No more Tears without Tiers? The Impact of Indirect Settlement on liquidity use in TARGET2

Paulick, Jan; Berndsen, Ron; Diehl, Martin; Heijmans, Ronald

Publication date:
2021

Document Version
Early version, also known as pre-print

CentER

Discussion Paper

No. 2021-022

NO MORE TEARS WITHOUT TIERS? THE IMPACT OF INDIRECT SETTLEMENT ON LIQUIDITY USE IN TARGET2

By

Jan Paulick, Ron Berndsen,
Martin Diehl, Ronald Heijmans

17 August 2021

ISSN 0924-7815
ISSN 2213-9532

TILBURG UNIVERSITY

No more Tears without Tiers? The Impact of Indirect Settlement on liquidity use in TARGET2*

Jan Paulick† Ron Berndsen‡ Martin Diehl§ Ronald Heijmans¶

Abstract

We study the impact of tiered settlement on relative intraday liquidity use (liquidity consumption) for settlement banks in TARGET2. We estimate a panel data model employing transaction-level data from 2010 to 2019 which shows that a higher share of tiered payments from client banks reduces relative liquidity consumption by settlement banks. Metrics on timing, delay, and payment priorities suggest that settlement banks can make use of more leeway in settling tiered payments from client banks compared to their own payments. Payment timing as a proxy for external delay suggests that tiered payments are used to smooth settlement banks' liquidity positions. Results on payment delay within the system show no clear dynamic over time, whereas payment priorities are consistently lower for tiered payments. We conclude that to some degree settlement banks employ tiered arrangements to manage intraday liquidity more efficiently. To a certain extent this hints to "free riding" or higher recycling of liquidity from client banks' payments. However, the results

*The authors thank participants of the 55th Annual Conference of the Canadian Economics Association and the 13th Payment and Settlement System Simulation Seminar at the Bank of Finland. We thank James Chapman, Anneke Kosse and Segun Bewaji for very helpful comments and suggestions and Constanza Martínez for an excellent discussion of preliminary results,. Excellent research assistance was provided by Josefine Quast during early stages of the work. Diehl, Heijmans and Paulick are members of one of the user groups with access to TARGET2 data in accordance with Article 1(2) of Decision ECB/2017/2080 of 22 September 2017 on access to and use of certain TARGET2 data. The Deutsche Bundesbank, De Nederlandsche Bank and the MIB have checked the paper against the rules for guaranteeing the confidentiality of transaction-level data imposed by the MIB pursuant to Article 1(4) of the above mentioned issue. The views expressed in the paper are solely those of the authors and do not necessarily represent the views of LCH, the Deutsche Bundesbank, De Nederlandsche Bank or the Eurosystem.

†Deutsche Bundesbank and Tilburg University, Tilburg School of Economics and Management (jan.paulick@bundesbank.de).

‡Tilburg University, Tilburg School of Economics and Management and LCH (r.j.berndsen@tilburguniversity.edu).

§Deutsche Bundesbank (martin.diehl@bundesbank.de).

¶De Nederlandsche Bank (ronald.heijmans@dnb.nl).

are also consistent with settlement banks' monitoring role or tiered payments potentially exhibiting different characteristics which may be attributable to contractual arrangements.

Keywords: RTGS systems, banks, payments, tiering, liquidity, TARGET2

JEL classification: E42, E58, G21.

1 Introduction

Internal and external risk mitigation is the foundation for the smooth functioning of financial market infrastructures (FMIs). Payment systems form the underlying infrastructure for the settlement of debt obligations in an economy. The Principles for Financial Market Infrastructures (PFMIs), developed by CPSS-IOSCO (2012), formulate high international standards for these FMIs and offer guidance on potential sources of risk and risk mitigation.

The settlement of payments on behalf of clients by direct system participants, called tiering, is a universal feature of payments systems. Principle 19.4 of the PFMIs state that "An FMI should regularly review risks arising from tiered participation". Risk exposures operators and overseers look at include credit, liquidity and operational risk. According to the PFMI these risks may be especially large for highly tiered systems.

Instead of directly sending payments to a payment system, some banks[1] choose to delegate settlement. The arrangement of an indirect participant (client bank) processing payments through a direct participant (settlement bank) forms a tiered arrangement. The underlying economic reasons that influence banks' decision on how to access a payment system are manifold. For smaller banks it might be more cost-efficient to chose tiered settlement arrangements, avoiding costs related to operational setup and liquidity management.

Tiered participation not only entails risks, but can increase the efficiency of payment systems. Costs of payment settlement decrease with tiered participation as direct participants can profit from economies of scale (see for example Adams, Galbiati, and Giansante, 2010; Chapman, Chiu, and Molico, 2013). Pooling liquidity leads to lower cost of capital as settlement banks can use higher traffic volumes to offset payments in the system or settle payments internally on their own books without entering them into the payment system and drawing on liquidity.

From a settlement bank's perspective, tiered payments feed into the overall liquidity disposition of payments that are settled in a way to minimize liquidity use. In this study, we investigate the effect of tiering on the relative intraday liquidity use (liquidity consumption) of settlement banks in TARGET2.[2] empirically. Liquidity consumption is defined as the maximum amount of liquidity needed intraday to settle the payments of a direct participant relative to all payments sent by that participant. The measure indicates how efficient a bank uses liquidity sources to make payments. Assuming liquidity is costly, settlement banks exhibiting lower values of liquidity consumption settle payments in a more cost-efficient manner. Tiering generally decreases liquidity needs as payments offset when concentrated among fewer direct participants. However, little is known about the effect of tiering at the participant level and how tiering factors into banks' liquidity management. To shed some light on this question, we employ a panel data model and identify channels via which tiering affects liquidity consumption.

[1] With regard to terminology, we use credit institution interchangeably with the term bank throughout the paper. Direct participants in a payment system are referred to as settlement banks, indirect participants are referred to as client banks. For brevity, we at times refer to settlement banks as banks and direct participants as participants.

[2] TARGET2 refers to the second generation Trans-European Automated Real-time Gross Settlement Express Transfer System operated by the Eurosystem.

Using transaction-level data from TARGET2, we find that higher shares of tiered payments reduce relative liquidity needs for settlement banks. The results are robust controlling for pooling effects via bank fixed effects, payment activity and other factors. The main driver appears to be that banks have more discretion in settling tiered payments. Payment timing suggests that tiered payments help settlement banks to smooth their liquidity positions by assigning lower priorities to them compared to banks' own or in-house payments. To some degree this indicates discriminatory practices, as settlement banks treat their own payments with higher urgency, thus using more liquidity for settling own payments relative to tiered payments.

However, settlement banks reducing their cost of liquidity is also consistent with their role in monitoring client banks and offering cost-efficient settlement services based on private information on creditworthiness (see for example Chapman et al., 2013). Smoothing liquidity positions from this perspective may be a way to mitigate settlement banks' risk from tiered arrangements. The findings are also consistent with tiered payments exhibiting different characteristics. Tiered payments may arrive later in the day and by nature be less urgent, so settlement banks can use these payments to optimize their liquidity positions. Treating tiered payments with less urgency may also result from contractual bilateral arrangements between client banks and their settlement banks. As no information is available on payments before they enter the system, such reasoning cannot be ruled out here. The findings show that once payments enter the system, tiered payments are different to in-house payments.

We conclude that tiered arrangements help settlement banks in managing liquidity more efficiently. However, this gain in efficiency comes at the potential cost of concentration and hence operational bulk risks. In addition, there could be a higher credit risk for client banks in tiered arrangements resulting from settlement banks' active liquidity management. However, the trade-offs and settlement banks' risk mitigation vis-à-vis client banks is outside the scope of this study. TARGET2 makes up only one (though important) part of banks' overall liquidity position. Other systems, bilateral relationships and exposures may play a significant role for some banks' liquidity disposal.

2 Tiering in large-value payment systems

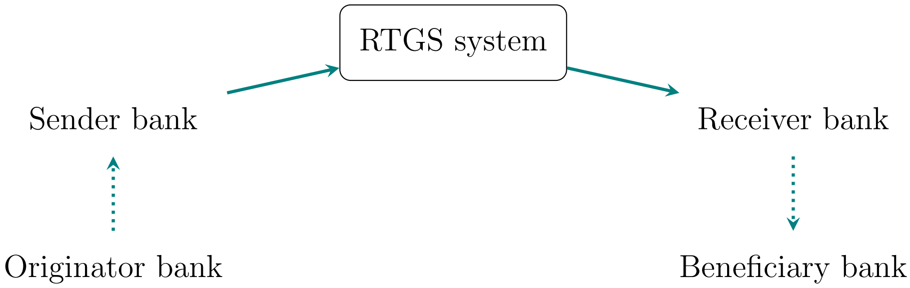
Large-value payment systems (LVPSs) typically settle transfers with a high value or high priority. Many LVPSs, such as TARGET2, settle transactions immediately on a gross basis and are also referred to as Real-Time Gross Settlement (RTGS) systems. This stands in contrast to net settlement systems in which payments are settled at a specified time on a net basis. Hence, RTGS systems typically require higher amounts of liquidity for settling payments.

Aside from central banks and government entities, direct access to an LVPS is mostly restricted to credit institutions. Credit institutions can access payment systems directly or indirectly through a correspondent bank, though there are regulatory restrictions and access criteria that may apply.[3] Importantly, participation in monetary policy operations may require direct access to an LVPS. Indirect participants do not hold an account in the LVPS and thus settle payment obligations via direct participants subject to bilateral

[3] For an overview of RTGS system features and institutional design see CPSS (2005).

agreements as illustrated in Figure 1.

Figure 1: Tiered settlement



The level of tiering differs widely across systems. While there are over 1,000 direct participants in TARGET2, there are only around 30 direct participants in the UK's payment system CHAPS.[4] As indirect participants, almost 700 credit institutions from the European Economic Area (EEA) and more than 4,000 correspondents worldwide can settle payments via TARGET2.[5] For CHAPS the number is quite similar, as roughly 5,000 financial institutions settle payment via CHAPS. The ratio of direct to indirect participants is roughly 1:5 for TARGET2 and 1:160 for CHAPS, meaning CHAPS is a much higher tiered system than TARGET2.

The numbers of direct and indirect participants gives an indication of how broadly banks access a system. In addition, the number of direct participants hints to the number of options potentially available to client banks. However, not all direct participants offer settlement on behalf of client banks. In TARGET2, out of 1,209 participants in the sample, 438 do not send any tiered payments, only 266 settle tiered payments greater than 1 percent of their traffic, and only 128 participants settle tiered payments greater than 5 percent of their traffic. As smaller participants are much less likely to engage in settlement on behalf of client banks, we restrict the sample to larger participants for robustness. The concept of tiering employed here refers to volumes and values of payments rather than the number of participants.

Levels of tiered participation depend on institutional design and the system's pricing policy. Depending on what outcome a regulator desires, legal requirements and rules of access may be designed in a way to encourage direct participation. The risks of tiered settlement are often emphasized by policymakers and regulators. As described by Finan, Lasaosa, and Sunderland (2013), the Bank of England persuaded large indirect participants to become direct participants in the UK's highly tiered CHAPS system on account of financial stability considerations. CHAPS can be considered as an extreme example, with historically few direct participants. However, even in this setting Benos, Ferrara, and Gurrola Perez (2017) find, using transaction-level data, that the effects of the largest indirect participants becoming direct participants (de-tiering) have small effects on risk measures.

[4]See `ecb.europa.eu/paym/target/target2` and `bankofengland.co.uk/payment-and-settlement/chaps` for information and recent numbers.

[5]In TARGET2 there are so-called indirect participants and addressable BICs (Bank Identifier Codes). In both cases, banks use a direct participant to connect to TARGET2, but only supervised credit institutions established within the EEA can become indirect participants. In the context of this study the difference is not relevant and we refer broadly to indirect participants.

Table 1: Benefits and risks of tiered participation from a client bank's perspective

	Positive effects of tiering	Negative effects of tiering
Credit risk	Risk exposures against other banks may be more efficiently managed by settlement bank.	Credit risk against settlement bank. Risk exposures against other banks may accumulate if inefficiently managed by settlement bank.
Liquidity risk	Liquidity may be more efficiently managed by settlement bank. Client bank is charged cost of liquidity and profits.	Settlement bank may draw on liquidity provided by client banks. Costs of liquidity and operations may be lower than settlement bank fees.
Operational risk	No operational setup costs and fewer own resources dedicated to operations. High operational proficiency via outsourcing to larger players.	Operational proficiency dependent on settlement bank. Dependency on settlement banks may lead to lock-in effects.

For other systems, such as the US RTGS system Fedwire, information on tiered payments is not available from transaction data. Thus, the analysis of risk relies on information gathered from other sources. Overall, risks for Fedwire from tiered arrangements are believed to be small and manageable through regular reviews and by the mitigation of risks posed by direct participants (see Fedwire Funds Service, 2019).

Tiered participation partly reflects the banking system structure and historical developments. In the case of the Australian RTGS system, for example, restrictions were previously applied to tiered arrangements. These were lifted in 2003, allowing participants with 0.25 per cent of overall payment value to process payments via settlement banks. Potentially due to setup costs, there has been inertia in changing access, with few banks making adjustments (see Arculus, Hancock, and Moran, 2012).

For banks, a variety of factors influence the decision on how to access a payment system. Table 1 summarizes benefits and risks of tiering from a client bank's risk perspective. Cost-effectiveness and exposure to risks have to be balanced. Direct participation may entail operational setup costs and investments in liquidity management. Indirect participation may give rise to credit risk, as exposures accumulate during the day against settlement banks. In addition, payment services to client banks may be bundled together with other services, thus making direct participation less attractive for some banks. Typically smaller domestic banks and foreign banks are more likely to become indirect participants.

Tiering often leads to uncollateralized, credit positions between banks. Rochet and Tirole (1996) study tiered arrangements in the context of interbank monitoring and systemic risk. Kahn and Roberds (2009) discuss the trade-off between widespread access to an LVPS versus the efficiency gains achieved by private monitoring in tiered relationships. Chapman et al. (2013) show that tiered arrangements can arise via two channels. The first is through settlement banks monitoring client banks. In a setting with imperfect information, settlement banks leverage private information on creditworthiness by offering different settlement modes. The modes of settlement are similar to system-level differences between deferred net settlement systems and RTGS systems. Tiering represents a balance between deferred settlement, with lower liquidity costs but higher credit risk, and immediate settlement, with high liquidity costs but low or absent credit risk. The second channel is through settlement banks benefiting from economies of scale that reduce overall cost in the system. Given their roles, failures of settlement banks would lead to substantial welfare losses in terms of operational risks and loss of information.

From a central bank perspective, monitoring payment system activity is crucial for risk mitigation. A variety of approaches are available to identify different risks. Berndsen and Heijmans (2020) develop a traffic light approach, based on different indicators to identify credit, liquidity and operational risk in TARGET2. Triepels, Daniels, and Heijmans (2018) apply an unsupervised learning method to detect anomalies in RTGS systems. Sabetti and Heijmans (2021) apply a similar approach to Canadian LVPS data and discuss how deep-learning methods could be implemented by operators. Rubio, Barucca, Gage, Arroyoa, and Morales-Resendiz (2020) built on their work to asses deep networks to detect anomalies in the largest systemically important payment system in Ecuador. Aside from anomalies that can relate to different sources of risk, liquidity risk is of particular interest for the smooth functioning of payment systems and financial stability. Heuver and Triepels (2019) apply supervised machine learning in an experimental setting to identify banks encountering liquidity stress.

From a settlement bank's perspective, liquidity needed to fund payments in RTGS systems needs to be obtained from the central bank or the interbank market at a cost. The central bank may also offer overdraft facilities for banks to fund payments. Additionally, received payments allow banks to recycle liquidity from other participants to fund outgoing payments. McAndrews and Rajan (2000) develop a measure to decompose different sources of payment funding and find incoming payments account for 25 to 40 percent of liquidity sources during the day in Fedwire.

Intraday behavior in RTGS systems is also studied by Bech and Garratt (2003) using a game theory approach. Typically, banks have an incentive to postpone payments when liquidity is costly and they thus delay payments and recycle incoming payments. To account for banks changing behavior during disruption events, rather than assuming a given behavior Arciero, Biancotti, D'Aurizio, and Impenna (2009) employ agent-based modelling to simulate payment activity. Liquidity saving mechanisms in RTGS systems can affect banks' behavior as shown by Martin and McAndrews (2008). One example is the use of limits in TARGET2 which allow maximum bilateral or multilateral exposures to be set (see Diehl and Müller, 2014).

Banks relying heavily on incoming payments as a liquidity source can be labelled free-riders. Diehl (2013) provides an overview of different measures and interpretations in the context of free-riding in TARGET2. Heijmans and Heuver (2014) show that banks react dynamically to stress events and some banks delay payment. They find that indicators on timing can help detecting liquidity problems. Abbink, Bosman, Heijmans, and van Winden (2017) study the effect of disruptions on banks' reactions in an experimental setting. Path dependency of disruptions may lead to inefficient coordination outcomes at the system level. Concerning market structure, a homogeneous market could relate to a highly tiered system with few active banks. The study finds that a heterogeneous market structure achieves efficient coordination more easily due to a leadership effect.

Depending on banks' use of liquidity, costs incurred by direct participants are passed on to indirect participants. Adams et al. (2010) simulate the emergence of tiered arrangements in a network structure where banks balance the liquidity costs incurred through direct participation and the service fees they pay as indirect participants. The service fee consists of direct participants' liquidity costs and profits. Cost of liquidity as determined by central banks is found to influence choices on system participation. Liquidity pricing is modelled proportionally to liquidity usage or up to a certain amount as free when banks have to post collateral to the central bank for prudential reasons. In such regimes, banks can draw on liquidity provided against collateral without incurring additional cost.

Arango and Cepeda (2017) study the trade-off between increased liquidity savings and larger credit risk with a higher degree of tiering in the context of the Colombian RTGS. Liquidity savings are found to increase non-monotonically. At the same time, credit risk changes little when smaller participants become indirect members, while substantial increases are found if large participants become tiered. This points to the fact that finding an optimal balance between credit and liquidity risks depends on the banking structure and type of banks. Lasaosa and Tudela (2008) use a simulation approach to study tiering in CHAPS. Results indicate that increasing tiering would lead to significant liquidity savings stemming from pooling. At the same time, concentration risk would increase substantially, while effects on credit risk appear to be small.

Operational disruptions due to technical outages in a payment system can affect the whole system or its individual participants. In the context of tiering, participant disruptions are of interest. Tiering has at least two opposite effects which are hard to quantify (see for example Arculus et al., 2012). Since tiering contributes to a higher concentration of settlement banks, the impact of any operational failure of a settlement bank becomes larger. However, a bank transmitting significantly more payments than others may be better at fulfilling its operational duties. Client banks are in general smaller in terms of transaction volume and value and may lack the funds to invest in state-of-the-art operational systems and to dedicate more payment specialists to the tasks of liquidity management. This aspect is reinforced by the sizable complexity of modern RTGS-systems, which offer a large range of options and mechanisms and require some degree of specialization among the bank's liquidity managers. Moreover, only a limited share of banks offer tiering and can be considered to have specialized. Therefore, we may assume that the probability of a failure of a large settlement bank is lower than the probability of an operational failure of a client bank. However, as comprehensive data on operational outages for direct and indirect participants is not available[6], this assumption is difficult to verify. We are inclined to assume that the operational risks are at least not significantly changed by tiering and that it is more likely that tiering leads to higher operational proficiency.

The effect of tiering on operational and credit risks is not considered here. Contractual arrangements between direct and indirect participants on prefunding of payments, collateral and limits are not taken into account as these factors are unobserved. In addition, internal payments that give rise to credit risk are unknown from TARGET2 data.

[6] On the availability and identification of operational outage data in different jurisdictions, see for example Klee (2010), Glowka, Paulick, and Schultze (2018) and Arjani and Heijmans (2020). Note that the constructed data in these studies is not representative, as data for smaller banks is usually less reliable.

3 TARGET2 data

3.1 Overview and sample

TARGET2 is the largest LVPS in Europe and one of the largest RTGS systems in the world. The system is owned and operated by the Eurosystem. In 2019 around 340,000 transactions were settled on average per business day, amounting to roughly 1.7 trillion euro.[7] Annual payments settled in TARGET2 amounted to 37 times the annual GDP in the euro area. Even though TARGET2 relies on a single technical platform, from a legal perspective, individual central banks in the Eurosystem own separate (national) components. In addition, some EU central banks that are not members of the Eurosystem are connected to TARGET2. In the system, domestic and cross-border payments in euro are settled in real time, including interbank and customer payments, monetary policy operations and transfers with ancillary systems and other financial market infrastructures. Underlying business reasons for large-value or urgent transfers are manifold, including for example payments for goods and services, the purchase or sale of securities, loan payments or transactions based in the real economy.

The measures in section 4 are constructed using TARGET2 transaction data from 2010 to the end of 2019. We focus on transactions of commercial banks as participants of TARGET2. Transaction-level data is filtered for central bank operations, participants' liquidity transfers between their own accounts and technical transfers in order to focus on business-related payments that affect settlement banks' liquidity position during the day and to exclude payments that serve the purpose of liquidity management. In addition, we disregard start-of-day balances that banks hold, in part, for fulfilling minimum reserve requirements. The filtering allows us to study payment behavior and intraday liquidity, irrespective of how liquidity used for payments is provided.

Besides customer and interbank transactions, we include transactions to ancillary systems and other market infrastructures, such as the securities settlement system T2S. For some ancillary systems, such as continuous linked settlement (CLS) for foreign exchange related transactions, there are fixed time windows for settlement. Thus, participants may not be able to time such payments according to their own preferences. Nevertheless, these payments affect participants' liquidity constraints during the day. Central banks and ancillary systems themselves are not included as participants as they typically do not engage in active liquidity management and exhibit different characteristics than commercial banks.

The sample spans over 2,500 business days with a total of more than 1,200 direct participants. Note that the term participant relates to BICs (Bank Identifier Codes), i.e. accounts in TARGET2. Banks may use multiple BICs to settle their payments. Different accounts of the same participant are not grouped together, but results are similar when sub-accounts are consolidated.[8]

Due to changes in the banking system structure, settlement banks drop in and out of the sample. In addition, some banks do not interact with TARGET2 everyday creating an unbalanced panel. We drop observations where direct participants only send or receive payments and when payments sent are below a threshold of 1,000 euro. In these cases,

[7] See https://www.ecb.europa.eu/pub/targetar/html/ecb.targetar2019.en.html.
[8] This stems from the fact that many banks use one or few main accounts for payments.

active liquidity management on the part of settlement banks is deemed irrelevant and payment activity too low to generate meaningful results. More than 1.7 million daily observations remain in total after the adjustments.

3.2 Tiering concept applied to TARGET2

Credit institutions established in the European Economic Area (EEA) are eligible as direct participants, while credit institutions from outside the EEA may use direct participants as access points to TARGET2 which is also referred to as correspondent banking. TARGET2 data includes transaction details that make it possible to identify payments sent and received on behalf of client banks. While these fields in payment messages are optional, they are typically filled by banks in TARGET2 in order to enable a quick routing of the payments. Arguably, the provided transaction details allow to identify the vast majority of tiered payments sent and received.

Banks settling payments on behalf of client banks are referred to as senders and receivers, the client banks using the service of settlement banks are called originators and beneficiaries (for illustration see Figure 1). In the transaction data there are multiple message fields, in some instances forming a chain of on-behalf information. Only the first and last BIC in a chain of payment information are used in the analysis to identify the ultimate client banks.

Tiered payments may be settled internally in the accounts of a settlement bank. These payments do not provide a source of intraday liquidity for the settlement bank or act as a drain on its intraday liquidity as they do not link to the payment system. However, these *internalized payments* do have implications for exposures and liquidity positions between settlement and customer banks and thus for potential risks. Surveys of correspondent banks in the UK have shown that internalized payments make up around one third of interbank payment values (see Adams et al. (2010)). In the case of TARGET2, it might be assumed the share is lower as the system is less tiered. Internalized payments are out of scope here, as no information on internal transactions is available from payment system data. Importantly, such information is also not available to system operators and overseers.

Tiering is defined here in a narrow sense as the settlement on behalf of client banks which do not belong to the same banking group, similar to, the definition employed by Benos et al. (2017) among others. In a wider sense, tiering can be seen as settlement on behalf of any client bank, irrespective of affiliations. The reasoning for choosing the narrow definition here, stems from the fact that intragroup settlement arrangements may differ in economic terms from arrangements with outside banks. Intragroup payments may exhibit other properties due to broader interconnections between banks that entail more than payment operations stretching across other areas of banking. Therefore, extra-group relations provide a less biased measure of tiered settlement arrangements for investigating the effects of indirect settlement on participants' behavior. Henceforth, we refer to tiering as tiering in the narrow sense and intragroup transactions as a separate category.

Initially, transactions on behalf of clients include intragroup transfers as well as transfers on behalf of clients outside the banking group. To distinguish extra-group transfers as tiered settlement, we use data from the SWIFT Bank Directory Plus[9] to classify pay-

[9] See `swift.com/SWIFTRef` for further information on the dataset.

ments according to banking group structures. The directory data includes information on individual BICs and their affiliated banking groups, which is mapped to data from TARGET2. Data from the directory is available from 2012 onward. Data before might not reflect banking group structures accurately, as mergers and other changes to the group structures are not accounted for. The further back in time one looks prior to the available data, the greater the inaccuracies even though group structures typically remain relatively stable. In order to avoid too much potential distortion in the data, we include only two previous years, starting in 2010. Therefore, the data should exhibit only a few inaccuracies and is the most reliable information available.

The SWIFT data on legal heads of banks is combined with transaction data. When originator and sender (or respectively the receiver and beneficiary) of a payment have the same legal head institution, these payments are labelled as intragroup transfers. Tiering henceforth refers only to payments that are respectively sent or received by settlement banks on behalf of an originator or beneficiary outside the banking group of the acting bank. Own payments are those transactions where no originator or beneficiary is involved in the transaction.[10]

4 Measures

This section describes the indicators employed to measure the impact of tiering. In order to analyze the effects of tiered settlement, we construct measures related to liquidity consumption, timing and delay. The measures are calculated using only the aforementioned subset of TARGET2 transactions.

4.1 Liquidity use and consumption

Importantly, measures on liquidity use do not entail sources of liquidity such as participants' account balances, liquidity transfers and monetary policy operations. In the setting relevant here, the actual liquidity needed by direct participants to settle payments intraday is of interest.

The payments sent by a participant i on a business day b are given by:

$$S_i^b = \sum_{t=0}^{T} s_i^b(t) \tag{1}$$

With individual payment values in a time interval t (ranging from 0 to T) given by s. Respectively, payments received R are given by:

$$R_i^b = \sum_{t=0}^{T} r_i^b(t) \tag{2}$$

Total payments sent on a given business day in TARGET2 are given by the sum of

[10] In addition, cases where the originator or the respective beneficiary coincide with the sender or receiver are treated as own payments.

payments sent by participants i (with i ranging from 1 to N) on day b:

$$S^b = \sum_{i=1}^{N} S_i^b \tag{3}$$

Liquidity needed to settle payments during the day is given by the debit position of participants which has a positive value here, while received payments factor in negatively.[11] The debit position D (running balance) of each participant at a time interval t is given by the difference between sent (s) and received (r) payments:

$$D_i^b(t) = s_i^b(t) - r_i^b(t) \tag{4}$$

As described in Leinonen and Soramäki (1999), the liquidity needed to settle all payments during the day given their order is expressed by LN which is calculated as the maximum of the running balance for the payment categories included in the study. This gives us the daily maximum debit position of each participant. The minimum is set at zero, which is the assumed start-of-day balance of the participants. Consequently, negative debit positions, i.e. arising intraday credit positions, are not considered:

$$LN_i^b = \max_{t\in[0,T]}(D_i^b(t), 0) \tag{5}$$

An LN above zero occurs when the value of the sent payments exceeds the value of payments received at some point during the day.[12]
for a participant i on a business day b.
And on the system-level, with S_b from Equation 3 as:

$$LC^b = \frac{\sum_{i=1}^{n} LN_i^b}{S^b} \tag{6}$$

We call LC liquidity consumption, which is bounded by 0 and 1. As LN can never be larger than the sum of sent payments, a value of 1 means all payments are sent by a participant before any payments are received. A value of 0 means a participant does not draw on liquidity for settling payments, with incoming payments being recycled to fully fund outgoing payments.

The reasoning for using the inverse is that we focus on participants rather than the system-level. For participants that use incoming payments for funding payments, LN might become very small, causing very high values of LC.[13]
In line with Denbee, Garratt, and Zimmerman (2014) we also use the cost-based measure

[11] This is contrary to typical account statements.

[12] A positive LN can also be referred to as maximum exposure, largest net debit position, or liquidity provision to the system.

[13] Take for example a participant starting the day with a payment of one euro and using incoming payments for the rest of the day without drawing on their own liquidity. If payments sent amount to 1 million euro, the turnover ratio in Benos, Garratt, and Zimmerman (2014) would become 1 million. On the system-level considered in that study, such extreme values do not occur, as such outcomes are not possible on aggregate. However, given the focus on participants here we use the inverse.

of relative liquidity need for robustness, which is defined as:

$$cLN_i^b = \frac{LN_i^b}{\sum_{i=1}^{n} LN_i^b} - \frac{s_i^b}{\sum_{i=1}^{n} S_i^b} \tag{7}$$

Negative values signify that a bank provides less liquidity to the system relative to its share of payments, and vice versa for positive values.

4.2 Timing

One channel via which banks may manage liquidity is by postponing payments before they enter the system. Internal queue management is one tool that banks may employ to shuffle payments and manage liquidity positions more efficiently.

Timing indicators show when payments are settled on average in the system. We follow Massarenti, Petriconi, and Lindner (2012) who apply timing indicators to TARGET2 data as described by Kaliontzoglou and Müller (2015). However, for tiered payments no information is available to observe when client banks send instructions to the direct participants. Therefore, the lag between receiving instructions from client banks and sending them to the system is unknown. However, we could assume that there is no reason why there may be significant and consistent differences for indirect participants relative to direct participants. Reasons why there may be consistent difference are banks' business models with regard to client banks. For example, in terms of European time, indirect participants located in the US are late payers and indirect participants located in Asia are early payers. Abstracting from such reasoning, the settlement time and time differences of own payments and tiered payments can provide indications of how settlement banks time different types of payments and how they may differ structurally.

The average timing of sent payments TS of bank i on day b is given by:

$$TS_i^b = \frac{\sum_{i=1}^{n} (s_i^b(t) * t)}{\sum_{i=1}^{n} (s_i^b)} \tag{8}$$

The respective average receiving time of payments TR is given by:

$$TR_i^b = \frac{\sum_{i=1}^{n} (r_i^b(t) * t)}{\sum_{i=1}^{n} (r_i^b)} \tag{9}$$

The difference between received and sent payments TD indicates whether payments are recycled or whether banks, on average, send out payments before incoming payments arrive. The measure can therefore be interpreted as a proxy for the external delay of payments:

$$TD_b = TR_b - TS_b \tag{10}$$

Assuming there are no structural reasons for timing differences between direct and indirect participants, differences in TD for non-tiered and tiered payments would result from direct participants treating tiered payments differently in terms of timing, for example via internal queue management. Contractual arrangements between direct and indirect participants are unknown. Therefore, postponing settlement of payments on behalf of indirect participants may be in line with contractual provisions.

A negative value of TD indicates that banks send payments later than they receive them, while a positive value shows that banks send payments earlier than they receive them. Abstracting from structural differences, a negative value implies that banks recycle liquidity rather than providing it. If it is assumed that all payment instructions arrive at banks equally distributed during the day, the difference in timing would measure external delay. Differences in timing would occur if banks rearranged payments and thus delayed payments outside of (external to) the system.[14] The actual transmission and obligation to pay is unobserved, as payments show up in the data only upon entering the system. Assuming that payments do not differ structurally in terms of when direct participants receive payment instructions, payment timing can be regarded as a proxy for how participants manage their payments outside the system. Payment timing across different categories of payments can serve as an approximation for the treatment of payments in internal queues. Arguably, for a definitive interpretation of results, the unobserved given conditions outside the system are critical.

4.3 Delay indicator

Through delaying payments, direct participants may hold back liquidity and rely on incoming funds for making payments. Delays occur in two ways. First, as described above, participants can externally delay sending payments for settlement in TARGET2. Second, within the system, delay can occur between when payments are sent to the system and when they are actually settled in the system. Delay between when direct participants receive payment instructions and when payments are sent to the system can only be observed indirectly. By contrast, delay within the system can be observed directly. Delay within the system occurs when liquidity is not sufficient for settlement and payments get queued. Banks may also use different liquidity saving mechanisms available in TARGET2. These include reserving liquidity for highly urgent payment, which means this liquidity is not available for lower priority payments. Participants may also set bilateral and multilateral limits, thus limiting their net positions vis-à-vis other participants.

Following Kaliontzoglou and Müller (2015), we measure the delay in payments by comparing the introduction[15] and settlement time in the system relative to the latest possible settlement time. The latest possible settlement time considered here is the close of business. The indicator of delay is stated as:

$$DI_i^b = \frac{\sum_{i=1}^{n}(s_i^b(t) * (t_{2,i} - t_{1,i})}{\sum_{i=1}^{n}(s_i^b(t) * (T - t_{1,i})} \tag{11}$$

Where $t_{1,i}$ is the time during the business day when the payment is available to be settled, $t_{2,i}$ is the actual settlement time of the payment and T is the end of day, i.e. the latest possible settlement time.[16]

[14]It could be the case that tiered payments are sent to settlement banks later in the day. Note that on a system level, the timing of all sent and received payments is equal if all participants are observed. This is not the case for different categories of payments, such as tiered payments. The sending leg and receiving leg of payments may fall into different categories.

[15]Participants can specify the date and time when a payment should be executed. The first attempt for settlement by the system will be made at that point in time. In those cases we use the time for payment execution rather than when the instruction for later settlement reached the system.

[16]Cut-off times differ for different types of payment. For simplicity, we assume the latest cut-off for all

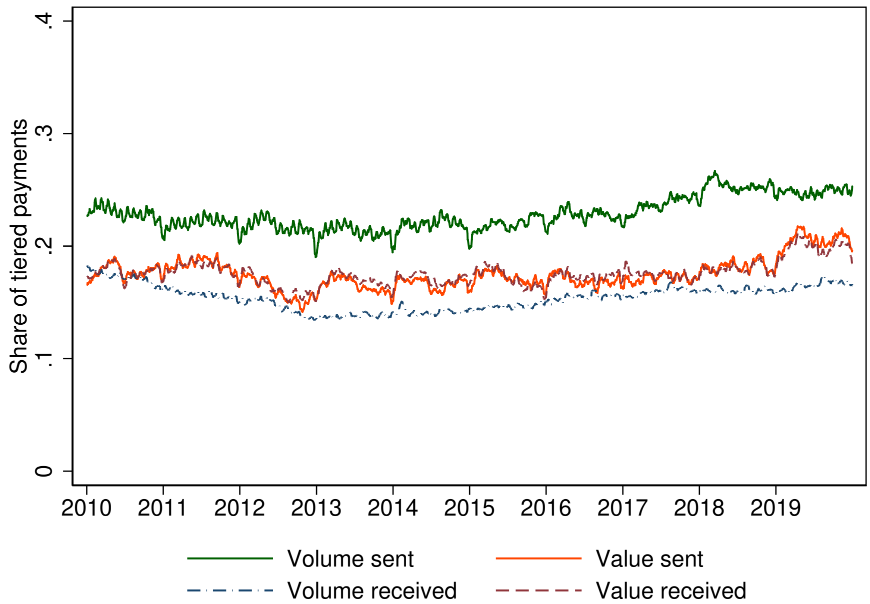
5 Results

The results are organized starting with the overall levels of tiering and liquidity consumption. To formally test the effect of tiering on liquidity consumption, we then estimate a panel data model on the settlement bank-level. Timing and delay indicators then identify channels via which tiering reduces relative liquidity use.

5.1 Tiering and liquidity consumption

The share of tiered payments, calculated as share based on Equation 1, lies roughly between 15 to 25 percent over the observation period (see Figure 2). The number of tiered payments is higher on the sending side. However, in terms of values, the share of tiered payments is similar on the sending and receiving side. This means the average size of payments on the receiving side is larger for tiered payments. At the same time, indirect participants send higher volumes of payments than they receive, which can either indicate that client banks have a greater number of lower denominated payment obligations or that they break up payment obligations into smaller tranches compared to received payments. Overall, the level of tiering is relatively low in TARGET2.[17].

Figure 2: Share of tiered payments on system level



Note: The share of tiering is calculated using the number and value of tiered payments divided by all included payments in the sample.

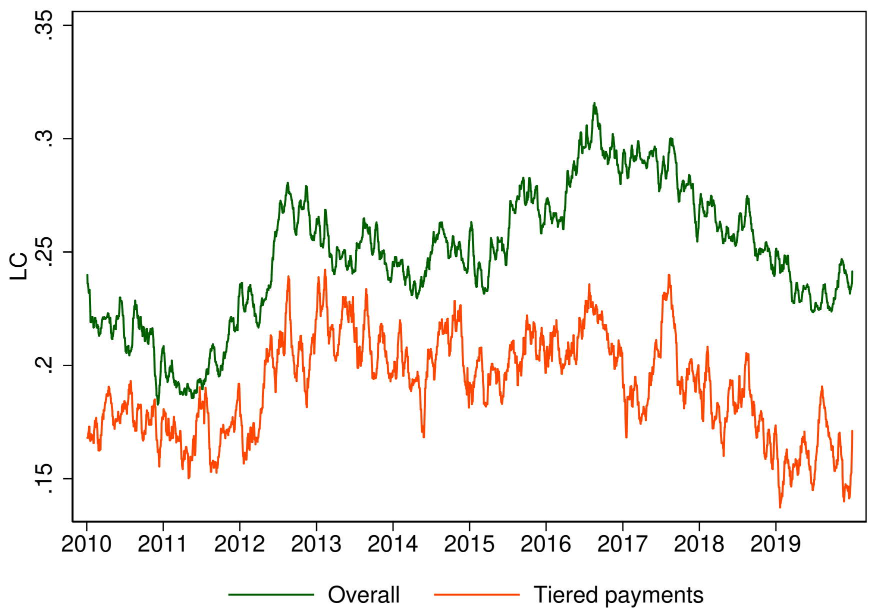
Figure 3 shows liquidity consumption based on Equation 6 calculated for tiered and non-tiered payments. Directly comparing outcomes in terms of the relative use of liquidity

payments to be the end of the day.

[17]For our subset of the data, tiering levels are higher compared to values on the overall system level. On yearly levels of tiering in TARGET2, see the respective Annual reports on TARGET2.

shows that participants use less liquidity relative to payments for tiered transactions. However, isolating different categories of payments here does not take into account the overall liquidity position of participants. There might be a bias, as liquidity management may change during the day, depending on a participant's net overall position. It cannot be ruled out that banks' own payments are by nature (and not by choice) of higher priority and need to be settled earlier in the day, thereby increasing banks' liquidity use for their own payments. Aside from such caution, the consistently lower levels of liquidity consumption for tiered payments indicate that tiered payments leave settlement banks more discretion, enabling them to use less liquidity.

Figure 3: Liquidity consumption on system level



Note: Moving averages over 30 calendar days. Liquidity consumption is calculated on the system level including all payments in the scope of the study and for outgoing and incoming tiered payments. For the indicator on tiered payments, all non-tiered payments are ignored. Intraday balances do not reflect actual liquidity positions, but a hypothetical scenario where only the payments of interest here would be processed.

5.2 Model of liquidity consumption

To test the effect of tiering and explain the outcomes in terms of liquidity consumption on the direct participant level, we estimate a panel data model using bank and time fixed-effects. We prefer fixed effects over random effects as the latter assume the unobserved bank-level effects are uncorrelated with the independent variables. As the level of tiering and size of settlement banks probably factor into the unobserved effects, we prefer fixed effects here. However, the results are robust to employing random effects. Liquidity consumption is calculated daily across direct participants. As the independent variable of interest, the share of tiered payments is included. Table 2 reports summary statistics for the variables in the model.

Table 2: Summary statistics

Variables	N	mean	sd	min	max
Tiering share	1,726,472	0.03	0.11	0.00	1.00
Liquidity consumption	1,726,472	0.43	0.33	0.00	1.00
Cost-based liquidity use	1,726,472	0.00	0.01	-0.12	0.13
Concentration out	1,726,472	0.79	0.22	0.00	1.00
Concentration in	1,726,472	0.83	0.20	0.00	1.00
Priority of payments	1,726,472	1.63	0.69	1.00	3.00
Log value sent	1,726,472	17.69	3.05	6.91	25.90
Time difference	1,726,472	-0.15	3.14	-10.85	10.96
Money market rate	2,555	-0.02	0.42	-0.54	1.63
Log liquidity	2,555	13.43	0.81	11.64	14.54

Note: The share of tiered payments is calculated as the value of tiered payments sent relative to all payments sent by a participant, the log value sent is the log-transformed value of overall payments sent, the time difference is the difference in average timing between all received and sent payments, the concentration is measured by the Gini coefficient for outgoing and incoming payments, the priority of payments is the average priority of payments (values between 1 and 3), the money market rate is expressed as a percentage (calculated via loans identified from TARGET2 data), and log-transformed overall liquidity measured in millions of euro (ECB data).

We use the log of overall payments sent by direct participants as controls to account for size. Direct participants with more payments should be better able to manage liquidity, as they can smooth their liquidity usage by pooling payments (see Adams et al., 2010)). Accounting for size allows to abstract from such pooling effects. The average priority of the direct participant's sent payments controls for the urgency of payments, while the difference in the average timing of sent and received payments accounts for the degree of active liquidity management. In addition, we include the concentration of sent and received payments respectively, calculated as the Gini coefficient of payment values. The concentration of payments determines to some extent how granular participants can manage liquidity. Higher concentration of payments inhibits participants from shuffling payments. As controls for the cost of liquidity and the overall levels of liquidity, the overnight interbank money market rate and overall liquidity[18] are included. The money market rate is calculated using an algorithm proposed by Furfine (1999), applied to TARGET2 data following Arciero, Heijmans, Heuver, Massarenti, Picillo, and Vacirca (2016) and Frutos, Garcia-de Andoain, Heider, and Papsdorf (2016). We use a modified version of the latter to calculate the euro money market rate.[19] The algorithm identifies interbank loans by matching payments with plausible repayments the next business day.

We estimate the model using fixed effects for direct participants and time effects on a yearly basis to account for changes over time. Changes over time can occur as a

[18] Calculated as the sum of current account holdings and the use of the deposit facility, minus the use of the marginal lending facility.

[19] For a discussion on measurement of money market rates, see Müller and Paulick (2020).

result of shifts in banking structures or payment processing. Events such as Brexit may trigger changes in how banks access TARGET2, for example by consolidating liquidity management or client banks using a different direct participant to route payments.[20]

The effect of tiered arrangements may partly be picked up in bank fixed effects. Specifications without fixed effects exhibit higher coefficients and significance levels for tiering and other control variables.[21] The estimated model may therefore be regraded as a conservative estimate of the effects of tiered arrangements.

The model for liquidity consumption is stated with the share of tiered payments by settlement bank i on business day b as the independent variable of interest and different control variables in vector X'_{it}. Bank-level effects are denoted α and time effects y as π.

$$LC_i^b = \alpha_i + \beta_1 tiering_{ib} + \beta_2 X_{ib} + \pi_y + \epsilon_{it} \tag{12}$$

One issue in the case of TARGET2 is that direct participants with very low payment activity may distort results using relative measures. Small participants may only access TARGET2 for certain types of payments or are simply very small and do not actively engage with the system or play any significant role within the system.

We estimate the model for all direct participants, and sub-samples for direct participants with at least 0.1 percent (128 direct participants) of overall traffic value and a threshold of 0.5 percent (50 direct participants). Results are presented in Table 3. In terms of significance and magnitude, the effect of tiering is quite stable within different sub-samples. The results for the sub-samples of participants are more meaningful, as larger settlement banks are more relevant in the context of tiered arrangements and of higher interest due to their importance in the payment system. Including only the largest 50 settlement banks seems most useful to investigate differences for those participants that are most critical to the system and most active in offering tiered arrangements.

In all specifications, the share of tiered payments has a negative impact on liquidity consumption, meaning a higher share of tiered payments leads to participants using less liquidity relative to their payment obligations. The effect is statistically significant at least on the 10 percent level and significance increases when only including larger participants. In terms of economic significance, the effect increases as smaller participants are dropped. While the change in one unit of tiering has an effect of roughly 0.05 on liquidity consumption, the effect increases to around 0.21 for large participants. The effect of tiering does not constitute a mere pooling effect, given the control variables and estimation using fixed effects.

Concerning liquidity risk, the results indicate that settlement banks' liquidity risk is lower the higher the share of tiering. This result holds controlling for other factors relevant to liquidity management and to settlement banks' business models. Therefore, tiering allows settlement banks to save on liquidity input beyond mere pooling effects.

The size of direct participants measured by log value sent leads to increases in liquidity consumption. Larger participants thus appear to provide more liquidity relative to payments to the system, but the effect is not significant when smaller direct participants

[20] The model is robust to employing time fixed effects on a monthly basis. However, including monthly fixed effects leads to multicollinearity with the prevailing money market rate and overall liquidity. We therefore prefer the yearly fixed effects to allow for the interpretation of the effects of the money market rate and liquidity conditions.

[21] Results are available upon request.

are dropped. This is counter-intuitive to the hypothesized direction. The fixed effects specification of the model may partly capture the effect of the size of participants as larger participants take advantage of pooling effects, which could explain this result.

Unsurprisingly, the average difference in the timing of payments leads to increases in liquidity consumption and is significant at the 1 percent level in all specifications. Participants sending payments earlier than they receive them, on average, use more liquidity. As expected, a higher concentration of outgoing payments increases liquidity usage, while the opposite is true for the concentration of incoming payments. Highly concentrated sent payments gives direct participants less leeway for liquidity management as few large payments affect intraday balances. For incoming payments, the same reasoning applies, as receiving banks have less leeway in liquidity management when payments arrive in larger bulks. A higher average priority has negative effects, although the effects are not significant in most specifications. While higher average priorities could lead to payments being settled in a more timely manner and thus acting as a drain on liquidity, those participants who use them may be engaged more actively in liquidity management.

It is expected that the cost of liquidity measured by the overnight money market rate will have a negative effect and overall liquidity will have a positive effect. Higher money market rates imply that liquidity is more expensive and thus banks put more effort into managing liquidity more conservatively. High levels of overall liquidity arguably loosen the liquidity constraints on banks and provide less incentive for active liquidity management. The effects are substantial and significant in all specifications for the money market rate. The effect of overall liquidity is positive and significant in most specifications.

For robustness, we estimate the model with an alternative outcome variable, the cost-based measure of liquidity need cLN:

$$cLN_i^b = \alpha_i + \beta_1 tiering_{ib} + \beta_2 X_{ib} + \pi_y + \epsilon_{it} \tag{13}$$

Results in Table 4 show a similar picture. The R squared for specifications including smaller direct participants is low. A likely explanation is the heterogeneity of direct participants in those specifications. Direct participants with little payment activity and probably little liquidity management likely lead to the low levels of explained variance. The effect of tiering is slightly less consistent and the significance of some control variables changes. The effect of payment concentration becomes less significant and changes direction for payments sent. Meanwhile, the effect of timing differences stays highly significant. The effect of liquidity cost mostly remains negative and that of overall liquidity is positive. However, for the cost-based liquidity need they are not statistically significant. Liquidity conditions and cost may be picked up to some degree by the yearly fixed effects. Notably, the explained variance is lower for the cost based measure compared to liquidity consumption.

5.3 Timing

As one route of explanation for the results on liquidity consumption, timing differences are observed for tiered and non-tiered payments. The timing indicators from Equation 10 are calculated for larger participants (0.1 percent threshold) and all other participants. For simplicity, these are called large and small participants, respectively. Types of payments are all payments sent and received, payments on banks' own behalf, intragroup payments and tiered payments. Figure 4a shows timing differences are positive for large participants for their own payments, but not for tiered payments. In terms of value-weighted timing, large participants receive tiered payments before they send them out. For non-tiered payments the opposite is the case. Non-tiered payments are on average sent earlier than incoming payments arrive. Intragroup payments do not show a clear pattern over time. In earlier years, timing differences of intragroup payments were in fact positive and only turned negative in recent years. At the same time, time differences for tiered payments lie in lower negative territory for the full time period. Banks' own payment hover above zero for most of the period before turning more positive in recent years, creating a wedge with intragroup payments. Given that results are value-weighted, figures for large participants are almost identical to the overall system level.

Comparing results with those of smaller participants, Figure 4b shows a highly uneven picture. Dynamics change over time and time differences for tiered payments move from negative to positive values. The volatile observations may be attributed to changes in group structures and payment routing. The dynamic probably also reflects that smaller banks less frequently settle payments on behalf of other clients and engage less actively in liquidity management.

Reasons for the observed differences between tiered and non-tiered payments could be that participants wait for incoming liquidity before sending payments on behalf of their client banks. This could be done by giving tiered payments a lower priority in internal or system queues. At the same time, client banks receiving payments earlier than sending their instructions to direct participants would also explain the observed differences. Importantly, the observed difference in treatment of tiered payments may result from settlement banks limiting exposures to their client banks. Chapman et al. (2013) argue that settlement banks monitor client banks and offer settlement modes based on credit risk. Thus, settlement bank may limit exposures to their client banks by de-prioritizing client payments.

Importantly, timing differences can serve as a proxy for internal payment queuing of direct participants. This assumes for different categories of payments that there is no difference between the sending and the receiving side in when direct participants become aware of them. Whether this assumption is realistic or not can hardly be validated, as bank internal data is not available.

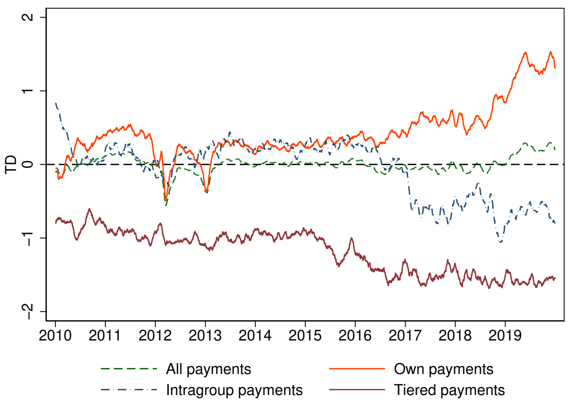
5.4 Delay

Delay indicators from Equation 11 depicted in Figure 5 show an uneven development over time. While tiered payments tended to exhibit higher levels of delay in earlier years, in recent years the levels have fallen below the delay of banks' own payments. One reason could be that the expansion of monetary policy and the asset purchases of the Eurosystem have decreased active liquidity management incentives at the system level, as liquidity has become less sparse. In conjunction with timing differences, some banks may have shifted liquidity management outside the system, as liquidity constraints within the system have decreased in importance. For recent years, we find no evidence of significant differences across tiered and non-tiered payments, meaning tiered payments are not delayed once sent to the system for settlement.

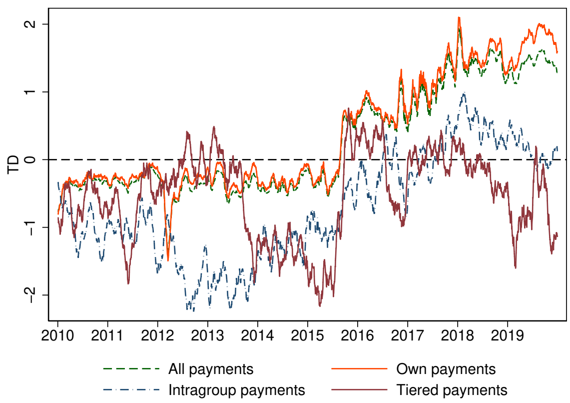
Interestingly, delay in TARGET2 has been accompanied by an overall decrease in

Figure 4: Timing differences

(a) Large participants

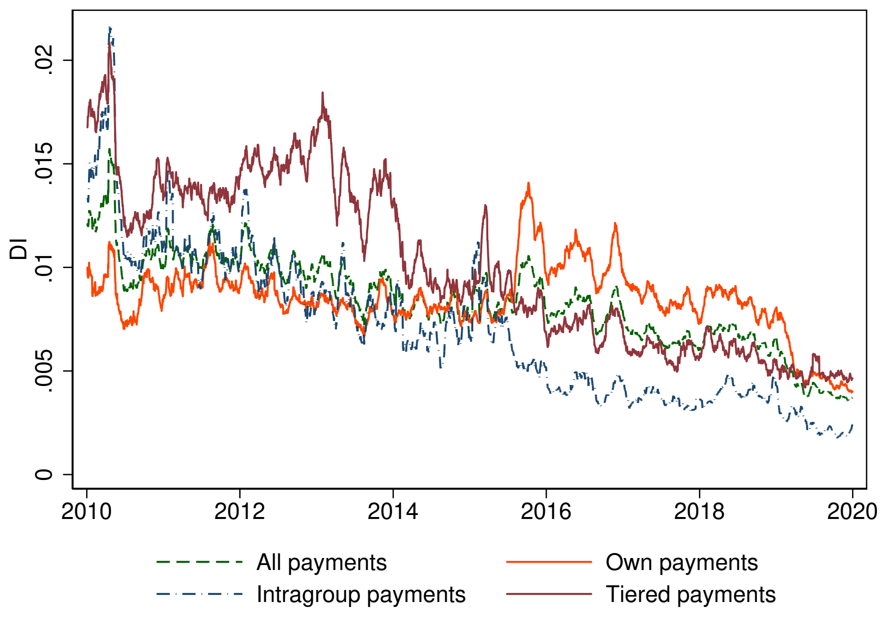


(b) Small participants



Note: Moving averages over 30 calendar days. Results for large participants depicted on the left-hand side are almost identical to the overall system level. Large participants are those with at least 0.1 percent of overall sent payments over the observation period, accounting for 91 percent of traffic.

Figure 5: Delay indicator for different payment types

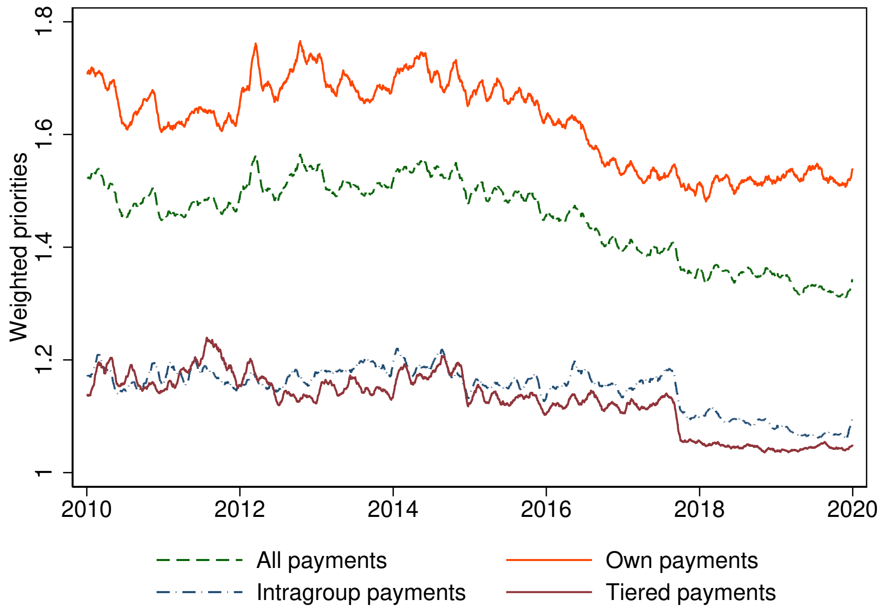


Note: Moving averages over 30 calendar days.

the use of priorities. We categorize priorities from normal (1) to highly urgent (3).[22] Value-weighted priorities are lower for intragroup and tiered payments, while banks' own payments are prioritized higher.

[22]We deviate from the values in the original data, which range from 2 (normal, 4 (urgent) to 7 (highly urgent.

Figure 6: Value-weighted priorities for different payment types



Note: Moving averages over 30 calendar days. Priority categories constructed with range from 1 (normal) to 3 (highly urgent).

6 Discussion

The analysis is limited to information from systems data focusing on payments once they enter TARGET2. Information on settlement banks' internal procedures and contractual arrangements with client banks is obtained only implicitly. Importantly, TARGET2 is only one part of banks' overall liquidity position. Other systems, bilateral relationships and exposures may play a significant role for some banks' liquidity disposal. These limitations of the study point to the need to shift the focus of policy to participants, rather than focusing solely on systems as a whole. Importantly, agreements between direct and indirect participants cannot be observed. Taking a more holistic, participant-centric view could be highly beneficial. Gathering more data on participants and their internal procedures for settlement, could shed more light on questions of potential free-riding, postponement of payments and exposures.

In terms of operational proficiency, tiering may have benefits, that are not directly observable in the system. The results on a participant-level in this study have highlighted differences between large and small participants and areas where closer investigation from a regulatory perspective would be useful. Tiering may pose additional risks, such as banks' giving preference to own payments over tiered ones. This could put indirect participants at a disadvantage if direct participants face financial stress or experience outages. At the same time, tiering should not only be regarded as a source of risk.

Liquidity needs for settling payments are lower when tiering is more prevalent and may lead to an operationally more stable system. Heterogeneity between participants at a system level should be taken into account. Therefore, policies on tiering at a system-level should consider cases of individual participants and their behavior, with special attention given to large and interconnected participants.

Direct participants managing tiered payments in a way that allows them to save on liquidity could be beneficial for indirect participants, as the cost of liquidity is lower compared to a situation in which more participants join the system as direct participants. The more efficient direct participants manage liquidity needs, the lower the fees paid by indirect participants should be.

7 Conclusion

This paper investigated the impact of tiered settlement on liquidity consumption using TARGET2 transaction data. Our results show that tiering has beneficial effects on liquidity risk. Tiered payments enable settlement banks to smooth their liquidity positions intraday beyond a mere pooling effect. The results are robust, including several controls and bank fixed-effects. Lower liquidity needs are therefore unlikely to occur, due to pooling effects or heterogeneous liquidity management across banks. Timing and priorities of payments appear as channels via which tiered payments are incorporated into settlement banks' active liquidity management. Payment timing as a proxy for external delay suggests tiered payments are treated with less urgency than settlement banks' own or in-house payments. Payment priorities also point in this direction as they are consistently lower for tiered payments. Results on payment delay within the system show no clear dynamic over time. This is in line with findings from the literature that the use of liquidity saving mechanisms in payment systems can be low, as banks use in-house tools to manage payment queues before entering the system.

While in line with contractual arrangements, some degree of "free-riding" or higher recycling of liquidity from client banks' could pose risks for indirect participants, as their payments are treated with less urgency. However, the results are also consistent with settlement banks' monitoring of indirect participants and their differing terms of settlement for their clients. While seemingly less likely, sent and received tiered payments could inherently exhibit different characteristics due to geographical and other factors.

Policy makers need to balance efficiency gains and potentially emerging risks. Arguably, internal processes of banks would need to be better understood to evaluate risks posed by tiered arrangements. As system overseers and operators typically have no access to bank internal contracts and data, our analysis relies on inference and system-internal dynamics.

Table 3: Liquidity consumption model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Liquidity consumption											
Tiering share	-0.054**	-0.046**	-0.054**	-0.046**	-0.165***	-0.154***	-0.165***	-0.154***	-0.213***	-0.209***	-0.213***	-0.209***
	(0.024)	(0.023)	(0.024)	(0.023)	(0.048)	(0.050)	(0.048)	(0.050)	(0.057)	(0.057)	(0.058)	(0.057)
Log value sent	0.008***	0.018***	0.008***	0.018***	0.014	0.011	0.015*	0.012	0.003	0.002	0.003	0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.009)	(0.008)	(0.009)	(0.008)	(0.012)	(0.011)	(0.012)	(0.011)
Time difference	0.053***	0.055***	0.053***	0.055***	0.057***	0.058***	0.057***	0.058***	0.051***	0.051***	0.051***	0.051***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.005)	(0.006)	(0.005)
Concentration out		0.041***		0.041***		0.225***		0.224***		0.179		0.180
		(0.013)		(0.013)		(0.083)		(0.083)		(0.112)		(0.112)
Concentration in		-0.464***		-0.464***		-0.192**		-0.192**		-0.192		-0.191
		(0.018)		(0.018)		(0.090)		(0.090)		(0.124)		(0.125)
Priority		0.014**		0.014**		0.036**		0.036**		0.031		0.031
		(0.005)		(0.005)		(0.014)		(0.014)		(0.031)		(0.031)
Money market rate			-0.024***	-0.023***			-0.030***	-0.028***			-0.023**	-0.021**
			(0.003)	(0.003)			(0.006)	(0.006)			(0.009)	(0.009)
Log liquidity			0.009***	0.010***			0.014***	0.015***			0.015**	0.016**
			(0.002)	(0.002)			(0.005)	(0.004)			(0.007)	(0.007)
Constant	0.278***	0.424***	0.176***	0.310***	-0.047	-0.066	-0.216	-0.243	0.181	0.156	-0.003	-0.038
	(0.047)	(0.045)	(0.056)	(0.053)	(0.195)	(0.195)	(0.204)	(0.203)	(0.269)	(0.286)	(0.285)	(0.309)
Observations	1,726,472	1,726,472	1,726,472	1,726,472	268,496	268,496	268,496	268,496	110,830	110,830	110,830	110,830
R-squared	0.231	0.265	0.232	0.265	0.339	0.348	0.340	0.349	0.298	0.304	0.299	0.305
Direct participants	1,216	1,216	1,216	1,216	128	128	128	128	50	50	50	50

*** p<0.01, ** p<0.05, * p<0.1

Note: All the specifications include settlement bank and year fixed effects. Heteroskedasticity robust clustered standard errors (for serial correlation) in parentheses. The main variable of interest is the share of tiered payments, calculated as the value of tiered payments sent relative to all payments sent by a participant. Additional controls include log-transformed overall payments sent, the difference in average timing between all received and sent payments in hours, concentration measured by the Gini coefficient for outgoing and incoming payments, the average priority of payments (values between 1 and 3), the money market rate in percent (calculated via loans identified from TARGET2 data), and log-transformed overall liquidity measured in millions of euro (ECB data).

Table 4: Cost-based model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Cost-based liquidity use											
Tiering share	-0.001***	-0.001***	-0.001***	-0.001***	-0.165***	-0.007**	-0.007***	-0.007**	-0.213***	-0.016***	-0.016***	-0.016***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.048)	(0.003)	(0.003)	(0.003)	(0.057)	(0.005)	(0.005)	(0.005)
Log value sent	0.000***	0.000***	0.000***	0.000***	0.014	0.002***	0.001***	0.002***	0.003	0.002**	0.001*	0.002**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.009)	(0.000)	(0.000)	(0.000)	(0.012)	(0.001)	(0.001)	(0.001)
Time difference	0.000***	0.000***	0.000***	0.000***	0.057***	0.001***	0.001***	0.001***	0.051***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	(0.006)	(0.000)	(0.000)	(0.000)
Concentration out		-0.001**		-0.001**		-0.009		-0.009		-0.018*		-0.018*
		(0.000)		(0.000)		(0.006)		(0.006)		(0.010)		(0.010)
Concentration in		-0.001***		-0.001***		-0.007*		-0.007*		-0.008		-0.008
		(0.000)		(0.000)		(0.004)		(0.004)		(0.010)		(0.010)
Priority		-0.000		-0.000		0.000		0.000		0.000		0.000
		(0.000)		(0.000)		(0.001)		(0.001)		(0.002)		(0.002)
Money market rate			-0.000	-0.000			-0.000	-0.000			0.000	-0.000
			(0.000)	(0.000)			(0.000)	(0.000)			(0.001)	(0.001)
Log liquidity			0.000	0.000			0.000	0.000			0.001	0.000
			(0.000)	(0.000)			(0.000)	(0.000)			(0.001)	(0.001)
Constant	-0.003***	-0.003***	-0.003**	-0.003**	-0.047	-0.020**	-0.030**	-0.021**	0.181	-0.021	-0.041*	-0.026
	(0.001)	(0.001)	(0.001)	(0.001)	(0.195)	(0.008)	(0.012)	(0.010)	(0.269)	(0.015)	(0.023)	(0.021)
Observations	1,726,472	1,726,472	1,726,472	1,726,472	268,496	268,496	268,496	268,496	110,830	110,830	110,830	110,830
R-squared	0.018	0.020	0.018	0.020	0.339	0.123	0.111	0.124	0.298	0.158	0.139	0.158
Direct participants	1,216	1,216	1,216	1,216	128	128	128	128	50	50	50	50

*** p<0.01, ** p<0.05, * p<0.1

Note: All the specifications include settlement bank and year fixed effects. Heteroskedasticity robust clustered standard errors (for serial correlation) in parentheses. The main variable of interest is the share of tiered payments, calculated as the value of tiered payments sent relative to all payments sent by a participant. Additional controls include log-transformed overall payments sent, the difference in average timing between all received and sent payments in hours, concentration measured by the Gini coefficient for outgoing and incoming payments, the average priority of payments (values between 1 and 3), the money market rate in percent (calculated via loans identified from TARGET2 data), and log-transformed overall liquidity measured in millions of euro (ECB data). Numbers are rounded to three decimal digits and may therefore exhibit values of zero, more detailed results are available upon request.

References

Abbink, K., R. Bosman, R. Heijmans, and F. van Winden (2017). Disruptions in large-value payment systems: An experimental approach. *International Journal of Central Banking 13*(4), 63–95.

Adams, M., M. Galbiati, and S. Giansante (2010). Liquidity costs and tiering in large-value payment systems. Bank of England working papers 399, Bank of England.

Arango, C. A. and F. H. Cepeda (2017). Non-monotonic Tradeoffs of Tiering in a Large Value Payment System. *Journal of Financial Market Infrastructures 6*(1), 45–78.

Arciero, L., C. Biancotti, L. D'Aurizio, and C. Impenna (2009). Exploring Agent-Based Methods for the Analysis of Payment Systems: A Crisis Model for StarLogo TNG. *Journal of Artificial Societies and Social Simulation 12*(1).

Arciero, L., R. Heijmans, R. Heuver, M. Massarenti, C. Picillo, and F. Vacirca (2016). How to measure the unsecured money market: The Eurosystem's implementation and validation using TARGET2 data. *International Journal of Central Banking 12*(1), 247–280.

Arculus, R., J. Hancock, and G. Moran (2012). The Impact of Payment System Design on Tiering Incentives. RBA Research Discussion Papers 2012-06, Reserve Bank of Australia.

Arjani, N. and R. Heijmans (2020). Is there anybody out there? Detecting operational outages from LVTS transaction data. DNB Working Papers 683, De Nederlandsche Bank.

Bech, M. and R. Garratt (2003). The intraday liquidity management game. *Journal of Economic Theory 109*, 198–219.

Benos, E., G. Ferrara, and P. Gurrola Perez (2017). The impact of de-tiering in the United Kingdom's large-value payment system. *Journal of Financial Market Infrastructures 6*(2/3), 31–62.

Benos, E., R. Garratt, and P. Zimmerman (2014). The role of counterparty risk in CHAPS following the collapse of Lehman Brothers. *International Journal of Central Banking 10*, 143–171.

Berndsen, R. and R. Heijmans (2020). Near-real-time monitoring in real-time gross settlement systems: a traffic light approach. *Journal of Risk 22*(3), 39–64.

Chapman, J., J. Chiu, and M. Molico (2013). A Model of Tiered Settlement Networks. *Journal of Money, Credit and Banking 45*(2-3), 327–347.

CPSS (2005). New developments in large-value payment systems. CPMI Papers 67, Bank for International Settlements, Committee on Payment and Settlement Systems.

CPSS-IOSCO (2012). Principles for Financial Market Infrastructures (PFMI). CPMI papers 101, Bank for International Settlements, Committee on Payment and Settlement Systems and International Organization of Securities Commissions.

Denbee, E., R. Garratt, and P. Zimmerman (2014). Variations in liquidity provision in real-time payment systems. Bank of England Working Papers 513, Bank of England.

Diehl, M. (2013). Measuring free riding in large-value payment systems: the case of TARGET2. *Journal of Financial Market Infrastructures 1*(3), 31–53.

Diehl, M. and A. Müller (2014). Analysis of the use and impact of limits. *Journal of Financial Market Infrastructures 3*(1), 33–60.

Fedwire Funds Service (2019). Diclosure. 23 December, Fedwire.

Finan, K., A. Lasaosa, and J. Sunderland (2013). Tiering in CHAPS. *Bank of England Quarterly Bulletin 53*(4), 371–378.

Frutos, J. C., C. Garcia-de Andoain, F. Heider, and P. Papsdorf (2016). Stressed interbank markets: Evidence from the European financial and sovereign debt crisis. Working Paper Series 1925, European Central Bank.

Furfine, C. H. (1999). The microstructure of the federal funds market. *Financial Markets, Institutions & Instruments 8*, 24–44.

Glowka, M., J. Paulick, and I. Schultze (2018). The absence of evidence and the evidence of absence: an algorithmic approach for identifying operational outages in TARGET2. *Journal of Financial Market Infrastructures 6*(2/3), 63–91.

Heijmans, R. and R. Heuver (2014). Is this bank ill? The diagnosis of doctor TARGET2. *Journal of Financial Market Infrastructures 2*(3), 3–36.

Heuver, R. and R. Triepels (2019). Liquidity stress detection in the European banking sector. DNB Working Papers 642, De Nederlandsche Bank.

Kahn, C. M. and W. Roberds (2009). Payments Settlement: Tiering in Private and Public Systems. *Journal of Money, Credit and Banking 41*(5), 855–884.

Kaliontzoglou, A. and A. Müller (2015). Implementation aspects of indicators related to payments timing. In M. Diehl, B. Alexandrova-Kabadjova, R. Heuver, and S. Martínez-Jaramillo (Eds.), *Analyzing the Economics of Financial Market Infrastructures*, pp. 169–190. IGI-Global.

Klee, E. (2010). Operational outages and aggregate uncertainty in the federal funds market. *Journal of Banking & Finance 34*, 2386–2402.

Lasaosa, A. and M. Tudela (2008). Risks and efficiency gains of a tiered structure in large-value payments: a simulation approach. Bank of England working papers 337, Bank of England.

Leinonen, H. and K. Soramäki (1999). Optimizing liquidity usage and settlement speed in payment systems. Research Discussion Papers 16/1999, Bank of Finland.

Martin, A. and J. McAndrews (2008). Liquidity-saving mechanisms. *Journal of Monetary Economics 55*(3), 554–567.

Massarenti, M., S. Petriconi, and J. Lindner (2012). Intraday patterns and timing of TARGET2 interbank payments. *Journal of Financial Market Infrastructures 1*(2), 3–24.

McAndrews, J. J. and S. Rajan (2000). The timing and funding of Fedwire funds transfers. *Economic Policy Review*, 17–32.

Müller, A. and J. Paulick (2020). The devil is in the details, but so is salvation - Different approaches in money market measurement. Discussion Paper 66/2020, Deutsche Bundesbank.

Rochet, J. and J. Tirole (1996). Interbank lending and systemic risk. *Journal of Money, Credit and Banking 28*(4), 733–62.

Rubio, J., P. Barucca, G. Gage, J. Arroyoa, and R. Morales-Resendiz (2020). Classifying payment patterns with artificial neural networks: An autoencoder approach. *Latin American Journal of Central Banking 1*(1-4).

Sabetti, L. and R. Heijmans (2021). Shallow or deep? detecting anomalous flows in the canadian automated clearing and settlement system using an autoencoder. *Latin American Journal of Central Banking (forthcoming).*

Triepels, R., H. Daniels, and R. Heijmans (2018). Detection and explanation of anomalous payment behaviour in real-time gross settlement systems. In S. Hammoudi, M. Śmiałek, O. Camp, and J. Filipe (Eds.), *Enterprise Information Systems*, Volume 321, pp. 145–161. Springer.