks' reluctance to borrow from the discount window for fear of the stigma associated with it, an issue that is typically overlooked in the above models. Such a problem typically does not occur in OMOs. Nevertheless, lending to the market as a whole would mainly rely on the existence of a well functioning interbank market, which would effectively redistribute the liquidity in the system.

In the absence of such an interbank mechanism, the literature argues that TAs

from time to time in a more judgmental manner than the ECB marginal lending rate. In a sense, it is easier to see why the literature, which is based on US data, treats TA in the sense of borrowing from the discount window. Finally, note that in the case of the ECB, marginal lending facilities are included in OMOs. The equivalent of the US OMOs is the MROs of the ECB.

[53] However, the authors mention that if the central bank cannot distinguish between illiquid and insolvent banks, then a central bank is most likely to make losses, irrespective of the type of operation.

[54] A bank can be deemed too-big-to-fail when its failure may trigger a chain of subsequent failures. Goodhart and Huang (1999) produce a rational for the Too-Big-to-Fail doctorine, arguing that the threat to financial stability related to the size of the failed bank. However, in Rochet and Tirole (1996) this too big to fail policy can be avoided by subsidizing the troubled institution's counterparties instead of bailing out the troubled firm itself.

can be a more flexible and efficient way to tackle liquidity deadlocks. Notably, Flannery (1996) talks about distorted risk-taking investments induced by a policy of lending broadly to banks, regardless of their credit condition. He argues that OMO cannot replace TA, in cases of broad market crises, where the interbank market is severely impaired and cannot redistribute liquidity to market participants who really need it. In that case, OMOs would not solve the problem, whereas TAs in the form of discount window lending could assure the fastest and most cost-efficient means of resolving the crisis. In a similar note, Ewerhart and Valla (2008) show that open market operations would invite moral hazard, given that banks in distress and "greedy" investors would compete for excess funding provided during the crisis, given frictions in the interbank market.

What is the role of monetary policy stance in crisis periods? Liquidity implementation policies can act independent or not from the monetary policy stance. In crisis periods, the central bank might choose to change its stance, if the malfunctioning of liquidity linkages in the financial system is perceived to have an effect in the real economy or the long-term targets of the central bank (e.g. induce changes to the monetary policy strategy)[55]. On the other hand, a central bank may be reluctant to respond fully to large liquidity shocks, because of the risk of mitigating the final monetary policy targets, such as inflation levels (e.g. in cases of unsterilised liquidity interventions, Sauer, 2007), because of fearing the need to take opposite action at a later time, a practice that has been felt could provide mixed signals of the central bank's policy stance (Bartolini and Prati, 2003) or because of the risk of fuelling moral hazard in lending and thus encouraging further crises. More precisely, expansionary monetary policies in times of crises may propel moral hazard, resulting to aggressive search for yield by investors, increased risk appetite and over-investing, finally destabilising the financial system and creating vagabond-

[55]Thorbecke (1997) argues that monetary policy responds to macroeconomic rather financial factors. Eisfeldt (2004), however, develops a model where endogenous fluctuations in market liquidity are correlated with real fundamentals such as productivity and investment.

ing bubbles around the globe (Ioannidou et al., 2007; Kindleberger, 2000; Gunther and Hoffmann, 2007; ECB, 2007).

We focus on the role of the monetary policy in affecting market and funding liquidity during crises. As will be seen, monetary policy stance can affect market and funding liquidity and the other way round. Whether the central bank should separate the monetary policy stance from its liquidity implementation framework depends on the institutional set-up and the operational objectives of each central bank and are not discussed in this project.

Looking at the direction from monetary policy stance to market and funding liquidity, an accommodative monetary policy stance raises the supply of highly liquid assets and should lower the expected costs of converting less liquid assets into cash (Berger and Harjes, 2007), thereby stimulating funding liquidity and market liquidity. More precisely, a corrective monetary policy during a financial crisis could inspire confidence about the fundamentals of the economy, reduce the credit costs (and risks) of outstanding bank loans, loosen refinancing conditions (i.e. central bank liquidity) and help stabilise financial markets, thereby potentially reducing the causes of coordination failures and restoring the good functioning of liquidity linkages. At a microstructural level, monetary policy stance can enhance funding and market liquidity by loosening trading constraints during periods of market turbulence. More specifically, a loose monetary policy stance can affect liquidity by altering the terms of margin borrowing and alleviating borrowing constraints of dealers (Garcia, 1989), thereby reducing costs on margin loan requirements, and enhancing the ability of dealers to finance their positions (Brunnemeier and Pedersen, 2007). Subsequent fund flows into stock and bond markets can affect trading activity and thereby influence market liquidity (Chordia et al. 2005).

On the other hand, reduced liquidity and increased volatility could spur the central bank to soften or at least not toughen its monetary stance, to the extent that they have real effects on the economy (Chordia et al., 2005). Empirical evidence on

this front is, however, scant[56]. Following this line, Illing (2007) suggests that the central bank should lower interest rates to prevent fire sales of assets by distressed banks which have to restore their capital adequacy requirements in turbulent periods. Freixas and Jose (2007) argue against rate hikes in crisis periods, claiming that under asymmetric information in the interbank market the effect of a monetary policy tightening combines with quantity rationing in the bank loan market and reinforces each other, propagating larger shocks than merely the ones caused by the monetary policy. Nevertheless, looking at the longer run consequences, it might be that monetary policy stance creates an environment of cheap liquidity for everyone, thereby loosening market discipline and stimulating moral hazard in investing. As a consequence, more risky and therefore less liquid investments will be made, leading to future liquidity crises (Ioannidou et al., 2007).

The role of central bank: A review. Looking back to the analysis on the role of the central banks in crisis periods, we see that it is significant, but it does not necessarily have guaranteed success. More precisely, the main problem in providing emergency liquidity assistance by a central bank is that, in an environment of incomplete markets and asymmetric information the central bank can not distinguish between an illiquid and an insolvent bank. Under such conditions, the efficiency and effectiveness of any actions by the central bank will be constrained and uncertain[57]. Ultimately, it could be argued that the optimal rule for central bank intervention is decided on a cost trade-off analysis. From the one hand, the central bank faces the danger of welfare costs due to costly bank runs and forced liquidations. On the other hand, it has to be prepared to face spiralling costs linked to excessive risk-taking, the possibility of future liquidity crises (related to the moral

[56] Chordia et al. (2005) find evidence that policy stance declined significantly (by about 33%) in the crisis period relative to the non-crisis period, suggesting loosened monetary policy (in the US) is associated with a contemporaneous increase in equity market liquidity during crises.

[57] Acharya, Gromb and Yorulmazer (2008) argue that a Central Bank can tackle interbank inefficiencies by standing to lend to affected banks, provided it has greater information about banks (for example, through supervision) compared to the outside markets, or absent such information access, it is prepared to make some loss-making loans.

hazard problems), increased counterparty (credit) risk in its portfolio (linked to the collateral value that it accepts)[58] and the risk of compromising its monetary policy objectives (Sauer, 2007). The decision, timing and form of intervention can depend on the relative weights of these costs (Sauer, 2007). A sufficient framework for allocating optimal weights is, as of yet, not presented in the literature and most research indicates multiple equilibria solutions (Cao and Illing, 2007; Sauer, 2007).

[58] This can be counterparty credit risk, liquidity risk and market risk. The central bank can shield against the latter two types, by keeping collateral liabilities to eternity, but cannot shield against the first one, and therefore should be prudential about the amounts that it receives, given that it can result to loss of public money.

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