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Stylized facts in money markets: An empirical analysis of the eurozone data

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Stylized facts in money markets: an empirical analysis of the eurozone data

No 3113

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ABSTRACT

Using the secured transactions recorded within the Money Markets Statistical Reporting database of the European Central Bank, we test several stylized facts regarding the interbank market of the 47-largest banks in the eurozone. We observe that the surge in the volume of traded evergreen repurchase agreements followed the introduction of the LCR regulation and we measure a rate of collateral re-use consistent with the literature. Regarding the topology of the interbank network, we confirm the high level of network stability but observe a higher density and a higher in– and out–degree symmetry than what is reported for unsecured markets.

- *JEL classification*: E42, E51, E52, G21, G28.
- *Keywords*: Liquidity Coverage Ratio, Excess Liquidity, Monetary Policy, Interbank Network, Collateral Re-use.

NON-TECHNICAL SUMMARY

The 2008 global financial crisis (GFC) revealed significant vulnerabilities in the banking sector, especially concerning how banks lend to each other in what is known as the interbank market. This market is crucial because it allows banks to manage their short-term funding needs efficiently. In response to the crisis, the ECB introduced new rules and tools to ensure that banks could rely on secured funding sources. One major regulatory step was the introduction of the Liquidity Coverage Ratio (LCR). This rule aimed to make sure banks maintain enough high-quality liquid assets to withstand a financial stress period. In this paper, we explore how these measures affected the eurozone's interbank markets. Before the GFC, banks heavily relied on unsecured lending, where loans are not backed by collateral. However, the crisis prompted a shift towards secured lending, particularly through repurchase agreements, or "repos," where banks provide collateral, such as government bonds, to back their loans. This shift minimizes risk since the lender can sell the collateral if the borrower defaults. To understand market dynamics, we analyzed comprehensive transaction data from the ECB's Money Market Statistical Reporting database, spanning from 2016 to 2022 and covering the largest 47 banks in the eurozone. Our study reveals that after the introduction of the LCR, there was a marked increase in the use of evergreen repos. These are special types of repos that are automatically renewed until one party decides to terminate them. They offer a strategic solution for banks to meet LCR requirements without affecting their liquidity position, showing a direct adaptation to regulatory changes. Additionally, we measured how often collateral, such as bonds, was reused in these transactions. The ability to reuse collateral efficiently points to improved liquidity management in the banking system. Furthermore, we examined the network characteristics of the interbank market. Traditionally, these markets were characterized by a sparse "core-periphery" structure — few banks are heavily interconnected, forming a core, while others mainly connect to this core. In contrast, our findings suggest a denser network for secured transactions with more evenly distributed connections across banks. This suggests an evolution in the structure where secured transactions lead to a more balanced lending environment. The stability of these connections over time is crucial for maintaining confidence in the financial system. We found that these relationships remained largely stable, implying strong trust among banks. Finally we observe an almost symmetrical pattern of banks' incoming and outgoing lending connections, dif-

fering from past observations in unsecured markets where such symmetry was less prevalent. These insights contribute to a deeper understanding of the current dynamics and structural properties of the eurozone's interbank market.

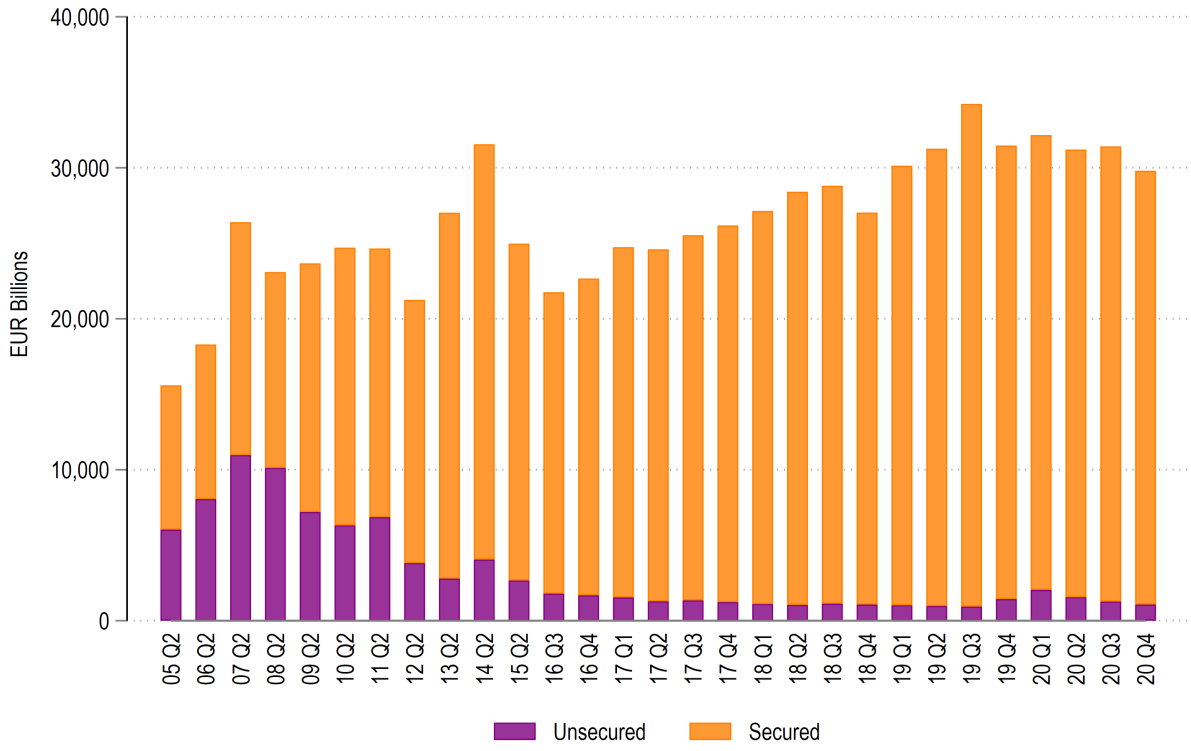
I. INTRODUCTION

Money markets are venues where banks carry out their refinancing activities. The 2008 Great Financial Crisis (GFC) led to heightened counterparty risk and, consequently, significant changes in money markets across Western economies. In response, the European Central Bank (ECB) introduced the full allotment procedure in October 2008, allowing banks to access unlimited central bank financing. Meanwhile, the Basel regulations mandated the Liquidity Coverage Ratio (LCR) to improve banks' short-term liquidity resilience, requiring them to hold a sufficient amount of high-quality liquid assets to meet their liquidity needs during stress scenarios. These rules resulted in the creation of excess reserves within the financial system (Renne, 2012; Piquard and Salakhova, 2019; Luca Baldo *et al.*, 2017). Additionally, the banking system's refinancing increasingly relied on collateralized lending, particularly through repurchase agreements (*repos*), with a notable rise in the practice of collateral re-use (Keller *et al.*, 2014; European Systemic Risk Board., 2017; Cheung *et al.*, 2014; Fuhrer *et al.*, 2016; Scaggs, 2018; Accornero, 2020).

The network topology of money markets, where transactions among banks are identified as links between nodes, has evolved in consequence but was not yet documented. This study aims at quantifying the changes of the secured funding operations of the 47 largest banks in the eurozone.

II. EXCESS LIQUIDITY AND DECLINING UNSECURED INTERBANK MARKETS

Following the GFC, the ECB introduced the full allotment procedure, enabling banks to meet any liquidity requirements without limitation (Renne, 2017). Consequently, volumes in the overnight unsecured interbank market declined markedly (see Fig. 1). As noted in a recent ECB survey (Luca Baldo *et al.*, 2017), the increase in excess liquidity between 2012 and 2018 can be attributed to three main factors: (i) heightened demand for central bank liquidity from banks, (ii) the implementation of the full allotment procedure, and (iii) the provision of longer-term refinancing operations. Since 2015, the ECB's asset purchase program (APP) further augmented excess liquidity in the banking system, with most banks reporting that client inflows were a predominant factor (Luca Baldo *et al.*, 2017). The subsequent decrease in unsecured lending was exacerbated by the introduction of the LCR in January 2018, which impeded liquidity redistribution (Luca Baldo *et al.*, 2017). Indeed,



Cumulative quarterly turnover in the euro area unsecured and secured money market segments. Source: Euro Area Money Market Survey until Q2 2015, Money Market Statistical Repoting (MMSR) data thereafter. Only transactions with deposit-taking institutions and CCPs are considered. Both borrowing and lending transactions are included; all collateral types and maturities are considered.

FIG. 1: Turnover in unsecured and secured euro area interbank money markets

Le Coz *et al.* (2024) demonstrated, through accounting analysis, that the interaction between the APP and the LCR requirement contributes to the persistence of excess liquidity in the financial system.

III. EVERGREEN REPOS TO ANSWER LCR REGULATION

The GFC underscored the presence of counterparty risk among banks, prompting a shift from unsecured to secured lending (di Filippo *et al.*, 2018). In these markets, collateralized borrowings

are executed through repurchase agreements (repos), which involve the exchange of collateral for cash over a specified period. This shift towards secured markets was further reinforced by the introduction of the LCR, as repos are treated more favorably than unsecured transactions under this regulation. An evergreen repo, a contract that is continually renewed by mutual agreement, exemplifies this adaptation. Le Coz *et al.* (2024) demonstrate that an evergreen repo with a one-month notice period has no impact on the LCR of the parties involved, as the collateral provided offsets any LCR loss due to the cash exchange.

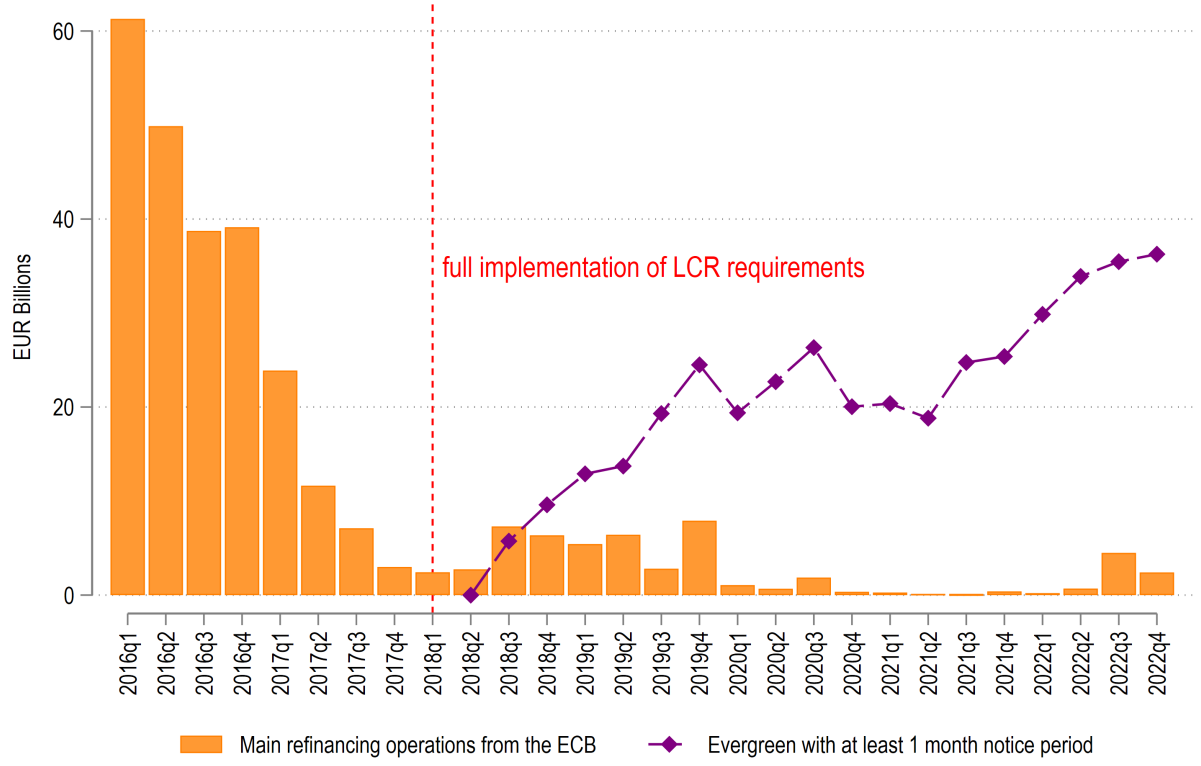
Figure 2 shows that the introduction of the LCR regulation coincides with an increase in the volumes of traded evergreen repos with a notice period longer than one month (see also Allen (2016)). We observe that the volume of evergreen repos traded among the 47 largest banks in the eurozone increased from negligible amounts in 2017 to ten billions per day in 2019. All the empirical results presented here were established for the 47 largest banks in the eurozone that are required to report their transactions to the Money Market Statistical Reporting database (MMSR) as detailed in appendix A.

IV. COLLATERAL RE-USE AND BOND SCARCITY

The one-month notice period of evergreen repos prevents the immediate unwinding of positions when the cash lender faces a liquidity requirement. This constraint facilitates the re-use of collateral in the market. Specifically, the cash lender j can re-use the collateral $S^c_{j,t}$ received from a reverse repo to secure cash in another repo transaction. The rate at which collateral is re-used has been defined in various ways within the literature (Accornero, 2020). Here, we define the re-use rate of collateral as:

$$\text{re-use}(t) = \frac{\sum_{i=1}^{N} S^r_i(t)}{\sum_{i=1}^{N} S^c_i(t)}. \tag{1}$$

As reported by Le Coz *et al.* (2024), various levels of collateral re-use, ranging from 0.1 to 3 have been measured across time and regions: notably a re-use rate around 1 was observed in European money markets (Keller *et al.*, 2014; European Systemic Risk Board., 2017), 0.6 in Australia (Cheung *et al.*, 2014), 0.1 in Switzerland (Fuhrer *et al.*, 2016), and 3 in the US (Scaggs, 2018). We confirm a re-use rate around 1 for the eurozone in Fig. 3 by measuring the weighted number of times the



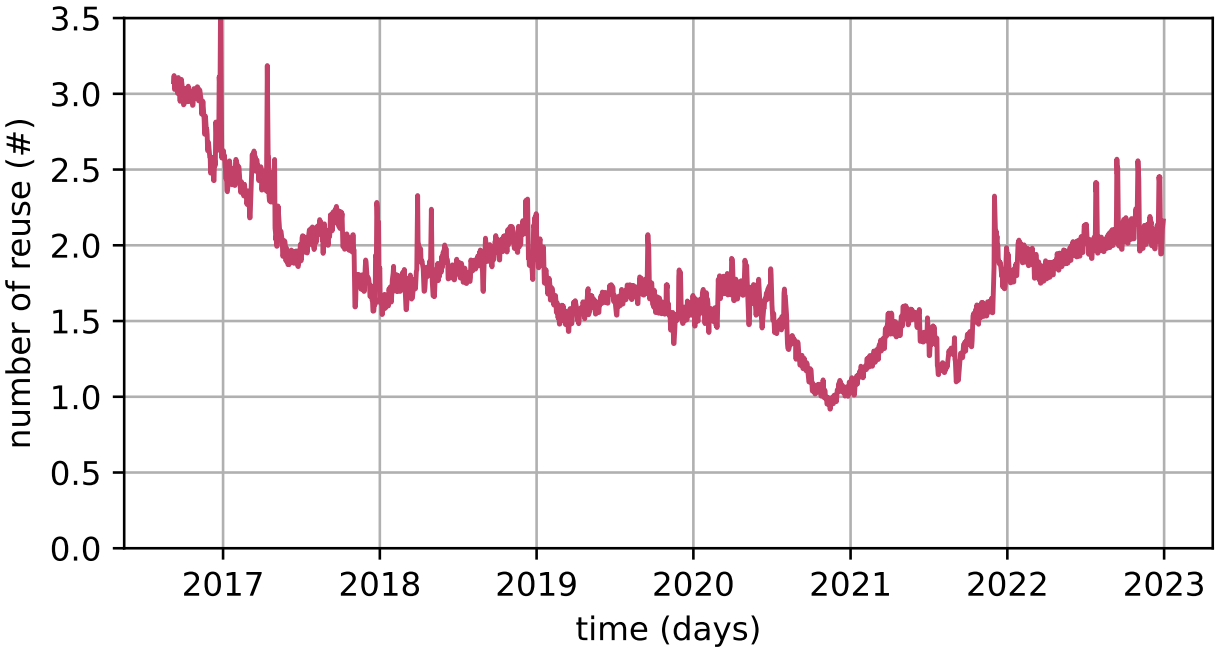
Aggregate quarterly volumes of main refinancing operations (MRO) implemented by the Eurosystem and aggregate volumes of traded evergreen repos with a notice period greater than 1 month. Source: Internal Liquidity Management for the MRO volumes and Money Market Statistical Reporting (MMSR) data for evergreen repos. Evergreen repos are identified by filtering on repo transactions with a notice period of at least 30 days, with repeating transactions for at least 1 day. Both borrowing and lending transactions are included; all collateral types are considered.

FIG. 2: Evergreen repos

ISIN code of a given collateral appears in the banking system on a given day.

V. THE INTERBANK NETWORK TOPOLOGY

a. Sparse core periphery structure? We define a link in the interbank network as the presence of at least one repo exposure between two banks over a specified aggregation period, which can range

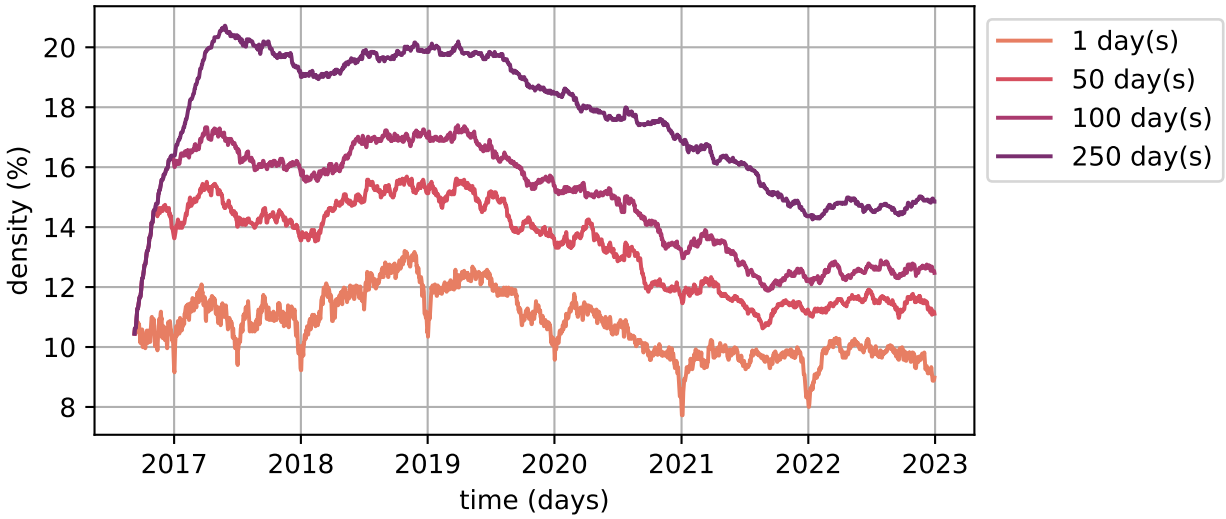


Aggregate daily number of collateral re-use for reporting banks in MMSR, measuring the length of collateral chains. Only transactions between deposit-taking corporations are considered, all types of collateral are included. Source: Money Market Statistical Reporting database (MMSR).

FIG. 3: Length of the chain of collateral among the 47 largest banks of the eurozone

from one day to one year. Historically, interbank market networks exhibited low density and a core-periphery structure (Bech and Monnet, 2016; Blasques *et al.*, 2018; Vari, 2020; Boss *et al.*, 2004). In this configuration, a central 'core' of highly interconnected nodes is surrounded by a 'periphery' of less connected nodes that primarily link to the core rather than to each other.

The switch of these markets towards secured transactions led, according to the MMSR data, to an increased network density. Indeed, Fig. 4 shows a network density ranging from 10% to 20% deepening on the link definition. We assume this higher density is due to the longer transaction maturity. The limited number of banks in our sample (47) prevented us from studying the core-periphery structure of secured markets.



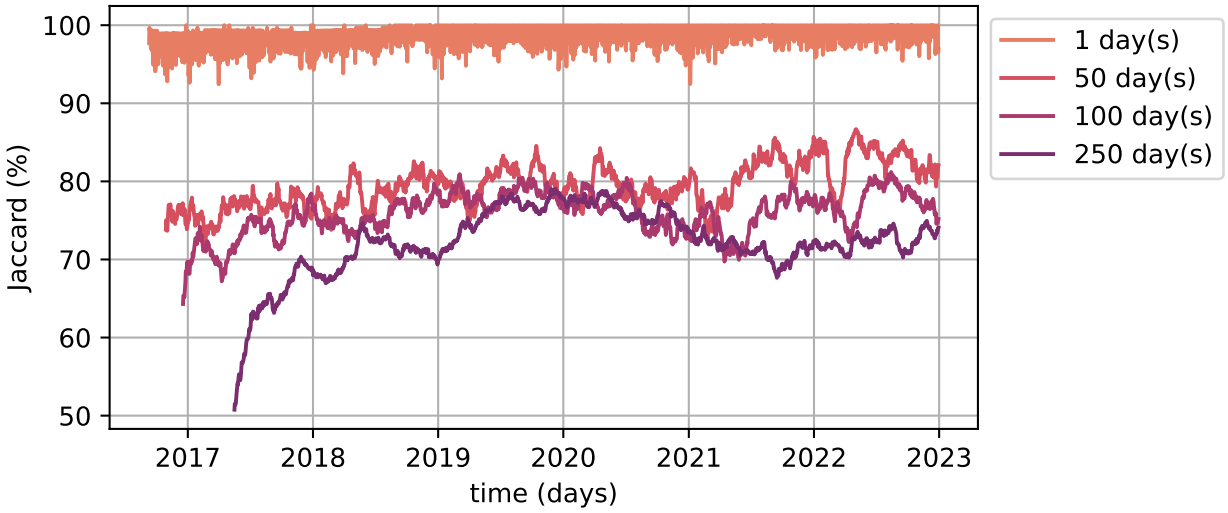
Density of the secured segment of the interbank money markets in the euro zone. A link between two reporting banks is defined as the existence of at least one repo transaction over different aggregation periods, each corresponding to a different color: (1) over 1 day, (2) over 50 days, (3) over 100 days and (4) over 250 days. Only transactions between deposit-taking corporations are considered, all types of collateral are included. Source: Money Market Statistical Reporting database (MMSR).

FIG. 4: Density of the repo interbank markets among the 47 largest banks of the eurozone

b. Stable bilateral relationships The existence of stable interbank relationship lending has been documented by, among others, Blasques *et al.* (2018); Furfine (1999); Afonso *et al.* (2013). We confirm this result in the case of secured markets by measuring the share of stable links from one period to another, namely the Jaccard network similarity index (Verma and Aggarwal, 2020). Figure 5 shows a Jaccard network similarity index ranging from 80 to 100% depending on the aggregation period.

c. Asymmetric in and out degrees Several authors reported an asymmetry between in and out degree distributions within unsecured interbank lending networks (Craig and von Peter, 2014; Anand *et al.*, 2015; Lux, 2015). Notably, Craig and von Peter (2014); Anand *et al.* (2015) observe that banks in Germany have in general fewer lenders than borrowers.

We observe a more symmetrical pattern in the case of the repo exposures among the 47 largest banks of the eurozone. Figure 6 shows that in–degrees expressed as a function of out-degree are



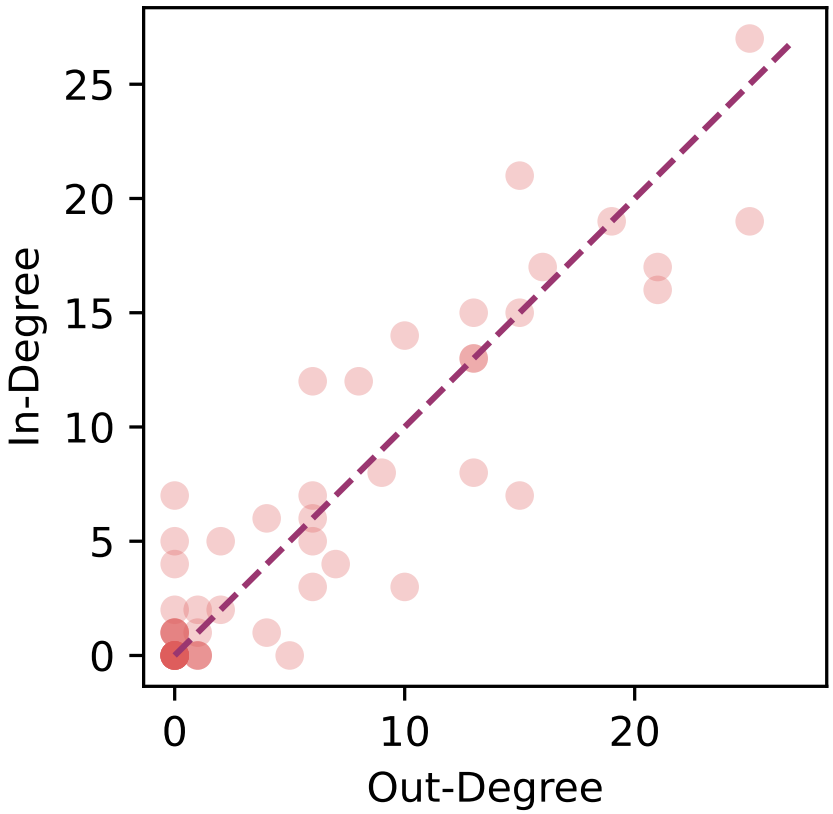
Jaccard similarity coefficient of the secured segment of the interbank money markets in the euro zone. A link between two reporting banks is defined as the existence of at least one repo transaction over different aggregation periods, each corresponding to a different color: (1) over 1 day, (2) over 50 days, (3) over 100 days and (4) over 250 days. Only transactions between deposit-taking corporations are considered, all types of collateral are included. Source: Money Market Statistical Reporting database (MMSR).

FIG. 5: Stability of the repo interbank markets among the 47 largest banks of the eurozone

almost symmetrical.

VI. CONCLUSION

In this study, we analyzed secured transactions documented in the Money Markets Statistical Reporting database of the European Central Bank to investigate various characteristics of the interbank market among the 47 largest banks in the eurozone. Our findings reveal a significant increase in the volume of evergreen repurchase agreements coinciding with the implementation of the LCR regulation. Additionally, our measurement of collateral re-use rates aligns with existing literature on the subject. When examining the structure of the interbank network, our results confirm its high level of stability. However, we also identified a higher network density and more pronounced symmetry in in-degree and out-degree connections compared to unsecured markets. These insights



This figure presents the relationship between in and out-degree within the secured interbank money market segment in the eurozone, as of July 3rd 2022. Links are defined through the aggregation of transactions that occurred within the last 50 days. Only transactions between deposit-taking corporations are considered, all types of collateral are included. Source: Money Market Statistical Reporting database (MMSR).

FIG. 6: In–degree as a function of out–degree on 31st December 2022

contribute to a deeper understanding of the current dynamics and structural properties of the eurozone's interbank market.

REFERENCES

J.-P. Renne, *A Model of the Euro-Area Yield Curve with Discrete Policy Rates*, Working Paper (Banque de France, 2012).

T. Piquard and D. Salakhova, SSRN Electronic Journal 10.2139/ssrn.3461534 (2019).

Luca Baldo, Benoît Hallinger, Caspar Helmus, Niko Herrala, and Débora Martins, *The Distribution of Excess Liquidity in the Euro Area.*, Tech. Rep. (Publications Office, LU, 2017).

J. Keller, A. Bouveret, C. Picillo, Z. Liu, J. Mazzacurati, P. A. Molitor, J. Söderberg, J. Theal, F. D. Rossi, and R. Calleja, SSRN Electronic Journal 10.2139/ssrn.3723337 (2014).

European Systemic Risk Board., *Collateral Scarcity Premia in Euro Area Repo Markets.* (Publications Office, LU, 2017).

B. Cheung, M. Manning, and A. Moore, *The Effective Supply of Collateral in Australia*, Tech. Rep. (Reserve Bank of Australia, 2014).

L. M. Fuhrer, B. Guggenheim, and S. Schumacher, Journal of Money, Credit and Banking **48**, 1169 (2016).

A. Scaggs, Financial times (2018).

M. Accornero, *Repo Markets, Collateral Re-use and Systemic Fragility. A Literature Review*, Tech. Rep. (Sapienza Universita di Roma, 2020).

J.-P. Renne, Studies in Nonlinear Dynamics & Econometrics **21**, 99 (2017).

V. Le Coz, M. Benzaquen, and D. Challet, to appear in Journal of Economic Behavior and Organization 10.48550/ARXIV.2410.18145 (2024).

M. di Filippo, A. Ranaldo, and J. Wrampelmeyer, *Unsecured and Secured Funding*, Tinbergen Institute Discussion Paper 18-038/IV (Tinbergen Institute, 2018).

F. Allen, Liquidity Regulation, Extended Repo and the Real Economy (2016).

M. Bech and C. Monnet, Journal of Economic Theory **164**, 32 (2016).

F. Blasques, F. Bräuning, and I. van Lelyveld, Journal of Economic Dynamics and Control **90**, 310 (2018).

M. Vari, Journal of Money, Credit and Banking **52**, 409 (2020).

M. Boss, H. Elsinger, M. Summer, and S. Thurner, Quantitative Finance **4**, 677 (2004).

C. H. Furfine, Financial Markets, Institutions & Instruments **8**, 24 (1999).

G. Afonso, A. Kovner, and A. Schoar, SSRN Electronic Journal 10.2139/ssrn.2266527 (2013).

V. Verma and R. K. Aggarwal, Social Network Analysis and Mining **10**, 43 (2020).

B. Craig and G. von Peter, Journal of Financial Intermediation **23**, 322 (2014).

K. Anand, B. Craig, and G. Von Peter, Quantitative Finance **15**, 625 (2015).

T. Lux, Journal of Economic Dynamics and Control **52**, A11 (2015).

Appendix A: Data sources

Our empirical analyses rely on the Money Market Statistical Reporting (MMSR) database which contains the transaction statistics of both the secured and unsecured legs of the euro area money markets. From July 2016 to December 2022, the database contains transaction-by-transaction level data on the euro money markets reported by a sample of 47 euro area banks.[1] They are required to report all their transactions of maturity inferior to one year with other financial institution.[2] On both segments, we have access to information on the type of money market instrument, the dates of trade, start and termination of the contract, the interest rate of the transaction, the volume, the sector of the counterparty, the volume of the transaction, the maturity of the transaction and the direction of the trading (lending vs borrowing). We also have the identifiers of the reporting banks and identifiers of the counterparties. For secured transactions, we also can identify the ISIN of the collateral. Banks in MMSR have the obligation to report all transactions until they mature, so that any deposit from another entity that is reported in the balance sheet of a given bank is reported everyday until the entity withdraws its deposits either partly or entirely.

a. General data retreatment. We keep any interbank transactions between MMSR reporting agents for which we have non missing reported information on the transaction volume, the LEI of the reporting agent, the LEI of the counterparty agent, the ISIN code of the collateral and the direction of the transaction (borrowing vs lending). We remove all canceled transactions from the database — i.e. a canceled transaction corresponds to any transaction which was initially reported and was later canceled, but is not equivalent to a transaction which was approved by the bank and later matured (these are the transactions we keep for our analysis). Additionally, we make sure that the dates in our sample only correspond to official euro area trading calendar dates.[3]

[1] The full list of reporting agents is available on the Money market statistical reporting webpage.

[2] Formally it is legal entities of 10 sectors of the economy: general government and other government institutions, non-financial corporations, central banks, deposit taking corporations, money market funds, investment funds, insurance corporations, pension funds and other financial intermediaries - this includes financial auxiliaries, captive financial institutions and money lenders, as well as another bundled category called "other financial intermediaries, except insurance corporations and pension funds".

[3] We list all calendar dates reported on the official statistical data warehouse of the ECB from the reported EONIA/ESTR rates time series.

b. Identification of evergreen repos. Our main data transformation consists in extracting information on the evergreen repos from the MMSR database. Evergreen repos are repos with an infinite maturity but are not flagged as such in the MMSR database. Evergreens have a notice period that usually vary between 1 to 100 days and are reported as a repo transaction with the same maturity band everyday until the day when one or both trading counterparties decide to stop the transaction. That day, the two counterparties have to agree on a date of final maturity, which will then be reported in the database. We thus identify evergreens as any repeated transactions between the two same counterparties for at least 1 day. Specifically, we identify a unique repo as the combination of the two identifiers of the transacting counterparties (the lender and the borrower), the nominal amount and the maturity and the ISIN code of the transaction. Any repeated combination of these unique repos for more than a day are considered evergreens.

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