EUROPEAN CENTRAL BANK

EUROSYSTEM

Occasional Paper Series

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TARGET2 analytical tools for regulatory compliance

No 300 / August 2022

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Abstract

As the operator of a systemically important payment system (SIPS), the Eurosystem has the responsibility of regularly assessing the resilience of the Trans-European Automated Real-time Gross Settlement Express Transfer System (TARGET2) to various types of risks, as set out in the Principles for Financial Market Infrastructures (PFMIs) drawn up by the Committee on Payments and Market Infrastructures (CPMI) and International Organization of Securities Commissions (IOSCO). To identify, measure, monitor and mitigate these risks over time, the TARGET2 operator has developed specific approaches that include both qualitative and quantitative elements.

The paper offers a comprehensive overview of the quantitative tools developed and used by the TARGET2 operator, through the TARGET Analytics Group (TAG), to support the risk assessment processes required to comply with the PFMIs. The toolkit is based on transaction-level data analysis and ranges from individual statistical indicators to more complex methodologies using advanced analytics and specific tools, such as the TARGET2 simulator.

Since all major payment systems worldwide are required to comply with the PFMIs, this topic is of interest to the relevant operators and oversight bodies around the globe. Moreover, although mainly developed for regulatory compliance purposes, these indicators and studies offer important insights into traffic patterns, system efficiency, usage of different system features, liquidity flows, the behaviour of individual participants and their interconnections.

JEL Code(s): G20, E42, E58, (C10, C63)

Keywords: payment systems, TARGET2, FMIs, PFMIs

Non-technical summary

TARGET2 is the Eurosystem’s real-time gross settlement (RTGS) system that processes euro-denominated payments in central bank money. As a SIPS, it plays a pivotal role in the functioning and stability of the financial system. It is therefore of key importance that its risks are properly monitored and managed. TARGET2 is subject to the Regulation of the European Central Bank on oversight requirements for systemically important payment systems,[1] as amended,[2] which establishes a comprehensive regulatory framework for efficient risk management for payment systems by transposing the CPMI-IOSCO’s PFMIs into euro area legislation.

To support compliance with the PFMIs, the TARGET2 operator, through the TAG, has developed a broad quantitative toolkit based on data analytics of granular information on the system’s activity and participants. Quantitative analyses are, in particular, used for risk assessment in accordance with the following principles: Principle 3 (risks arising from interdependencies), Principle 7 (liquidity risk), Principle 17 (operational risk) and Principle 19 (tiered participation arrangements). They are, however, also instrumental in supporting compliance with other principles. Access to granular data has been fundamental for the development of these analytical tools. This paper presents a comprehensive overview of the TAG’s toolkit for risk assessment.

The Eurosystem’s quantitative compliance toolkit ranges from individual statistical indicators to more complex methodologies using advanced analytics and specific tools, such as the TARGET2 simulator. The analysis of interdependencies, which serves to quantify the risks arising from the interconnections that TARGET2 has with other entities, relies on a broad set of statistical and network indicators based on a general framework established by the CPMI. Various liquidity indicators, focusing also on the intraday dimension, and ad hoc studies of liquidity saving features or participants’ payments behaviour are used to monitor and assess liquidity risk, in accordance with the PFMI requirements. Data analysis supports two dimensions of compliance with general business risk requirements, namely cost recovery and fraud detection. For the latter, in particular, the TARGET2 operator has developed tools that are combined with machine-learning techniques for monitoring and detecting abnormal payments in the system.

Operational risk monitoring is also complemented by data analytics in several ways. Critical credit institutions in TARGET2 are identified by combining two criteria: (i) an indicator looking at the turnover generated by participants in the system, and (ii) an analysis of the impact on TARGET2 settlement capacity of a simulated technical failure using the TARGET2 simulator. The latter aims to capture the contagion effect of a potential operational failure of a participant. Moreover, the TARGET2 operator

1 Regulation of the European Central Bank (EU) No 795/2014 of 3 July 2014 on oversight requirements for systemically important payment systems (ECB/2014/28) (OJ L 217, 23.7.2014, p. 16).

2 Regulation (EU) 2017/2094 of the European Central Bank of 3 November 2017 amending Regulation (EU) No 795/2014 on oversight requirements for systemically important payment systems (ECB/2017/32) (OJ L 299, 16.11.2017, p. 11).

regularly assesses the impact of TARGET2 incidents by looking at the intraday cumulated settlement values and volumes. It also uses an algorithmic methodology to evaluate the potential of operational outages by TARGET2 participants. Finally, risks arising from tiered participation arrangements, namely when a direct TARGET2 participant settles transactions on behalf of another institution, are evaluated by indicators comparing the sender and receiver of a payment with its originator and beneficiary.

Although developed for the purposes of regulatory compliance, these tools have also been an important instrument for monitoring the system and gaining knowledge and understanding of its activity over time. Indicators and compliance-related studies offer, for example, important insights into traffic patterns, system efficiency, the effectiveness of different system features, liquidity flows, payment patterns, the behaviour of individual participants and their interconnections. They are therefore used by the TARGET2 operator in its regular activities and as an aid in exceptional events, such as incidents, or functional changes in the system. Data analyses have provided pivotal support for decision-making by the TARGET2 operator, and for more general policy discussions of the Eurosystem's financial market infrastructures (FMIs).

Given that a wide range of FMIs from around the world are required to comply with the PFMIs, this is a topic of interest to a vast audience of operators and overseers of systemically important payments systems around the globe. The Eurosystem, in publishing this paper, welcomes the opportunity to establish a fruitful exchange with other central banks around the world on the analytics for payments systems with the common objective of further improving the tools and understanding of RTGS systems. This is of particular importance in view of the future challenges and changes to be faced in the payment systems landscape.

1 Introduction

TARGET2, the RTGS system for euro payments that is owned and operated by the Eurosystem, is the backbone FMI for the euro area. It went live in November 2007[3] with the objective of supporting the implementation of the Eurosystem's single monetary policy and the functioning and integration of the euro money market, providing a safe, efficient and reliable mechanism for the settlement of euro payments on an RTGS basis, and ensuring the efficient processing of cross-border payments in euro. TARGET2 is therefore essential for ensuring financial stability in the euro area by substantially reducing systemic risk.

Given the systemically important role of payments systems such as TARGET2 in the functioning and stability of the financial system, it is of paramount importance that their risks are efficiently managed. They therefore have to comply with regulatory standards. In 2012, the CPMI-IOSCO's PFMIs[4] established new international standards for defining and assessing the robustness of FMIs in terms of risks and efficiency. The principles, drawn up after the outbreak of the 2008 financial crisis, are designed to ensure a robust infrastructure to support global financial markets that are able to withstand financial shocks. The compliance of TARGET2 with the PFMIs is a high priority for the Eurosystem. To support regulatory compliance, the TARGET2 operator has developed a broad range of analytical tools, adequately reflecting the importance of TARGET2 for the euro financial system.

TARGET2 is subject to the Regulation of the European Central Bank on oversight requirements for systemically important payment systems,[5] known as the SIPS Regulation, which transposes the CPMI-IOSCO PFMIs to the euro area. The SIPS Regulation provides a comprehensive regulatory framework to ensure the efficient management of payment system-specific risks, as well as sound governance arrangements and objective, risk-based and publicly disclosed criteria to ensure fair and open access to a systemically important payment system. It covers both large-value and retail payment systems of systemic importance, whether operated by the Eurosystem's central banks (CBs) or by private entities, and assigns to the payment system operator responsibility for regularly assessing and monitoring the resilience of the system to the risks to which SIPS are subject.

The risks to which TARGET2 is exposed are legal, credit, liquidity, operational and information security, custody and general business risks. For credit and custody risks, the TARGET2 operator applies the Eurosystem's risk management

3 TARGET2 was launched on 19 November 2007 and fully replaced the first-generation TARGET by May 2008.

4 These principles were developed by the CPSS (Committee on Payment and Settlement Systems), which was the predecessor of the CPMI (Committee on Payments and Market Infrastructures). See Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, "Principles for financial market infrastructures", April 2012.

5 Regulation of the European Central Bank (EU) No 795/2014 of 3 July 2014 on oversight requirements for systemically important payment systems (ECB/2014/28) (OJ L 217, 23.7.2014, p. 16).

framework that is primarily intended for monetary policy operations[6] and has no influence on this framework. All other risks are managed under other frameworks that have been developed by the TARGET2 operator and are aimed at identifying, measuring, monitoring and mitigating these risks within the specific context of TARGET2. These frameworks include both qualitative and quantitative assessments of TARGET2 risks, as defined by the PFMIs.

This paper provides a comprehensive overview of the Eurosystem's quantitative toolkit to support risk monitoring and assessment within the PFMI framework. Although the indicators and methodologies presented have mainly been developed with regulatory compliance in mind, they also offer important insights into TARGET2's activity and traffic patterns, its efficiency, the usage of different features, liquidity flows, the behaviour of individual participants and their interconnections.

[6] See Guideline (EU) 2015/510 of the European Central Bank of 19 December 2014 on the implementation of the Eurosystem monetary policy framework (ECB/2014/60) (OJ L 91, 2.4.2015, p. 3).

2 Data analytics for TARGET2 regulatory compliance

The fulfilment of the specific requirements established by the PFMIs needs to be supported by the analysis of granular data about the system's activity and participants. This is particularly the case for Principle 3 on the framework for the comprehensive management of risks, such as those arising from interdependencies, Principle 7 on liquidity risk, Principle 17 on operational risk, and Principle 19 on tiered participation arrangements, but is applicable also to other principles where risk assessment is supported and complemented by quantitative data analyses. For this reason, access to granular system-wide information is of the outmost importance for the TARGET2 operator. In the Eurosystem, only a limited number of staff have access to granular TARGET2 data that are subject to strict confidentiality rules.[7] This has made it possible for a group of experts, the TAG, to develop a set of analytical tools, under the aegis of the TARGET2 operator, to support compliance with specific PFMIs.

Granular TARGET2 data provide an incomparable richness of information. The database used by the Eurosystem for quantitative TARGET2 analyses keeps a record of each payment that has been processed through TARGET2 since June 2008, i.e. when all central banks completed the migration to the platform. Each payment includes, inter alia, information about the value, parties and counterparties involved, date and time stamps, transaction type and settlement status. To give an idea of its size, between 2009 and 2020 TARGET2 settled more than one billion payments for a corresponding value of more than €6,000 trillion. Moreover, the database contains information about the liquidity and the intraday credit line available to TARGET2 participants each day, as well as about the usage of certain liquidity management features, such as limits and reservations (see Section 6.2 for more detailed information).

The Eurosystem's quantitative compliance toolkit ranges from single statistical indicators to more complex methodologies using advanced analytics and specific tools. One of these tools is the TARGET2 simulator, an adapted version of the Bank of Finland Payment and Settlement System Simulator (the BoF PSS).[8] The TARGET2 simulator replicates the logic of all TARGET2 algorithms and is fed with real data on TARGET2 participants and payments. It allows its users to run simulations by changing the system parameters, the input data or both, and to build what-if scenarios. Simulations can be used for several purposes, such as for optimising the parameters of the system or its features, for replicating different events to understand their implications for payment processing and liquidity positions or for understanding network interdependencies and effects, e.g. the identification of possible channels of contagion.

[7] Decision of the European Central Bank of 29 July 2010 on access to and use of certain TARGET2 data (ECB/2010/9) (2010/451/EU) (OJ L 211 12.8.2010, p. 45), as revised in 2017 under Decision (EU) 2017/2080 of the European Central Bank of 22 September 2017 amending Decision ECB/2010/9 on access to and use of certain TARGET2 data (ECB/2017/29) (OJ L 295, 14.11.2017, p. 86).

[8] Bank of Finland (2009), "Product Information: Bank of Finland Payment and Settlement System Simulator BoF-PSS2", Version 2.4.0, Bank of Finland, 5 October.

Box 1
Overview of TARGET2 activity

TARGET2 is one of the largest wholesale payment systems in the world, settling approximately €1.8 trillion and 345,000 transactions every day. Every five days, TARGET2 processes a value close to the entire euro area gross domestic product (GDP). It settles payments on an individual basis, in real time and in central bank money, with immediate finality. It is used for payments connected with monetary policy operations, interbank payments, customer payments exchanged between banks, and transactions related to other payment and securities settlement systems. TARGET2 can be accessed through different channels, depending on the participants' needs. These include direct and indirect participation, addressable bank identifier codes (BICs) and multi-addressee access. Overall, TARGET2 connects around 1,000 direct participants from countries in the European Economic Area (EEA), sending payments on their own behalf or on behalf of their customers to around 44,000 banks[9] worldwide.

Over the years, the traffic processed in TARGET2 has responded to financial market events, regulatory changes, as well as changes in the FMI landscape. Between 2011 and 2012 the yearly TARGET2 turnover increased from €612.9 trillion to €634.1 trillion, whereas it experienced a drop to €493.4 trillion in 2013, mainly because of a change in the statistical framework, resulting in some transactions being excluded from the calculations.[10] After two years of stable figures, the TARGET2 turnover decreased between 2015 and 2017, following the launch of TARGET2-Securities (T2S). In 2017 the yearly total traffic stood at €432.8 trillion. It has followed a rising trend ever since. In volume terms, the traffic increased from 89.6 million to 92.6 million payments between 2011 and 2013. With the ending of the period for migration to single euro payment area (SEPA) instruments, the traffic significantly decreased between 2013 and 2015 to 88.0 million payments. Since 2018 TARGET2 traffic has stabilised at around 88.3 million transactions yearly. In 2020 a total of 88.7 million transactions were settled in TARGET2 for a value of €465.8 trillion (see Chart A, left-hand panel).

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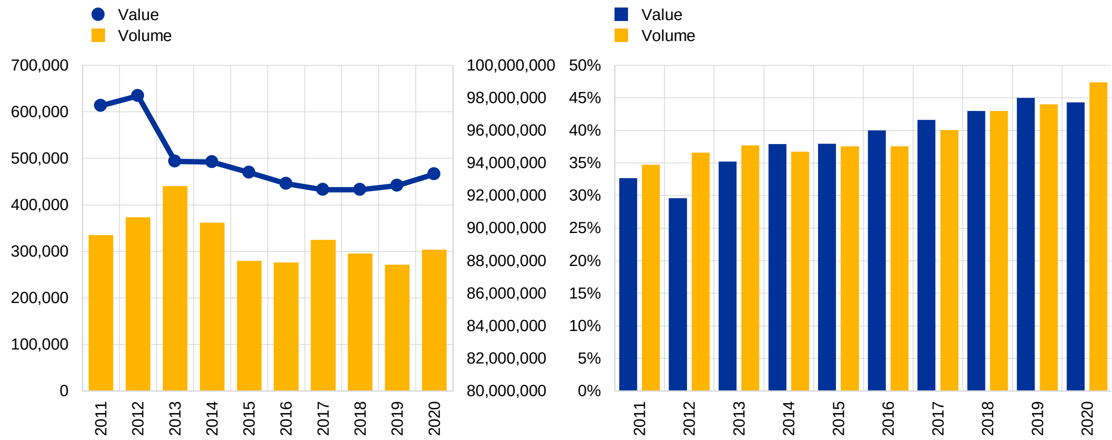
9 This figure takes into account bank branches and subsidiaries.

10 In part as a consequence of the Eurosystem's non-standard monetary policy in response to the financial crisis, the size of overnight deposits made by TARGET2 participants increased considerably, accounting for around 10% of the turnover of TARGET2 in 2012. Consequently, they have been excluded from the TARGET2 statistical indicators since then.

Chart A

TARGET2 traffic and cross-border activity

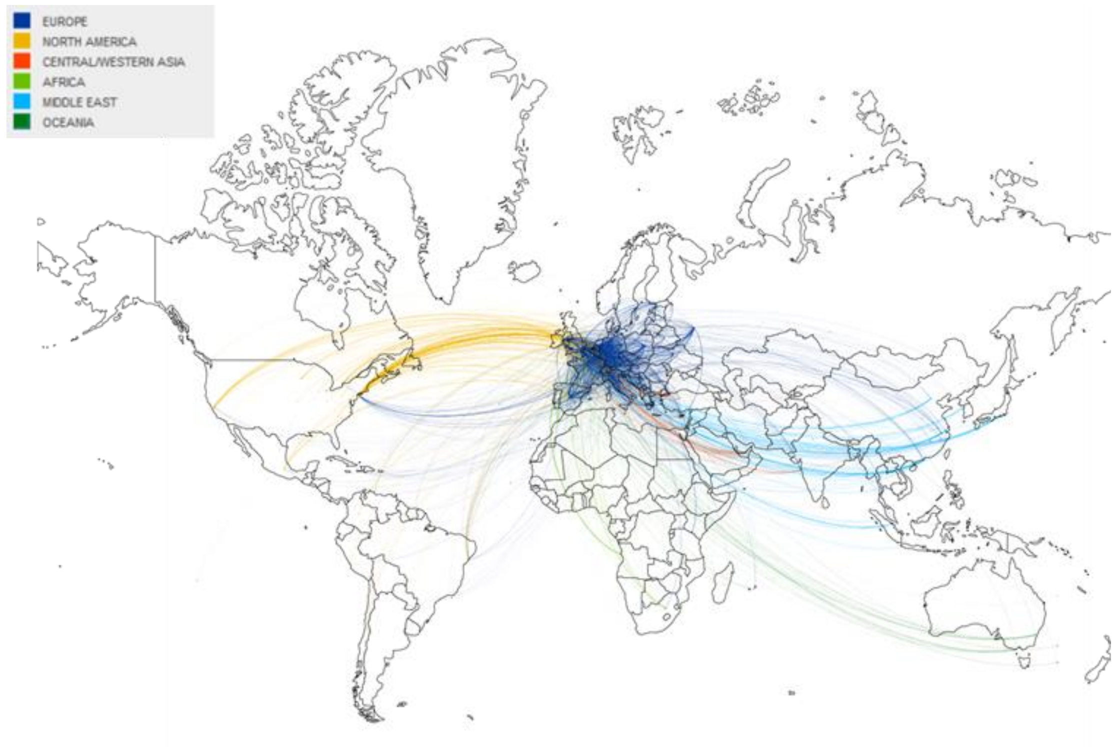
(left-hand panel: x-axis: year; y-axis: yearly total, EUR billions (left-hand side), yearly total, number of payments (right-hand side); right-hand panel: x-axis: year; y-axis: percentages)



Source: TARGET2.
Note: Cross-border activity is determined by the location of the central bank through which each direct participant accesses TARGET2.

TARGET2 connects financial institutions in Europe as well as worldwide. The broad reach of TARGET2 is illustrated by the share of TARGET2 traffic that is exchanged between participants belonging to banking communities located in different countries (see Chart A, right-hand panel). Cross-border traffic has been following a positive trend for the last ten years, both in value and in volume terms, suggesting that TARGET2 has supported financial integration in Europe. Cross-border traffic increased by more than a third between 2011 and 2020, from 32.7% to 44.3% in value and from 34.7% to 47.4% in volume. Moreover, as shown in Figure A, TARGET2 has a global reach and allows institutions around the world to exchange euro payments (see also Section 9).

Figure A
Map of TARGET2 payments at originator and beneficiary level



Source: TARGET2.
Note: Each colour represents the continent in which the originator bank is located.

3 Risks resulting from interdependencies

FMIs are, by their very nature, interconnected. On the one hand, interconnectedness positively contributes to reducing the costs and risks associated with transactions, thus strengthening the global payment and settlement infrastructure. On the other hand, extensive interlinkages among FMIs may lead to negative effects with the potential to amplify the spread of disruptions across participating institutions.[11] In order to ensure that the benefits of these interconnections outweigh the risks, PFMI Principle 3 requires an FMI to "have a sound risk management framework for comprehensively managing legal, credit, liquidity, operational, and other risks." In particular, an "FMI should regularly review the material risks it bears from and poses to other entities (such as other FMIs, settlement banks, liquidity providers, and service providers) as a result of interdependencies and develop appropriate risk management tools to address these risks."

FMIs may be interconnected in several ways. Linkages can arise from direct relationships among FMIs,[12] from indirect relationships among FMIs through the common participation of a financial institution, and from environmental factors, such as dependence on a common messaging service provider (e.g. SWIFT) or a third-party IT system service provider. The 2008 CPMI report on the interdependencies of payment and settlement systems[13] distinguishes between system-based, institutional and environmental interdependencies respectively. The TARGET2 operator has transposed and adapted the CPMI framework to the analysis of interdependencies in TARGET2 and uses it to monitor system interconnections and the associated risks, as well as to evaluate the appropriateness of the available mitigation tools. The sections below set out the indicators used for the identification and assessment of interdependencies in TARGET2.

3.1 System-based interdependencies

System-based interdependencies arise "from direct cross-system relationships among two or more systems where the performance of one system relies on the performance of another".[14] System-based interdependencies mainly give rise to liquidity and operational risks. Liquidity risks arise when transactions in one system become conditional on transactions or

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11 See Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

12 E.g. "central securities depositories and large-value payment systems may establish technical links or account relationships to facilitate efficient delivery versus payment settlement of securities transfers", see Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

13 Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

14 See Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

balances in a second system; where this is the case, liquidity shortages or securities failures in one system may affect the settlement flows of other interdependent systems.[15] Operational risks "arise when either the technical operations or settlement flows of one system become dependent on the technical operations of another system or on a link between systems."[16] System-based interdependencies can be further classified into vertical and horizontal interdependencies.

Vertical system-based interdependencies occur between FMIs along the clearing and settlement chain. In the case of TARGET2, vertical system-based interdependencies arise between TARGET2 and the other FMIs connected to TARGET2 for the final settlement or prefunding of their participants' positions in central bank money. Principle 9 of the PFMIs requires FMIs to conduct their settlement activities either in central bank money or in commercial bank money but with significant risk mitigation measures. For this reason, many FMIs in Europe, as well as the Continuous Linked Settlement (CLS) system, a privately owned global payment system offering settlement services for foreign exchange (FX) related transactions,[17] are connected to TARGET2. To analyse vertical system-based interdependencies, the TARGET2 operator regularly calculates statistical indicators that provide an overview of the number of FMIs active in the system, which are referred to as "ancillary systems" (AS) in TARGET2 jargon, and a break down by type and geographical area, as well as their traffic. At the end of 2020, 78 ASs used TARGET2 for settlement or funding purposes (see Chart 1, left-hand panel). The majority of these ASs are retail payment systems (RPSs) (37) – which also includes instant payment systems – and securities settlement systems (SSSs) (23), together representing 76.9% of the total, followed by 14 central counterparties (CCPs), two large-value payment systems (LVPSs) and two money market systems (MMSs).

15 See Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

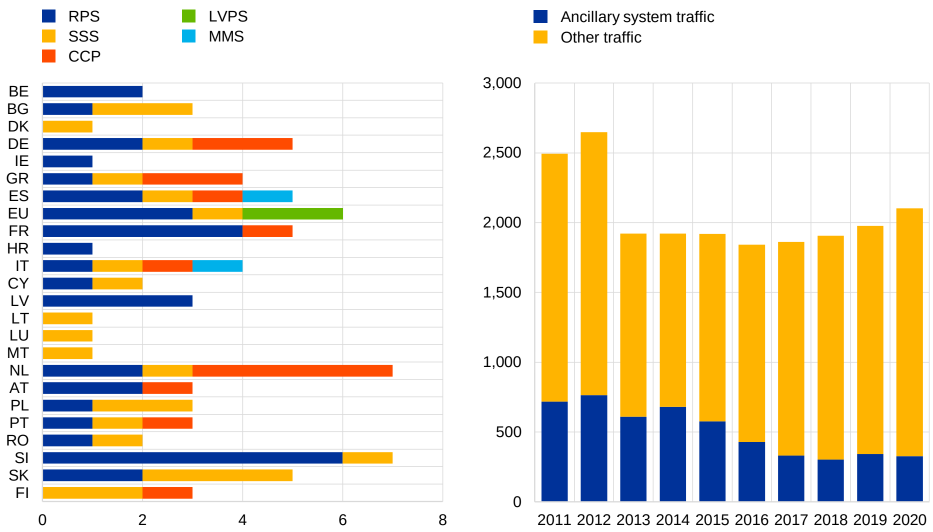
16 See Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", *CPMI Papers*, No 84, Bank for International Settlements, Basel, June.

17 For more information see the CLS website.

Chart 1

Distribution of ASs per country and contribution to TARGET2 traffic

(left-hand panel: x-axis: number of ASs; y-axis: countries; right-hand panel: x-axis: year; y-axis: value, EUR billions)



Source: TARGET2, TAG calculations.
Notes: The chart in the left-hand panel uses data as at the end of 2020. Only the BICs of the FMIs that were active in TARGET2 in 2020 with payments classified as AS transactions are included in the calculation.

AS traffic in TARGET2 is a measure of their liquidity interdependencies with TARGET2 and indicates the speed and amplitude with which risks emerging from these connections might spread. The AS daily activity represents a significant fraction of the overall daily value settled in TARGET2, standing at 24.6% on average, with a peak at 35.4% in 2014 (see Chart 1, right-hand panel). In 2020 AS traffic was on average €322 billion per day. Compared with 2019, the AS traffic showed a decrease of 6%, mainly attributable to one AS moving part of its business from TARGET2 to T2S. Going further back, the peak in traffic was registered in 2012 (€763 billion) and the lowest value in 2018 (€303 billion). The steep decrease in 2013 was mainly due to a change in the statistical framework,[18] whereas the more gradual reduction from 2015 to 2017 was attributable to the migration of central securities depositories (CSDs) to T2S. At the end of 2017 a settlement procedure dedicated to the prefunding of positions in the ACHs that process instant payments[19] was introduced.

The TARGET2 operator monitors specific ASs that are systemically important payment systems and highly relevant for TARGET2. Through the use of tailored indicators, the liquidity patterns arising from their activity in TARGET2 are analysed, especially at participant and intraday level. As an example, the TARGET2 operator monitors the payment patterns of the CLS system, as these payments are time-specific and can be very liquidity intensive for TARGET2 participants that are also CLS settlement members. Chart 2 shows that in 2020 the average daily value of CLS pay-ins (i.e. the amounts paid to the CLS system by participants with short net

18 Please refer to Box 1 for additional information on the change in the statistical framework.

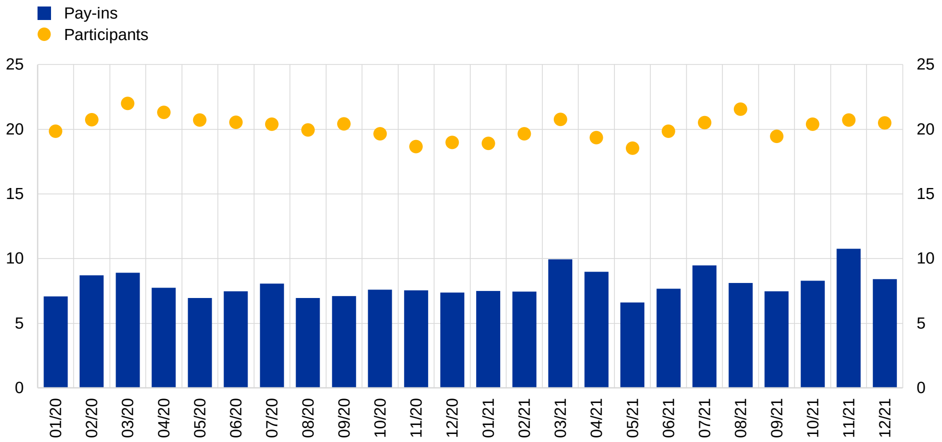
19 “Instant payments are electronic retail payments that are processed in real time, 24 hours a day, 365 days a year, where the funds are made available immediately for use by the recipient.” See the European Central Bank website under Payments and Markets, “What are instant payments?”.

positions) amounted to €8.4 billion,[20] while the average number of CLS settlement members actively sending pay-ins daily as direct participants in TARGET2 stood at 20.

Chart 2

CLS pay-ins through TARGET2

(x-axis: month; y-axis: daily average, EUR billions (left-hand side); number of participants (right-hand side))



Source: TARGET2, TAG calculations.

Horizontal system-based interdependencies also consist of direct relationships between two FMIs, but, unlike the vertical system-based interdependencies, they arise between two FMIs operating at the same stage of the clearing and settlement chain. In TARGET2, there are two FMIs that give rise to horizontal system-based interdependencies, namely T2S, the platform for the settlement of securities transactions, and the TARGET Instant Payment Settlement (TIPS) system for the settlement of instant payments. Both FMIs, also owned and operated by the Eurosystem, receive liquidity from TARGET2 for settling transactions on participants' accounts and thus have a liquidity interdependency with TARGET2. For T2S, participants can transfer part of the daily liquidity they hold in TARGET2 to T2S to ensure the smooth settlement of securities transactions. As regards TIPS, participants can pre-fund their TIPS accounts with liquidity from TARGET2 to ensure they have sufficient funds to settle instant payments. While liquidity can stay in TIPS overnight, in the case of T2S it has to be repatriated to TARGET2 at the end of the day. The TARGET2 operator monitors the development of liquidity transfers to T2S and TIPS on a daily basis. Due to the close interlinkage between TARGET2 and these two platforms, the horizontal system-based interdependency brings not only liquidity risk, but also operational risk. While liquidity risk arises because liquidity transfers from TARGET2 are necessary for T2S and TIPS to operate, their operational dependency stems from the fact that many of the events on their respective business days can affect smooth liquidity shifts across the systems and they therefore need to be monitored jointly.

[20] After the pay-ins are received, CLS transfers the final amounts to the participants with long net positions (the so-called "pay-outs"). As a result, each day the value of pay-ins equals the value of pay-outs at TARGET2 level, bringing the daily average activity of CLS in TARGET2 to €16.8 billion in 2020.

The interdependency between TARGET2 and T2S has strengthened over time. After the go-live of T2S, liquidity transfers from TARGET2 to T2S increased from 1.9% of TARGET2 traffic in July 2016 to 6.7% in October 2017, following the completion of the migration waves of CSDs to T2S (see Chart 3, left-hand panel). For the remainder of 2017 and until the first quarter of 2020, the share of liquidity transfers hovered around 6.4%, while after the start of the COVID-19 pandemic it reached its peak (7.7% of total TARGET2 traffic value) in July 2020 and then decreased towards the end of the year (7.0% in December 2020). Exceptionally, in 2020 the liquidity transfers from TARGET2 to T2S represented on average 7.1% of total TARGET2 traffic, as compared with 6.5% for 2019. This was a significant share of the TARGET2 traffic and corresponded to a year-on-year growth of 9.5%, which was mostly observed in the months following the outbreak of the COVID-19 pandemic. The right-hand panel of Chart 3 shows the cumulative liquidity transferred between TARGET2 and T2S at hourly intervals in 2020, indicating how changes in intraday liquidity reflect the main phases of the T2S settlement day. The TARGET2 operator can monitor these values by analysing the movements on a transit account through which all transfers between the two platforms take place. Every day, at the start of night-time settlement (NTS) in TARGET2, the balance of the transit account rises sharply from €0 to about €75 billion on average and remains relatively stable throughout the NTS period until the beginning of the real-time settlement (RTS) period in TARGET2, which begins at 07:00 CET. Then, the balance steadily increases to €107 billion until 16:00 CET. After that, a sharp decrease in the balance that is related to the optional cash-sweep at 16:30 CET can be seen. A further decrease is observed due to the automatic cash-sweep at 17:45 CET, when the balance of the transit account goes back to zero.[21] In general, the efficiency of the use of liquidity in T2S has an impact on the liquidity needed in TARGET2 and, thus, liquidity transfers from TARGET2 to T2S. Across 2020 the minimum and the maximum balance usually ranged between -€5 billion and +€10 billion around the transit account's mean balance. However, in the first few months of the COVID-19 pandemic the maximum balance ranges were wider, reaching +€45 billion in May 2020.

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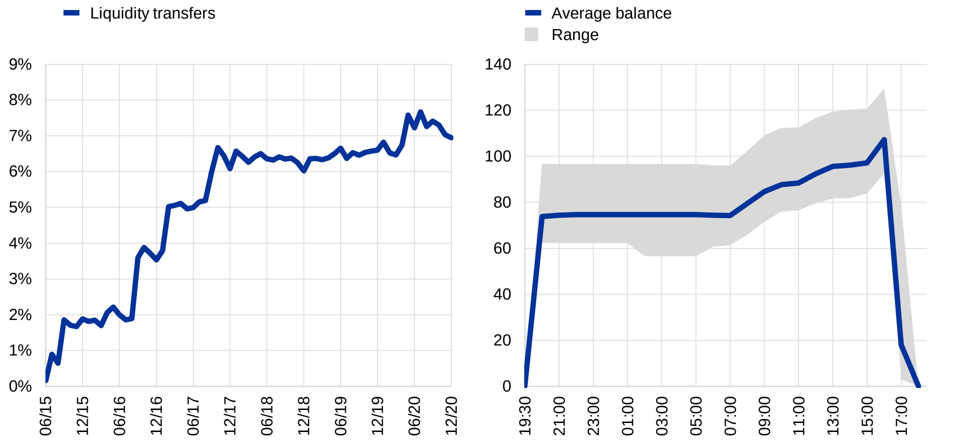
[21] See also Mastropasqua, C., Intonti, A., Jennings, M., Mandolini, C., Maniero, M., Vespucci, S. and Toma, D. (2021), "T2S-TARGET2-Securities. The pan-European platform for the settlement of securities in central bank money", *Markets, Infrastructures, Payment Systems series*, Vol. 4, Banca d'Italia, Rome, September 2021.

Chart 3

Liquidity transfers to T2S over time and by time of the day

(left-hand panel: x-axis: month; y-axis: share of TARGET2 traffic, percentages; right-hand panel: x-axis: hour; y-axis: value, EUR billions)

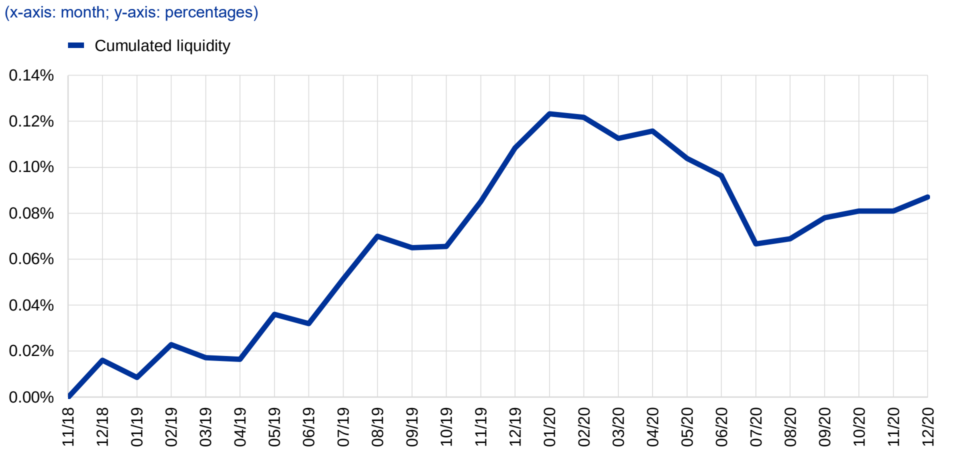


Source: TARGET2, TAG calculations.
Notes: The total TARGET2 settled value includes liquidity transfers to T2S and TIPS and excludes technical transfers. The balance of the transit account is computed as the cumulated sum of liquidity transfers from TARGET2 to T2S minus liquidity transfers from T2S to TARGET2. The dates of 11 August and 23 October 2020 are excluded from the calculation due to incidents in TARGET2.

The risks stemming from the interdependency between TARGET2 and TIPS have instead remained low. This is due to the relatively recent go-live of TIPS in November 2018 and the fact that TIPS traffic has picked up slowly. Since the second half of 2019, the percentage of liquidity that TIPS direct participants set aside for instant payments has ranged between 0.07% and 0.12% of TARGET2 turnover (see Chart 4). Following the measures approved in 2020 by the Eurosystem to increase the reachability of instant payments at a pan-European level,[22] the expectation is that the relevance of TIPS in the payments landscape will increase in the coming years.

[22] See “ECB takes steps to ensure pan-European reach of instant payments”, MIP News, European Central Bank, Frankfurt am Main, 24 July 2020.

Chart 4
Cumulated liquidity in TIPS



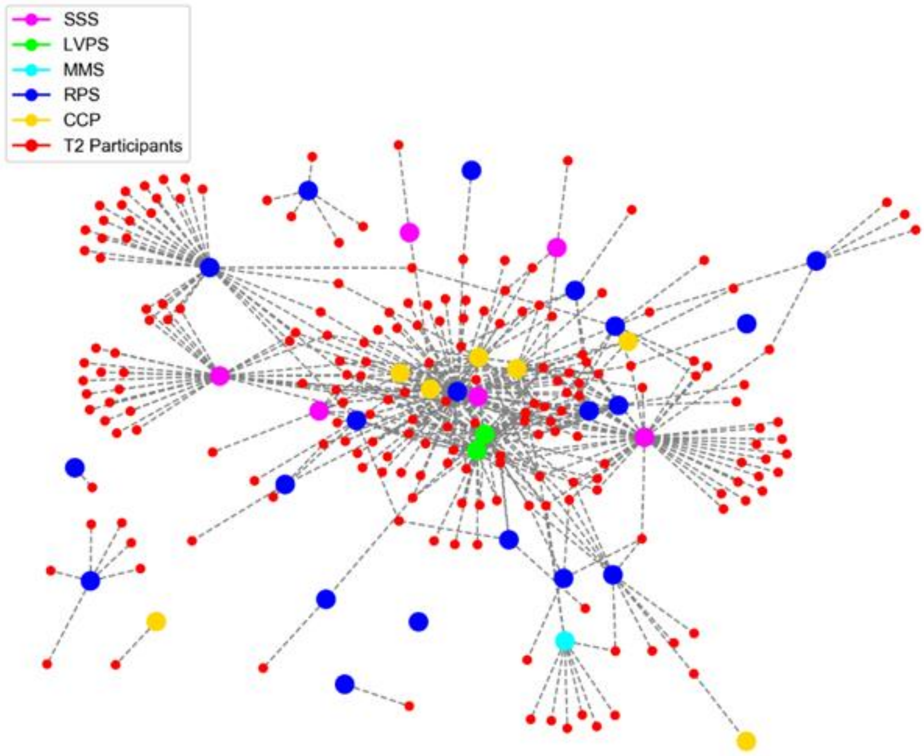
Source: TARGET2, TAG calculations.
Note: The cumulated liquidity in TIPS is computed relative to the liquidity held by TIPS direct participants in TARGET2.

3.2 Institution-based interdependencies

Institution-based interdependencies are indirect relationships among FMIs occurring through a common financial institution. In other words, this happens when the same bank participates in two or more FMIs. TARGET2 is naturally exposed to institution-based interdependencies, since its participants are also members of the TARGET2 ASs. To evaluate this type of interdependency, the TARGET2 operator mainly relies on network analysis measures and visualisation tools, seen as being most suited to capturing this type of interconnection. The AS network connections and the connected financial institutions, i.e. direct TARGET2 participants, provide an overview of the institution-based relationships between FMIs that are intermediated by common participants (see Figure 1).

Figure 1
Network of institution-based interdependencies in TARGET2

(TARGET2 participants)



Source: TARGET2, TAG calculations.
Notes: The network shows the unique relationships between TARGET2 participants and the AS accounts in TARGET2. TARGET2 participants are displayed in red, while the nodes coloured differently denote ASs by their type. Only relationships above a daily average of €0.1 billion and involving ASs with at least 0.1% share of overall AS traffic are displayed.

In general, indirect interconnections through a common participant may lead to contagion effects. This could arise in two ways. First, in the event of a problem experienced by a financial institution that has a simultaneous knock-on effect on more than one FMI. Second, in the event of a problem experienced by an FMI which then spreads to another FMI through a financial institution. This could happen for example when a financial institution fails to cover its liquidity requirements vis-à-vis one FMI because the institution has not received liquidity that should have been provided by another FMI.

Although a considerable number of bilateral connections between TARGET2 participants and its ASs exist, the overall connectivity of the network is extremely low. RPSs have the highest number of interconnections (1,131), computed as the sum of the links between an AS and its connected direct participants; they are followed by SSSs (677) and CCPs (672). This result is driven by the higher number of these AS categories, as shown in Figure 1. By AS type, the most interconnected are LVPSs, each with an average of 52 connections, closely followed by CCPs with 48 and SSSs with 34. However, the connectivity of the TARGET2 network, as measured by the ratio between the number of actual connections between AS and TARGET2 participants and the maximum possible number of such connections with values between 0 (no connectivity) and 1 (maximum connectivity), is very low and stands at 0.04. This suggests that the risk of contagion effects is low overall and is driven by the fact that 70% of the TARGET2 participants have either one or two links to ASs.

3.3 Environmental interdependencies

Environmental interdependencies are indirect relationships that arise from broader factors, including the reliance of several FMIs on a common service provider or financial market. As it is the case for most FMIs in Europe, TARGET2 relies on SWIFT network services. Consequently, the most prominent environmental interdependency to which TARGET2 is subject is its relationship with SWIFT. This creates a tight interdependency with other major systems that are also SWIFT-based and a concentration risk with respect to the SWIFT network.

TARGET2 has a very high degree of dependency on SWIFT for its normal operations since all messages to the central processor are sent and received via the SWIFT network. However, TARGET2 uses a range of SWIFT services and, therefore, situations may occur where one SWIFT service is adversely affected by an operational disruption, while another is still up and running. In addition, even if SWIFT were to be unavailable, TARGET2 has a contingency network in place that could be activated to provide a payment channel. In contrast to the other types of interdependencies to which TARGET2 is exposed, the TARGET2 operator primarily conducts a qualitative analysis for environmental interdependencies.

4 Liquidity risk

Payment systems settle transactions by exchanging funds among their participants, hence the systems, or their participants, may be exposed to liquidity risk. This is the risk of incurring losses when a counterparty, whether a participant or another entity, has insufficient funds to meet its financial obligations as and when required, although it may be able to do so in the future. PFMI Principle 7 requires an FMI to "effectively measure, monitor, and manage its liquidity risk". In particular, this principle requires that FMIs should have effective operational and analytical tools to identify, measure, and monitor their settlement and funding flows on an ongoing and timely basis, including their use of intraday liquidity.

The TARGET2 system as such is not subject to liquidity risk, however its participants are. In TARGET2, payments are settled only if sufficient funds are available on the participants' accounts and, irrespective of a possible insolvency of a participant, remain final and irrevocable once they are settled given that TARGET2 settles on a gross basis. In a broader context, however, TARGET2 can be viewed as a network that interlinks several participants. In an interconnected network, the failure of one participant to fulfil its payment obligations in their entirety or on time may endanger the liquidity position of the payment recipient and, in turn, result in the recipient not being able to meet its payments obligations. Liquidity risk analysis for TARGET2 therefore encompasses the entire system and all its participants. The TARGET2 operator has developed and regularly monitors a wide range of liquidity data and indicators that look, among others, at the intraday dimensions, both at aggregate and participant level. A subset of these indicators is described in Section 6.1.

Settlement in RTGS systems like TARGET2 can be very liquidity-intensive for the participants given that all payments are settled one by one, based on the available funds. Since the introduction of RTGS systems in the 1980s, operators have been searching for ways to mitigate the high liquidity requirements. TARGET2 offers its participants comprehensive and up-to-date optimisation and liquidity management tools to support effective liquidity usage, reduce liquidity risk and potentially mitigate counterparty and operational risks. These tools are a combination of customer services and in-built instruments referred to as "liquidity saving features" (LSF).[23] They include, inter alia, priorities, reservations, timed payments, all these being referred to as "liquidity management features", as well as highly advanced offsetting and queue management algorithms, these being known as liquidity-saving mechanisms (LSM). In addition, participants can use the intraday credit line (ICL) facility offered by the Eurosystem when the liquidity on their TARGET2 accounts is not sufficient to settle payments. The TARGET2 operator regularly monitors the usage of these features and has carried out dedicated studies to analyse their

23 A detailed explanation of the various liquidity saving features in TARGET2 can be found in the Annex hereto.

efficiency and impact over time. Sections 6.2 and 6.3 describe a subset of these studies.

PFMI Principle 7 also requires FMIs to determine the amount of their liquidity resources and regularly test their sufficiency through rigorous stress-testing. Stress-testing is the evaluation of an FMI's performance under severe but plausible scenarios to assist the system operator in managing liquidity risk. The TARGET2 operator has carried out a stress test of liquidity risk in TARGET2, which is described in Section 6.4.

4.1 Liquidity monitoring

4.1.1 Intraday liquidity indicators

The funds that TARGET2 participants hold on their TARGET2 accounts correspond to their central bank liquidity, i.e. the liquidity, including minimum reserves, held by banks with their central bank. These funds are used to make payments throughout the day and, if they are not sufficient, participants may have recourse to the ICL. The ICL is offered free of interest against eligible collateral that participants post with their national central banks (NCBs).[24] The TARGET2 operator may monitor the level of liquidity in the system as well as the credit line available to make payments at any point in time, both at system and participant levels.

Between June 2008 and December 2020, the overall liquidity in TARGET2 increased more than ten times. Chart 5 shows the overall liquidity available in TARGET2 calculated as the sum of the liquidity available in all TARGET2 accounts at the start of day since June 2008. Liquidity in TARGET2 significantly rose at the time of the sovereign debt crisis in 2011 and 2012, amid measures taken by the Eurosystem to accommodate banks' liquidity demand. Then, the launch of the public sector purchase programme (PSPP) in March 2015 brought a new surge in liquidity levels. After a period of small fluctuations, liquidity further rose due to the additional stimulus provided by the Eurosystem in the context of the COVID-19 pandemic through the pandemic emergency purchase programme (PEPP), standing at €3.2 trillion at the end of 2020.[25] Over the same period, the overall value of the available credit line set by TARGET2 to cover potential intraday overdrafts remained largely stable, ranging between €1.5 trillion and €2.3 trillion. In December 2020 it amounted to €1.6 trillion.

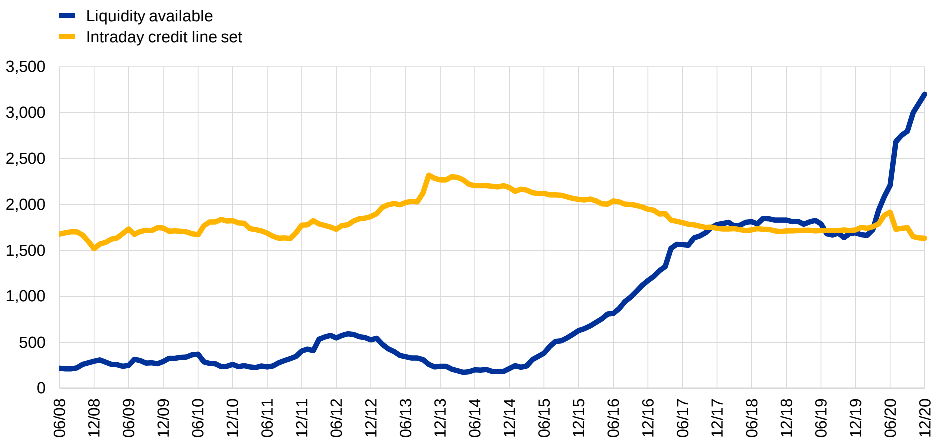
[24] At the end of the day, if the participant is also an eligible counterparty for Eurosystem monetary policy operations and cannot cover its negative position, the intraday credit becomes overnight credit and is charged at the rate of the marginal lending facility. No extension to overnight credit is possible for participants not eligible for Eurosystem monetary policy operations.

[25] For additional information on the evolution and distribution of liquidity in TARGET2, see Duca-Radu, I. and Polo Friz, L. "Liquidity distribution and payments in TARGET2", *Economic Bulletin*, Issue 5, European Central Bank, Frankfurt am Main, August 2021.

Chart 5

Liquidity available and ICL set in TARGET2

(x-axis: month; y-axis: value, EUR billions)



Source: TARGET2, TAG calculations.
Note: The values are computed at the start of the day in TARGET2.

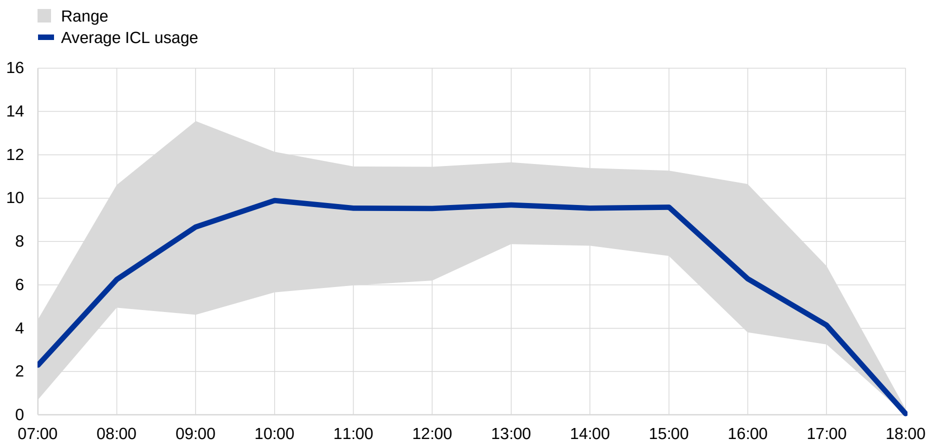
The monitoring of liquidity and intraday credit available to settle payments may also take place at intraday level. The TARGET2 operator has created a Eurosystem-wide, almost real-time database to be able to monitor liquidity and intraday credit levels at an hourly frequency for all direct participants. By using payment-level information, it is possible to calculate the payment flow and the liquidity available at very granular time intervals. This means that the TARGET2 operator has information to hand on how much liquidity sits on the TARGET2 accounts at any point in time during the day. This analysis makes it possible, for instance, to compare aggregate or individual liquidity levels or to cluster direct participants by payment behaviour. This information could prove invaluable for the operator, especially during a crisis situation, and could represent a possible future service enhancement for participants.

Through intraday analysis of liquidity available on participants' accounts, the TARGET2 operator is also able to monitor usage of the credit line. Participants make use of the credit line when they do not hold sufficient liquidity on their accounts to settle their payments obligations. As an example, Chart 6 shows the daily average usage of the credit line in TARGET2 during the month of December 2020 at the change of each hour. In general, the intraday pattern of overdraft usage in TARGET2 has been relatively stable over time, with more intense recourse to intraday credit in the core hours of the business day, and it has always remained at relatively low levels. During 2020, it decreased even further owing to the ample liquidity levels in the system. The fact that TARGET2 participants rely on intraday credit only to a very limited extent indicates that the intraday liquidity risk for TARGET2 participants is low. Nevertheless, if the monitoring activity signals peak values or outliers, these are typically investigated by the TARGET2 operator.

Chart 6

Intraday usage of the credit line in TARGET2

(x-axis: TARGET2 opening hours; y-axis: value, EUR billions)



Source: TARGET2, TAG calculations.
Note: Total TARGET2 RTGS accounts' intraday credit usage (overdraft) at the change of each hour during the business day.

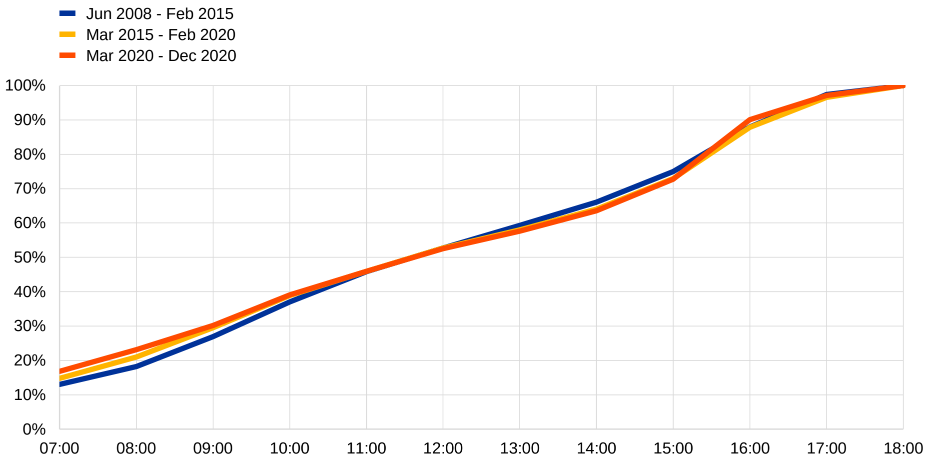
The distribution of payments settlement throughout the day and over time is also monitored by the TARGET2 operator, as it can reflect operational and liquidity risk for the system and its participants. Typically, the earlier payments are settled the better, since the concentration of a significant number of payments towards the end of the business day could increase operational risk.[26] One important aspect to monitor for a payment system operator is how specific events or changes in system parameters affect intraday payment distribution. Chart 7 compares the intraday payment patterns in TARGET2 at different liquidity levels in the system, namely before March 2015, between March 2015 and February 2020, and after March 2020, when the COVID-19 pandemic broke out. Payment patterns in TARGET2 have remained generally stable over time in value terms, with over 15% of payments already settled by 08:00 CET, and the cumulative share of settled value increasing at an almost constant pace throughout the day, with a small acceleration between 16:00 CET and 17:00 CET, i.e. towards the end of the day. By 13:00 CET more than 50% of the payments are already settled. In every period of increased system liquidity, the portion of payments that are settled at the beginning of the day increases by 2-3 percentage points (pp), between 07:00 CET and 09:00 CET. This small increase in the first two hours of the business day is smoothed out by the end of the morning. An alternative to intraday patterns is to aggregate the information in a single indicator such as the value-weighted average introduction or settlement time, making it possible to monitor trends and outliers more effectively over time.

[26] For instance, if a technical problem were to occur towards the end of the day, it would be much easier to handle it in a system that settles earlier in the day and which, by the time of the incident, would have already processed most of its payments, rather than in a system that settles later in the day.

Chart 7

Intraday pattern of payments settled in TARGET2

(x-axis: TARGET2 opening hours; y-axis: cumulated value, percentages)



Source: TARGET2, TAG calculations.
Note: The percentages displayed at hour H refer to all payments settled between H and H+1.

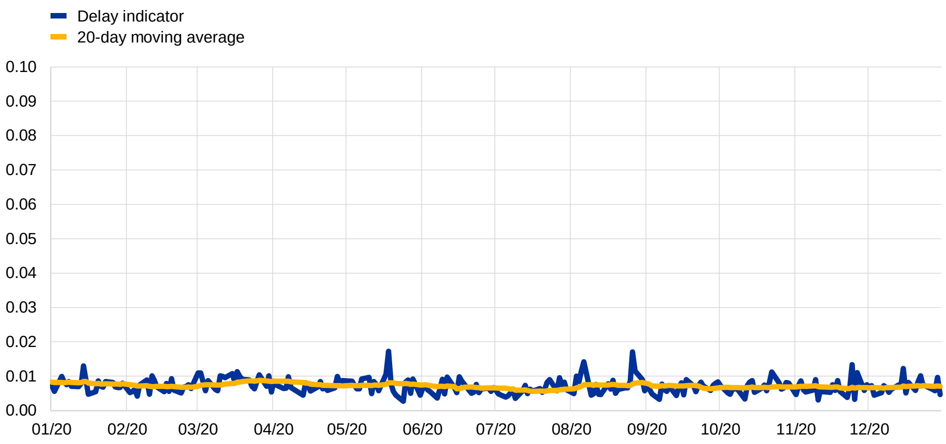
The TARGET2 operator can also analyse intraday payment behaviours looking at queues and payment delays. For example, the delay indicator[27] monitors how long customer and interbank payments are queued each day. The indicator is calculated as the ratio of the actual time payments have spent in the queue and the theoretical total time they might have stayed queued before becoming unsettled, both queuing times being weighted by the value for each payment. A value of zero means that no delay has happened (i.e. all payments are settled immediately), while a value of one indicates the maximum delay (i.e. payments are either settled at the last possible moment or remain unsettled). In 2020 payments spent very little time in the queue, partially owing to the high liquidity levels in the system (see Chart 8).

[27] Kaliontzoglou, A. and Müller, A. (2016), "Implementation aspects of indicators related to payments timing", in Diehl, M., Alexandrova-Kabadjova, B., Heuver, R. and Martínez-Jaramillo S. (Eds.), *Analyzing the Economics of Financial Market Infrastructures*, Hershey, PA: Business Science Reference, pp. 169–190.

Chart 8

Delay indicator in TARGET2

(x-axis: month; y-axis: delay indicator)



Source: TARGET2, TAG calculations.
Note: Methodology based on Kaliontzoglou, A. and Müller, A. (2016).

The intraday payment behaviour in TARGET2 can be also analysed at participant level. This helps to assess different dimensions of liquidity risk in TARGET2, such as potential free-riding behaviour or the contagion effects of a liquidity shortage. Moreover, payment patterns deviations that may indicate abnormal situations, such as an operational outage or anomalous payments, can only be detected at granular level. Chart 9 shows the payment profiles derived using a cluster analysis of the top 200 credit institutions participating in TARGET2.[28,29] The chart shows that participants can be clustered by relatively homogenous intraday payment behaviours displaying different characteristics between the one and the other. The majority of participants (41%) initiate the bulk of their transactions within the first hour of operation of TARGET2 (classified as either "early birds" or "extreme early birds"), whereas only a few participants (16%) send a significant share of transactions to TARGET2 in the second half of the day ("late payers"). Liquidity flows between different payment profiles may provide the TARGET2 operator with valuable insights into the effects of a system's or participant's operational outages during the day. Furthermore, by analysing the deviations in intraday patterns, early warning indicators at participant level may be developed.

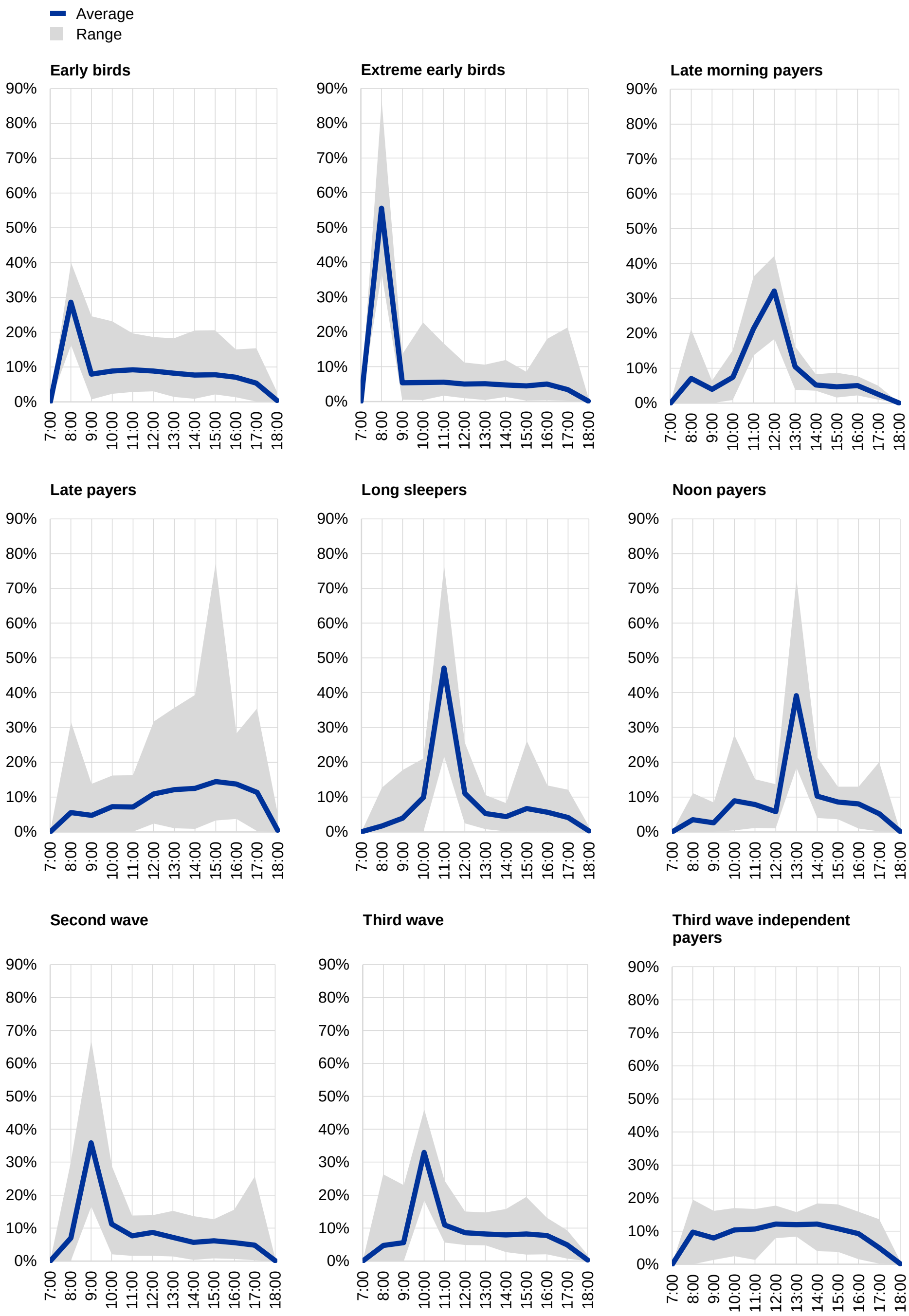
[28] See Glowka, M. (2019), "Profiling banks: how to use cluster analysis with payment system data", *The Journal of Financial Market Infrastructures*, Vol. 8, No 2, December 2019, pp. 21-45.

[29] The top 200 TARGET2 credit institutions represented 95.8% of the system's volume and 77.3% of its value in 2020.

Chart 9

Intraday payment behaviour of TARGET2 participants by payment profile in 2020

(x-axis: TARGET2 opening hours; y-axis: percentages, yearly average as a share of transaction volume)



Source: TARGET2, TAG calculations.
Note: Methodology based on Glowka, M. (2019).

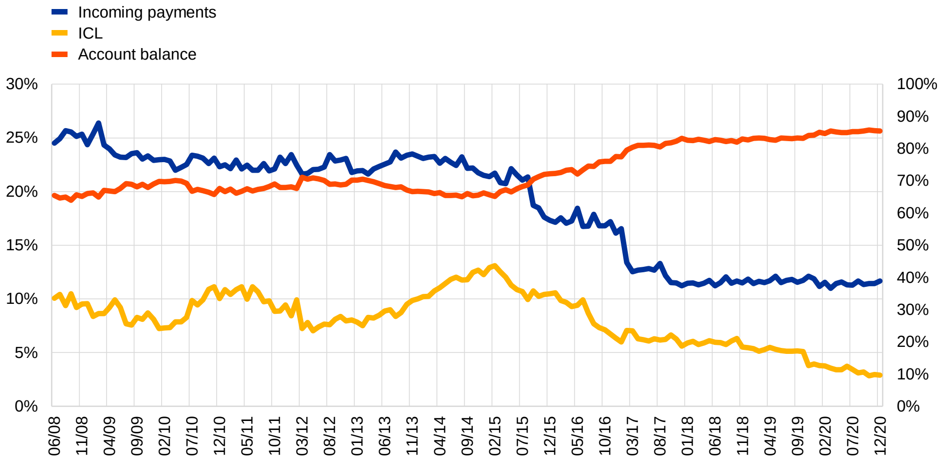
4.1.2 Liquidity usage indicators

Besides using the system's liquidity management tools to reduce the high liquidity costs associated with an RTGS system, participants can actively manage their own payment flows. One way to do this is by synchronising outgoing and incoming payments, thus making more efficient use of liquidity. To fund their payments, TARGET2 participants can generally rely on three sources of funds: incoming payments, their account balance, and intraday credit. The TARGET2 operator has developed a methodology for computing and analysing the usage of these three different sources.[30] In TARGET2, the main source of payments funding is the account balance (Chart 10). Since June 2010, participants have, on average, funded 73.0% of their payments using the liquidity available on their account balance, whereas incoming payments have constituted the second source of funding, covering, on average, 18.8% of the payment outflows. Intraday credit has been used to provide liquidity for 8.1% of outgoing payments. The usage of the different payment sources has responded to the upsurges in liquidity levels in TARGET2. In particular, the use of the account balance has increased over time, whereas the use of incoming payments and intraday credit has decreased.

Chart 10

Funding sources for payments in TARGET2

(x-axis: month; y-axis: incoming payments and ICL, percentages (left-hand scale); account balance, percentages (right-hand scale))



Source: TARGET2, TAG calculations.
Note: The chart covers the period from June 2008 to December 2020 at a monthly frequency.

Another way to measure how liquidity is used in an RTGS system is to look at its velocity. Velocity is the value of payments made for each unit of liquidity that is used for settling payments; this basically shows how many times one unit of liquidity

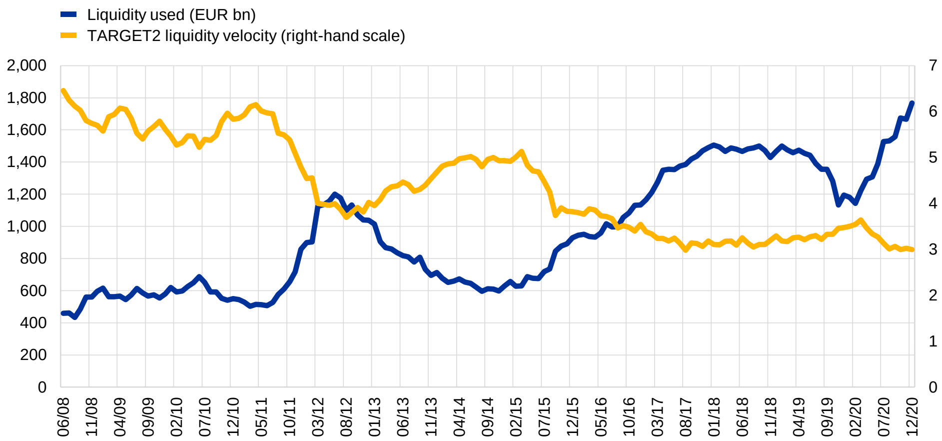
[30] See Duca-Radu, I. and Testi, S. "Liquidity usage in TARGET2", *Economic Bulletin*, Issue 3, European Central Bank, May 2021.

(in the case of TARGET2, one euro) changes ownership on average in a day.[31] The liquidity used encapsulates the central bank reserves available on the TARGET2 accounts that are actively utilised to settle payments as well as the liquidity drawn down from the ICL facility, i.e. overdrafts.[32] Liquidity velocity in TARGET2 fell with the upsurge in central bank reserves resulting from the Eurosystem's PSPP start in 2015 and, more recently, the monetary policy measures aimed at addressing the pandemic emergency. The liquidity velocity indicator in TARGET2 decreased from 5.1 in March 2015 to 2.99 in December 2020, with most of the decrease taking place between March and September 2015 (Chart 11). Since December 2016, the liquidity used for payments in TARGET2 has been below the liquidity available in TARGET2. The gap between the liquidity used and the liquidity available has steadily increased since then, with it surging over the course of 2020.

Chart 11

Liquidity used versus TARGET2 liquidity velocity

(x-axis: month; y-axis: liquidity used, EUR billions (left-hand scale); liquidity velocity (right-hand scale))



Source: TARGET2, TAG calculations.
Note: The chart covers the period from June 2008 to December 2020 at a monthly frequency.

4.2 Liquidity management features

Liquidity management features support payment system participants in using liquidity efficiently and effectively, and contribute to reducing liquidity, counterparty and operational risks. They generally increase the effectiveness and potential welfare of RTGS systems and should therefore be regularly monitored by the system operator. This section presents an overview of analyses of the

31 Here liquidity velocity is measured applying the methodology used in Benos, E., Garratt, R. and Zimmerman, P. (2012), "Bank behaviour and risks in CHAPS following the collapse of Lehman Brothers", *Working Paper Series*, No 451, Bank of England, London, 21 June. Other alternatives exist in the literature, in which, for instance, liquidity velocity is computed relative to the liquidity available, see also Garratt, R., Antoine, M. and McAndrews, J. (2014), "Turnover in Fedwire Funds Has Dropped Considerably since the Crisis, but it's Okay", *Liberty Street Economics*, Federal Reserve Bank of New York, New York, 25 August.

32 In practice, this is measured as the sum of the maximum positive net debit positions (outgoing payments minus incoming payments) on the TARGET2 accounts every time. This is, nevertheless, a proxy and there are alternative ways of measuring it.

reservations, priorities, limits, timed payments and liquidity pooling functionalities in TARGET2.

Reservations allow participants to devote a portion of their available liquidity to the settlement of those payments that have an urgent or highly urgent priority.[33] The impact of reservations on settlement depends on various factors, such as the use of priorities or limits as well as liquidity levels and individual payment behaviour. On the one hand, reservations can make settlement more efficient when the reserved liquidity makes it possible to settle (highly) urgent payments that would otherwise remain unsettled. On the other hand, if the reservations are set too high, the effect can be inverted when liquidity is lacking for normal payments.

Over the last few years, the use of reservations by participants in TARGET2 has decreased. In particular, while prioritisation is used to a greater extent,[34] only a few participants make active use of reservations in TARGET2. In 2020 the daily number of liquidity reservations for highly urgent payments fluctuated around 100 and for urgent payments around 50 (see Chart 12). In addition to the high liquidity levels in TARGET2, the introduction of T2S might be responsible for this trend. As securities settlement moved to T2S, participants ceased to reserve liquidity for the fast settlement of securities-related transactions in TARGET2. Moreover, the fact that few participants make use of reservations and that use is limited could be linked to banks' internal systems for payment submission, which, de facto, apply their own reservations and priorities. Furthermore, the cost of actively managing reservations is too high for smaller banks. An analysis carried out in 2014 quantified the impact of reservations and priorities on settlement using simulations done with the TARGET2 simulator. A comparison of various scenarios covering different configurations for reservations[35] revealed that reserved liquidity reduced settlement speed. However, the scenarios analysed had only a minor impact due to the limited use of reservations and because TARGET2 has a high settlement performance overall.

[33] In TARGET2, urgent and highly urgent payments may include payments such as FMI-related transactions, liquidity transfers to T2S and TIPS and interbank payments.

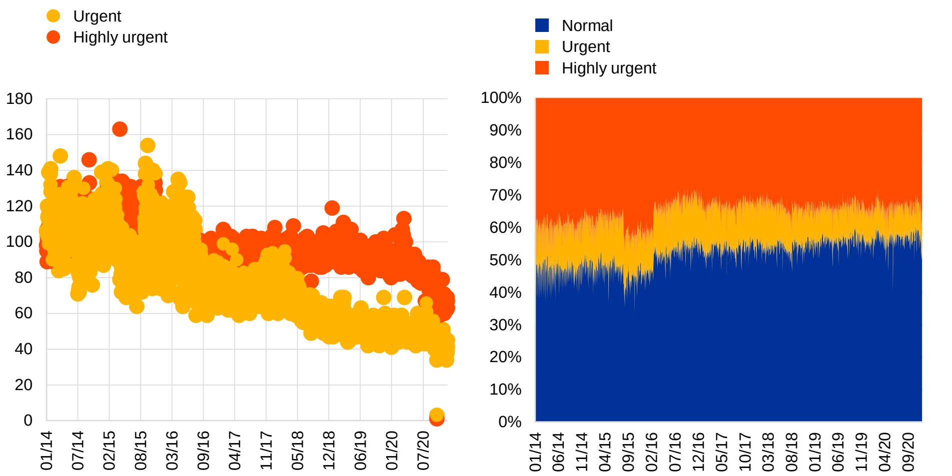
[34] The "highly urgent" priority is assigned by the system depending on their type; participants can assign the "urgent" priority.

[35] The three simulated scenarios were: (i) replication of normal usage of reservations as a benchmark simulation, (ii) consideration of highly urgent reservations only, and (iii) the deletion of all reservations.

Chart 12

Usage of reservations and priorities in TARGET2

(left-hand panel: x-axis: date; y-axis: number of reservations; right-hand panel: x-axis: date; y-axis: percentages)



Source: TARGET2.

Notes: Daily values. The right-hand panel includes all TARGET2 transactions except technical transactions and liquidity transfers between different accounts of the same participant in TARGET2.

While from a volume perspective most of TARGET2 payments have a normal priority, from a value perspective urgent and highly urgent payments tend to represent higher shares. The latter typically involve AS or monetary policy operations and represent only a minority of payments in TARGET2 in volume terms. In 2020 on average, around 33.9% of the total payment value had a highly urgent priority and 56.7% had a normal priority. Between 2014 and 2017, the share of highly urgent payments in value (mostly AS traffic) decreased, while the share of urgent payments increased. An explanation for this development might again be the introduction of T2S.

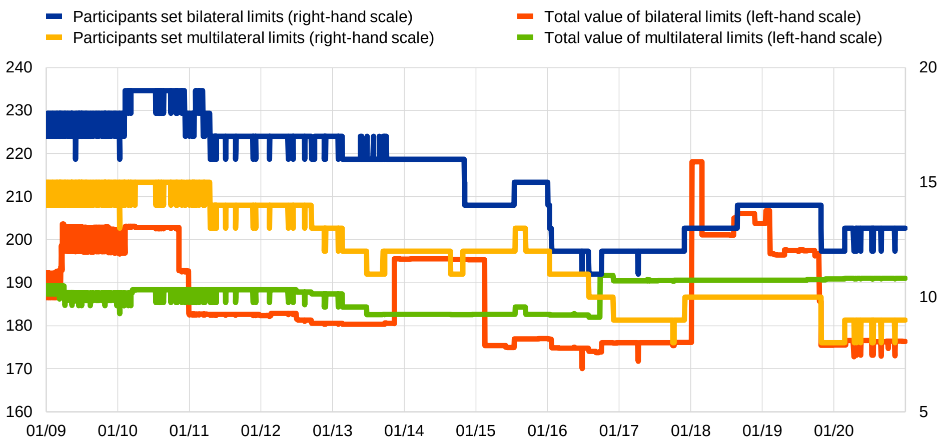
Limits in TARGET2 are set by the senders to determine the maximum cumulated net debit balance a participant is willing to have vis-à-vis another participant (bilateral) or all other participants (multilateral). While these limits are intended to serve as a risk management tool, they also aim to smooth the flow of payments and thus increase liquidity efficiency in the system. However, their effect on system performance is ambiguous and is split into first and second round. On the one hand, limits may result in more queued payments in the first round, when the accumulated net payment value against one or all counterparties exceeds the set limit. On the other hand, limits prevent liquidity traps on a small number of accounts, given that they redirect the liquidity and consequently reduce the number of queued payments in the second round. The strength of these opposite effects depends on the participants' payment behaviour and general liquidity conditions. For the TARGET2 operator it is important to monitor the uses made of these features and their impact.

Only a few participants have actively used limits in TARGET2 over the last few years. Since 2018 just 10 to 15 participants have used bilateral and multilateral limits (see Chart 13). Nevertheless, as can be the case with priorities and reservations, some participants may use internal systems outside TARGET2 to manage their liquidity in several FMIs. Furthermore, the use of limits is quite heterogeneous, with some participants heavily using limits by setting bilateral limits to hundreds of counterparties, while others use limits only vis-à-vis very few counterparties. Since 2013, the total bilateral and multilateral limit values have shown little daily change but have seen notable structural changes. Compared with the liquidity held on TARGET2 accounts (€3.2 trillion at the end of 2020), the value of limits is quite small. In addition, participants usually delete their limits at around 12:00 CET (see Chart 14), with the result that limits do not lock in any liquidity for the settlement of queued payments in TARGET2 for the afternoon.

Chart 13

Use of limits in TARGET2

(x-axis: date; y-axis: value, EUR billions (left-hand side); number of participants (right-hand side))

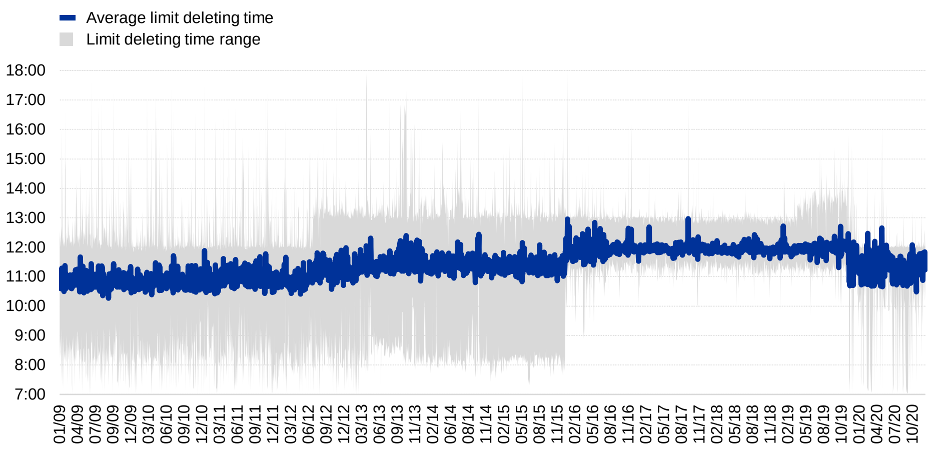


Source: TARGET2, TAG calculations.

Chart 14

Limit deleting behaviour in TARGET2

(x-axis: date; y-axis: TARGET2 opening hours)



Source: TARGET2, TAG calculations.

A study from 2014 quantified the opposing effects of limits in TARGET2 by simulating various scenarios with and without limits.[36] With limits, the outcome was a negative effect given that settlement delay in payments increases with the introduction of limits. However, given that limits delay the processing of a payment to just one counterparty, the liquidity can be used for the settlement of transactions with other counterparties. Thus, the first-round effects are at least partially offset by the second-round effects. The offsetting effects become stronger the more participants make extensive use of limits and this works even better in times of stress. The results also show that the initially negative effects of the limits primarily affect those participants who tend to process their own payments late. These delays correspond to the desired effect of limits and are therefore not to be assessed negatively. The outcome suggests a positive outcome overall from the existence and usage of limits.

Timed payments give participants the possibility of establishing points in time before and after which a single payment cannot be settled. In TARGET2 these are referred to as the "earliest" and "latest" debit times. On the one hand, the timing of payments gives participants the opportunity to manage their intraday liquidity.[37] On the other hand, a high share of timed payments may undermine the queue management of TARGET2 and thus lead to lower settlement efficiency. However, as the use of timed payments is currently relatively limited in TARGET2, the efficiency of settlement is not significantly affected. The number of payments tied to a latest debit time and to both an earliest and latest debit time in 2020 was between 3,000 and 4,000 payments per day each, whereas just setting an earliest debit time was the least used option (about 1,200 payments per day). Over time, the usage of this feature has been mainly influenced by changes in the settlement procedures for ASs in TARGET2 and the go-live of T2S.

The liquidity pooling services allow participants to consolidate the liquidity they hold in different TARGET2 accounts and centralise its management. This results in a better overview of the participants' liquidity positions at group level and thus lower complexity and costs. The TARGET2 operator has an interest in monitoring the use of liquidity pooling services. At the end of 2020, only 13 groups of accounts in TARGET2 made use of the aggregated liquidity functionality. Overall, 30 accounts belonged to these groups. Twenty-four groups with a total of 85 accounts used the consolidated information functionality. Due to the availability of centralised internal liquidity management tools outside TARGET2 for banking groups and the relatively high costs of participating in TARGET2, often only the group head opens an account in TARGET2 and settles payments on behalf of group members. This might explain the relatively low use of the liquidity pooling services.

Overall, TARGET2 offers a number of liquidity management features whose use and impact on the smooth processing of payments is regularly monitored by the operator. The current high liquidity levels, changes in the AS settlement procedures and the go-live of T2S have affected the use of such features by participants over time. Moreover, participants may rely on alternative internal liquidity

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36 See Müller, A. and Diehl, M. (2014), "Analysis of the use and impact of limits", *Journal of Financial Market Infrastructures*, Vol. 3, No 1, September, pp. 33-60.

37 Timed payments are also used in the context of AS procedures.

management systems. Thus, while TARGET2 participants make limited use of these features at present, some of the available liquidity management features may regain relevance in the future, should liquidity levels decrease. Liquidity management features may also have a high impact on the system's liquidity use, especially in times of stress. Their constant monitoring is therefore necessary to meet the requirements of PFMI Principle 8, regardless of current usage.

4.3 Liquidity saving mechanisms

Together with liquidity management features, TARGET2 offers highly advanced LSMs to support the efficient use of liquidity. These consist of five (event- or time-driven) settlement algorithms aimed at optimising the settlement process of queued payments and AS transactions. The algorithms search through the queuing facility in TARGET2 and try to match and offset payments.[38]

The TARGET2 operator undertook an analysis to gain a better understanding of the performance of LSMs in the system and their ability to effectively support the settlement capacity of the system. By using the TARGET2 simulator, "what-if" scenarios, in which the TARGET2 settlement logics were altered by removing one or more LSMs, were analysed. Four different scenarios were selected, starting with a scenario close to a plain RTGS system, i.e. where all LSMs were deactivated (Scenario 1), and then moving to scenarios where LSMs were progressively reintroduced. First, bilateral and multilateral offsetting (Scenario 2) were added, followed by partial and multiple queue optimisation separately (Scenario 3 and Scenario 4 respectively). This made it possible to test the effectiveness of the individual algorithms. End-of-day settlement levels in the simulated scenarios were then compared with the results obtained under normal TARGET2 parameters to assess the impact of LSMs on TARGET2 settlement. The analysis covered the period from 2014 to 2019 in order to account for different liquidity levels in the system.

In general, removing the LSMs leads to higher unsettled payments in TARGET2 in most of the periods under analysis. The closer the algorithm configuration comes to the TARGET2 set-up, the more settlement efficiency improves. The share of unsettled payments tends to decline and the queuing times are reduced. This holds true, in particular, for the bilateral and multilateral offsetting and for the multiple optimisation algorithms. LSMs not only reduce the level of unsettled transactions, but also smooth settlement by increasing settlement speed and reducing queuing times. Chart 15 shows the effect of removing algorithms on settlement times by comparing the average queuing time of customer and interbank payments in the different scenarios. The average daily queuing time at system level increases in all scenarios, in particular in the pure RTGS system scenario (Scenario 1). The impact is consistent with the severity of the constraints imposed. For example, in 2017 the median of the daily queuing time in Scenario 1 increased to 5.7 minutes as compared with 3 minutes in the benchmark simulation, while in

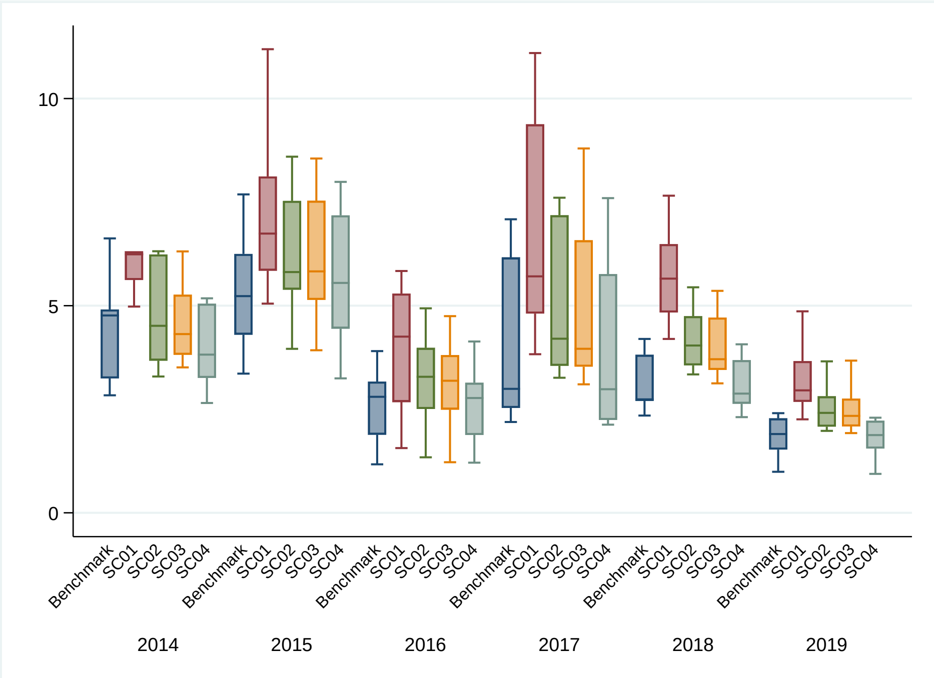
38 A description of the TARGET2 LSMs is provided in the Annex hereto.

Scenario 2 it stood at 4.2 minutes. In line with the previous results, improvements are more pronounced when re-introducing the offsetting and multiple optimisation algorithms.

Chart 15

Queuing time of payments across simulation results

(x-axis: simulated scenarios; y-axis: minutes)



Source: TARGET2, TAG calculations.
Notes: SC stands for scenario. The indicator takes into account all payments with all settlement statuses – directly settled, queued, and unsettled. Unsettled payments enter the calculation with a queue time until their respective cut-off time. The box displays the 25th, 50th and 75th percentiles, whereas the whiskers mark the minimum and maximum observations within the 25th/75th percentile ± 1.5 times the interquartile range. Outside values are excluded.

The study confirmed that LSMs in TARGET2 support the efficient use of liquidity and improve the settlement performance of the system. However, the impact of these features on settlement levels is somewhat marginal. This may be explained by two factors. First, LSMs process a small amount of TARGET2 payments. Second, the liquidity levels in TARGET2 have been extremely high due to the accumulation of excess liquidity, especially over the last few years of the analysis. The importance of LSMs is expected to increase, should liquidity conditions in the euro area return to normal.

4.4 Stress-testing

A Eurosystem task force composed of operators and overseers carried out stress-testing of liquidity risk in TARGET2 in 2013.[39] The exercise consisted of

[39] See Group on TARGET2 Stress Testing of the Market Infrastructure Board, Market Infrastructure and Payments Committee (2017), "Stress-Testing of liquidity risk in TARGET2", *Occasional Paper Series*, No 183, European Central Bank, Frankfurt am Main, February.

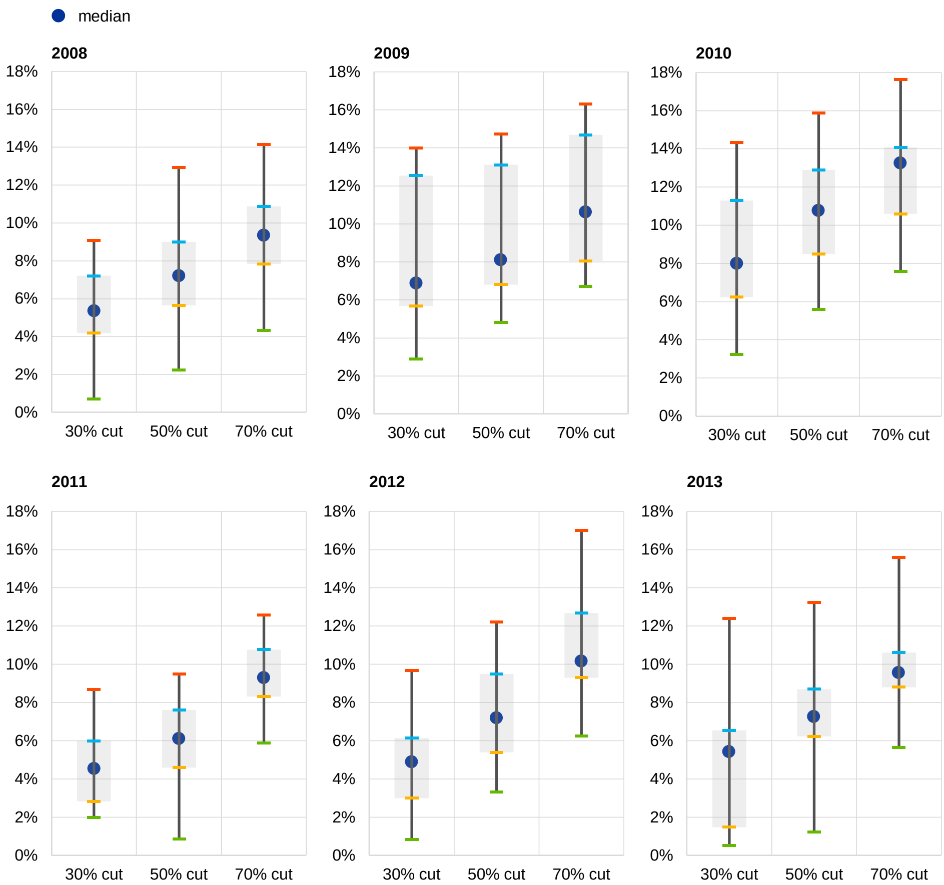
simulations of stress scenarios with liquidity shortages of different severity caused by collateral deteriorations. Sudden decreases in assets prices, i.e. collateral values, would reduce the TARGET2 intraday credit lines of TARGET2 participants, and hence reduce the available payment capacity of banks, defined as the sum of positive account balances and intraday credit lines. Such liquidity constraints could therefore affect the ability of participants to settle payment obligations in time (delayed payments) or at all (unsettled payments). The methodology used was based on collateral shocks of different level and type that would lead to a decrease in the intraday credit lines available in TARGET2 for participants and consequently to a lower payment capacity. The aim of the exercise was to assess how settlement levels would react or deteriorate as a consequence of the shocks in order to obtain an indication of the overall efficiency of the system, as well as to test the resilience of liquidity buffers and liquidity management features under tight liquidity conditions.

The results showed that TARGET2 is resilient under stress, and that liquidity levels seem to be appropriate and supported by the efficient liquidity management features of TARGET2. Even very severe liquidity shocks caused by most extreme collateral deteriorations led to relatively mild results. Chart 16 shows that, across the years and scenarios analysed, 80-90% of TARGET2 turnover would have been settled, even in the worst-case scenario of sudden drop of 70% of the collateral prices. The exercise was the first instance in which such a stress test was run on an RTGS system using real transactions and participant data within the replicated system functionalities. Thus, the Eurosystem has been at the forefront of this type of exercise applied to an RTGS system. In the light of the relatively comforting results and given that liquidity levels in TARGET2 have risen even further as compared with the period under analysis in the stress test, the TARGET2 operator has not repeated the exercise for the time being. Should a change in the Eurosystem monetary policy stance lead to a considerable reduction in liquidity levels, the TARGET2 operator stands ready to repeat the stress-testing of liquidity risk in TARGET2.

Chart 16

Unsettled payments in value

(x-axis: simulated scenarios; y-axis: percentage of total payments)



Source: TARGET2, Group on TARGET2 Stress Testing (GTST) calculations.
Note: The x-axis shows the simulated clean-cut scenarios, i.e. including both marketable and non-marketable assets.

5 General business risk

FMIs are exposed to general business risk, and thus operators are expected to properly identify, monitor and manage such risk. According to PFMI Principle 15, general business risk includes "any potential impairment of the FMI's financial position (as a business concern) as a consequence of a decline in its revenues or an increase in its expenses, such that expenses exceed revenues and result in a loss that must be charged against capital. (…) Business-related losses also may arise from risks covered by other principles, for example, legal risk (in the case of legal actions challenging the FMI's custody arrangements), investment risk affecting the FMI's resources, and operational risk (in the case of fraud, theft, or loss)." Consequently, the TARGET2 operator considers that general business risk may arise if the system's costs are higher or the revenues are lower than initially planned, or if a one-time loss occurs as a materialisation of another risk (i.e. operational or legal risk) such as a fraud.

5.1 Cost recovery

The TARGET2 operator assesses general business risk from a cost-recovery perspective. In other words, the TARGET2 operator expects the system to offset its development, running, overhead and capital costs with the revenues generated from the participants' fees. In 2007, based on assumptions of the future volumes of operations, a pricing scheme was established that was aimed at recovery of the costs by April 2014. At the same time, a public-good factor was reflected in the platform's pricing structure and has thus been taken into account when assessing the cost recovery situation of TARGET2 over time.[40] Following the overall economic slowdown and market conditions in the years since the go-live of TARGET2, the initial assumptions were revised and, as a result, a limited increase in the users' fees and an extension of the system's payback period were implemented from January 2013.[41]

The TARGET2 operator regularly monitors traffic developments and reviews the financial performance of the system. Traffic developments are monitored both in volume and in value terms, and are accessible to the Eurosystem through interactive dashboards. These dashboards display traffic at different aggregation levels, namely time evolution, payment types and countries. TARGET2 traffic has experienced both positive and negative growth rates over the last ten years. In value terms, TARGET2 traffic grew in 2011 and 2012 at an annual rate of +3.3% and +3.5% respectively (see Chart 17, left-hand panel). A drop of -22.2% in 2013 was

[40] See Bolt, W. and Humphrey, D. (2005), "Public good issues in TARGET, Natural monopoly, scale economies, network effects and cost allocation", *ECB Working Paper Series*, No. 505, European Central Bank, Frankfurt am Main, July; Holthausen, C. and Rochet, J. (2005), "Incorporating a "public good factor" into the pricing of large-value payment systems", *ECB Working Paper Series*, No. 507, European Central Bank, Frankfurt am Main, July.

[41] See TARGET2 Annual Report 2013, European Central Bank, Frankfurt am Main, May 2014.

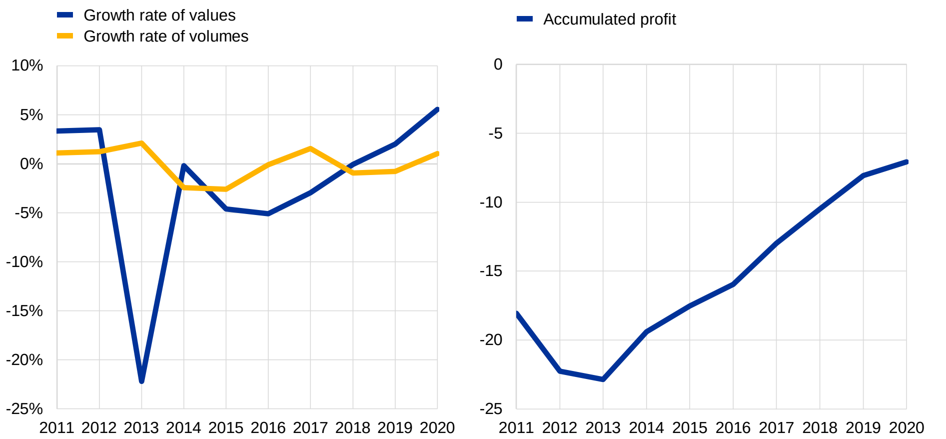
attributable to the change in the statistical framework (see Box 1). The go-live of T2S in 2015 led to a contraction in the turnover growth rates, which progressively narrowed until positive rates were registered again in both 2019 and 2020 (+2.0% and +5.6% respectively). In volume terms, the range of the growth rates was much smaller, with a minimum of -2.6% (in 2015) and a maximum of 2.1% (in 2013). TARGET2 volumes grew by only +1.0% between 2019 and 2020 given that the traffic was affected by the outbreak of the COVID pandemic.

The TARGET2 traffic dynamics are reflected in the path of cost recovery and profit accumulation. As explained in Box 1, the completion of SEPA migration and the go-live of T2S, with the consequent migration of CSDs, affected the TARGET2 traffic figures. In 2020 the total annual costs to be recovered amounted to €42.5 million. Given that the total revenues generated amounted to €43.5 million, the resulting annual profit was €1.0 million. At the end of 2020 the loss accumulated since the launch of TARGET2 had therefore decreased by the same amount, standing at €7.1 million (see Chart 17, right-hand panel).

Chart 17

Growth of TARGET2 traffic and accumulated profit over time

(left-hand panel: x-axis: year; y-axis: percentages; right-hand panel: x-axis: year; y-axis: value, EUR millions)



Source: TARGET2.

5.2 Fraud detection in TARGET2

The TARGET2 operator has developed and implemented tools that make it possible to monitor and detect abnormal payment behaviour in the system. The methodology is designed to support participants in their fraud prevention measures, by detecting anomalous activities in TARGET2 that could be due to potentially fraudulent payments. Fraudulent payments are defined as transfers of funds from one account in TARGET2 to another without the prior authorisation of the holder of the funds. These payments are very difficult to identify using a traditional statistical approach, especially when the approach cannot be validated against sufficiently reliable actual data. Instead, algorithms are able to capture the typical payment behaviour (or pattern) of a participant’s account and issue an alert every time there is a deviation from this behaviour. The idea behind the business transaction pattern monitoring mechanism applied to TARGET2 is that any deviation from a normal pattern might be an indication of potentially fraudulent activity.

The methodology developed by the TARGET2 operator is designed to work ex post and encompasses several indicators that capture different aspects of potential fraudulent payments. The principle underlying each of the indicators is that, based on a predetermined reference period, a pattern reflecting the typical behaviour of each individual TARGET2 participant is calculated and every time a deviation from this pattern occurs it is marked as an anomaly. The indicators focus on customer payments, i.e. payments that are done by banks on behalf of their customers, given that these transactions are more prone to fraud, but the focus could also be extended to other categories of payments in the future. At the beginning of each business day the anomalies detected for the previous business day are automatically reported to the TARGET2 operator (e.g. the service desk of the central bank participating in TARGET2).[42]

Each indicator is designed to deal with a particular attribute of the payment. Some of the indicators take into consideration the total daily values and volumes of payments by a participant, embedding seasonal adjustment techniques. Other indicators capture intraday patterns, although produced only ex post. Another important attribute is the relationship between the initial sender and the final recipient of the payment. Any new interaction between a sender and receiver that appears in the data is also carefully considered. Finally, as failed transactions are deemed to capture useful information, patterns arising from settlement failures are kept under observation. The reason for this is that an increase in the number of failed transactions might indicate a potential fraud involving many failed transactions until a correct form of the payments message is found. Weekends and holidays, when payments can still be submitted but not processed, are investigated separately.

More recently, the implementation of machine-learning techniques capable of detecting anomalies at transaction level was tested.[43] An additional advantage of machine-learning techniques is that they can account for combined information emerging from various attributes of a payment, such as all those listed above, at the same time. However, the absence of actual events and, consequently, a lack of training and validation possibilities prevents the application of the supervised learning methods often used in this context. So far, an approach that has been found to be particularly useful in the case of TARGET2 is the isolation forest methodology. This methodology does not rely on determining a pattern of normality. Instead, it focuses directly on anomalous data and provides an interpretable measure of abnormality. The methodology also makes it possible to incorporate non-numerical information, such as categorical variables, and it works efficiently with large data sets. While the business transaction pattern monitoring and the reporting of observed anomalies has already been implemented in the production environment, it should be noted that the machine-learning approach is still in an experimental phase.

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42 The business operator analyses the deviation from the normal pattern reported. If a specific transaction is suspicious, the business operator of the central bank with which the bank submitting the payment maintains a business relationship needs to follow this up with the bank.

43 See Betz, E. and Duca, I. (2019), "Unsupervised Anomaly Detection For Payment Systems At Transaction Level", 17th Payment and Settlement System Simulation Seminar, Helsinki, 29 August.

6 Operational risk

Operational risk is a major source of risk for FMIs, which is reflected in PFMI Principle 17. An FMI should "identify the plausible sources of operational risk, both internal and external (...)", as, "(...) [f]or example, participants can generate operational risk for FMIs and other participants, which could result in liquidity or operational problems within the broader financial system". Within this context, an FMI is required to "(…) identify, monitor, and manage the risks that key participants, other FMIs, and service and utility providers might pose to its operations". The TARGET2 operator has therefore developed a framework to identify and mitigate the risks related to its key players, the so-called critical participants (see Section 8.1). Operational risk may affect the TARGET2 system, as well as individual participants. When operational risk materialises in the form of a TARGET2 incident, the TARGET2 operator performs a thorough analysis of the incident's impact (see Section 8.2). Moreover, it is also in the interests of the TARGET2 operator to be kept informed of the occurrence of actual operational outages on the side of its participants (see Section 8.3).

6.1 Identification of critical participants

The TARGET2 operator regularly identifies the participants that are critical to the system. Under PFMI Principle 17, the identification should be "(…) based on the consideration of transaction volumes and values, services provided to the FMI and other interdependent systems, and, more generally, the potential impact on other participants and the system as a whole in the event of a significant operational problem". The identification of critical participants in TARGET2 is therefore based on these elements.[44]

Once identified, critical participants in TARGET2 must fulfil additional operational risk management requirements and mitigation measures. In particular, they are required to self-certify the fulfilment of a set of information security and business continuity requirements.[45] This provides reasonable assurance that the information security and cyber resilience of their internal systems are appropriately addressed, that business contingency and business continuity measures are in place and tested, and that outages exceeding 30 minutes are reported.

While the PFMIs give a general indication of characteristics that may make a participant critical, the concrete identification of such participants presents methodological challenges. The main challenge is the selection of indicators and thresholds to determine the binary decision of criticality or non-criticality. Given that a

44 The procedure is described in the official TARGET2 documentation. See Information Guide for TARGET2 users, Version 15.1, European Central Bank, Frankfurt am Main, March 2022 (Infoguide).

45 The detailed set of requirements can be found in Information Guide for TARGET2 users, Version 15.1, European Central Bank, Frankfurt am Main, March 2022.

definition or explicit economic characteristic of a critical participant does not exist, the data are, by default, unlabelled, and labels cannot be back-tested. The goal of the identification is therefore to assign to each participant a label, namely, whether it is critical or not. This is typically done based on indicators or statistics combined with expert knowledge, due diligence checks, and practicability considerations. The identification of critical participants in TARGET2 uses a broad set of data and analytics. The analysis is repeated every year and the methodology is continuously scrutinised and validated based on the outcome of every iteration.

Three types of institutions may be classified as critical in TARGET2, namely credit institutions, ASs and third-party service providers. For ASs, the identification challenge has been resolved by focusing on the type. In principle, LVPS, systemically important RPS, CSDs, international CSDs (ICSDs) and CCPs are classified as critical. For third-party service providers, which comprise the SWIFT Service Bureaus (SSB) and Group Hubs (GH), the methodology mainly consists of aggregating the turnover indicator used for credit institutions at third-party service provider level.

The identification process is more complex for credit institutions and requires the combination of two criteria, namely the turnover generated by a participant and the impact of a simulated technical failure of a participant on the settlement capacity of TARGET2. Each criterion has dedicated indicators and thresholds; participants are deemed critical if at least one of them is met. For both criteria, one indicator is calculated and used to rank participants. In a sequential step, simple hard thresholds are applied. Participants with a value greater than the threshold fulfil the criterion and are deemed to be critical. The thresholds are set on the basis of the results of the indicators and on the judgement of experts with the background and experience to evaluate risks. The combination of the two criteria, together with additional in-depth analysis of the results, makes it possible to overcome the identification challenge insofar as possible.

The classification also incorporates a time dependency element to avoid frequent reclassifications. A participant is categorised as critical only if the condition of criticality is fulfilled two years in a row. Similarly, a participant is declassified if the condition is no longer met for two years in a row. This rule is aimed at reducing the volatility in the group of critical participants by avoiding frequent reclassifications arising from temporary fluctuations and giving critical participants the constancy they require to meet the additional requirements. An exception may be made in extraordinary circumstances, such as an organisational change in the participation structure of a participant, a merger or an acquisition.

The first criterion measures the criticality of the participants by looking at the turnover in terms of value they generate in the system, in line with the approach suggested in the PFMIs. A participant is considered to be critical if it generates at least 1% of the total TARGET2 turnover in the first quarter of each year.[46] Since the identification of critical participants, as laid down in the PFMIs,

[46] The traffic for a participant is computed at technical platform level, i.e. if participants share a common technical platform, their traffic is aggregated given that an operational failure would affect the entire technical platform and not just an individual participant using it.

focuses on the potential impact of an operational failure of a participant, the relevant traffic for the computation of the first criterion encompasses solely those payments that are actively initiated by the participant. Payments where the participant is debited but that are initiated by others, such as payments for AS settlement or direct debits, would still be settled in the event of an operational failure and are therefore filtered out. By aggregating the values at SSB/GH level, the methodology can also be transposed to third-party service providers.

While a participant's turnover is a good proxy for its criticality in TARGET2, the largest impacts in an interconnected network may not necessarily be caused by the largest participants failing. Hence, focusing solely on the traffic share of a participant neglects potential contagion effects in the system. This contagion is often referred to as a "liquidity sink": a participant with an operational failure still receives payments but is unable to send payments, i.e. the liquidity it receives is no longer available in the system but disappears into the "liquidity sink". This lack of liquidity can lead to the system not being able to settle the payments of other participants who are relying on the incoming liquidity from the failed participant to fund their own payments. Hence, the introduction of the second criterion was deemed to be necessary.

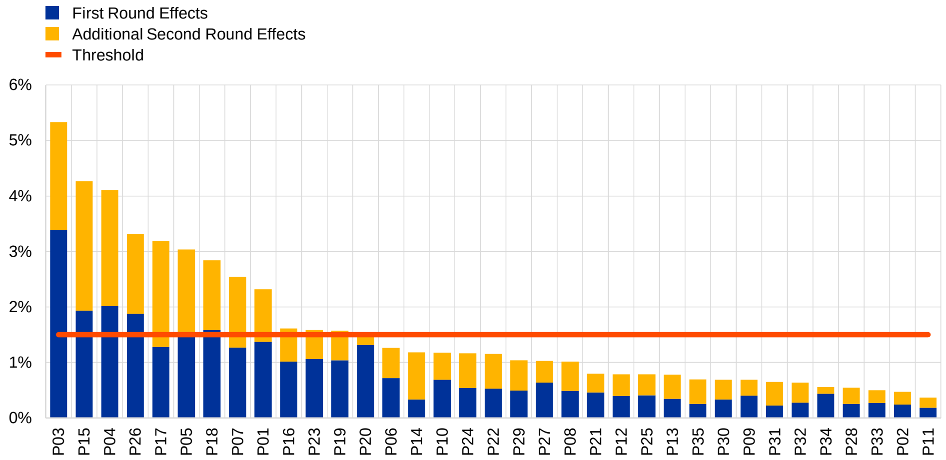
The second criterion addresses the more general definition of criticality as potential impact of an operational failure on other participants and on the system. The operational failure of a potential critical participant is simulated using the TARGET2 simulator. The simulation scenario is generated by removing all the payments sent by the participant over an entire day, except for ancillary system payments debited from its account that are sent by the AS itself and changes in the participant's ICL. The payments of all other participants remain unchanged. By assuming that no behavioural reactions and mitigation measures at participant level take place, the simulation scenarios represent a "worst-case" scenario. For each participant, independent scenarios for ten business days are generated and simulated. The simulation results are evaluated in terms of increased unsettled payments at system level due to the operational failure. A participant is considered to be critical if it causes at least 1.5% of unsettled payments on average in value terms in the period analysed (see Chart 18). While the threshold check itself is as straightforward as for the first criterion, the indicator calculation is more complex given that a large number of simulation scenarios have to be generated and executed. To reduce the number of scenarios, the simulations are executed for a group of top TARGET2 participants.

Chart 18

Simulations of the technical failure of participants in TARGET2

Criterion 2 (Simulations), first and second-round effects, sample year

(x-axis: participant ID; y-axis: average share of unsettled transactions (value) in percent for each potential critical participant)



Sources: TARGET2, TAG calculations.

The simulation results make it possible to distinguish between the first-round effects, caused by payments not sent due to the operational failure, and the second-round effects, whereby other participants are not able to settle their payments. While the first-round effect is conceptually identical to the turnover of the first criterion, the second-round effect precisely measures the potential contagion not considered by the first criterion. The scenario is designed as a worst case and the threshold is set accordingly. For recent years, simulation scenarios have been generated and executed for 32 to 37 participants each year, while the final group of critical credit institutions after the combination of the two criteria consists of 19 to 21 participants. Overall, the "simple" indicator of the first criterion identifies the majority of critical participants, whereas the second criterion captures a lower, although not negligible, number of critical participants. In addition, the data generated from the simulation results can be further analysed to increase understanding of the diversity of contagion channels and the importance of non-linear effects. One of the main advantages of this analysis is to focus on the participants affected in the second round.

Box 2

Additional analysis of simulated operational failure

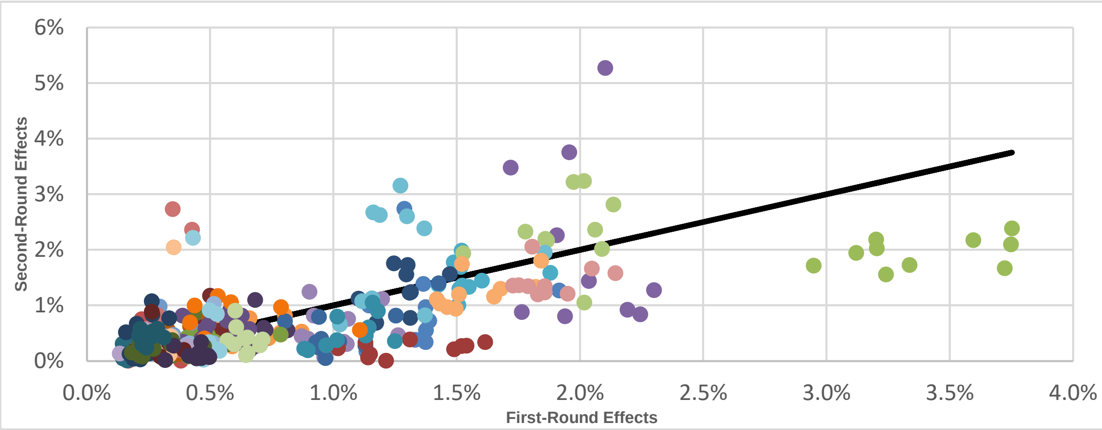
The TARGET2 operator further analyses the simulation results calculated for fulfilment of the second criterion to gain a better understanding of the contagion effects and potential hidden risks due to network characteristics.[47] In a first step, the relation between first- and second-round effects is analysed at a more granular level by looking at daily simulation results instead of averages. This makes it possible to detect outliers that call for further attention (see Chart A).

[47] See Müller, A., Papsdorf, P. and Polo Friz, L. (2017), "Critical Participants in TARGET2", 15th Payment and Settlement System Simulation Seminar, Helsinki, 1 September.

Chart A

Simulation results for individual business days, sample year

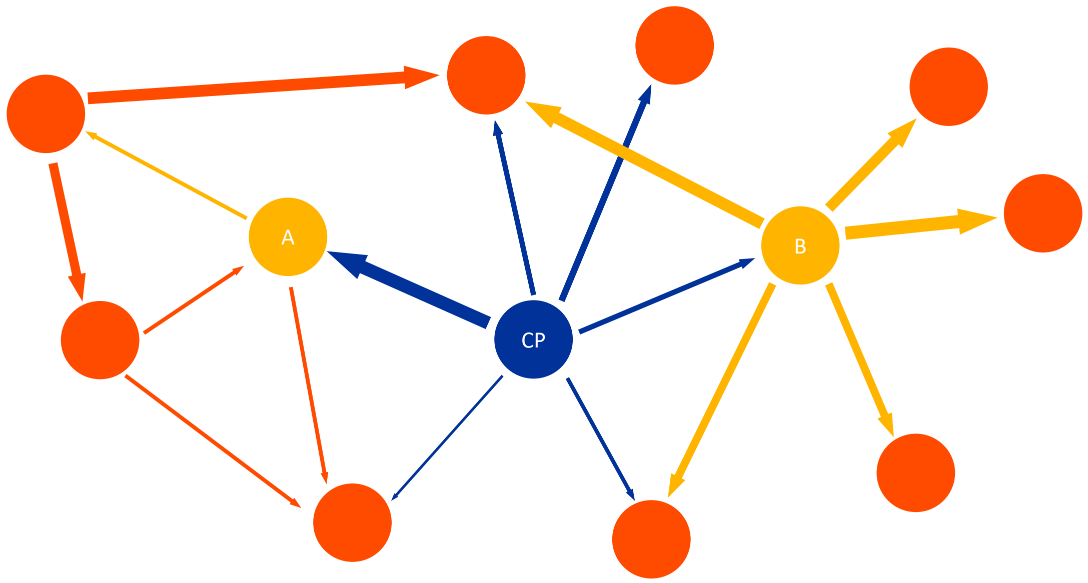
(x-axis: first-round effects, percentages; y-axis: second-round effects, percentages, share of unsettled transactions (value) in percent for each day simulated)



Source: TARGET2, TAG calculations.

The contagion effect mainly occurs if some participants affected by an outage generate large second-round effects relative to the first-round effects they suffer from, i.e. the lack of incoming payments from a potential critical participant is relatively small compared to the amount of the payments they are themselves not able to settle as a consequence. Such participants can be considered to be catalysts, given that they spread the initial shock of the operational outage further through the system. Such participants are not critical in the sense that their own operational outage generates risks, but the impact on other participants or on the system is significant. The contagion effect is illustrated in the sample network depicted in Figure A. Each node represents a participant, and each link is sized to the amount of payments that remain unsettled and no longer reach the participant indicated by the arrow. In the example, participant A is affected more than participant B by the unsettled payments that are no longer forthcoming from the critical participant (CP) in the first round (shown in blue). At the same time, participant B generates a much larger share of unsettled payments in the second round (shown in yellow) as compared with participant A and thus acts as a catalyst. From a risk perspective, the identification of participants amplifying the effect of another participant's failure makes it possible to target mitigation actions more effectively, e.g. through back-up payments from the participant suffering an outage to these catalyst participants.

Figure A
Sample network of unsettled payments



Source: TAG.
Notes: The size of the arrows is proportional to the value of unsettled payments. Blue indicates the first-round effects, and yellow the additional second-round effects.

To complement the analysis, ad hoc network visualisations of unsettled payments in a scenario similar to the sample in Figure A make it possible to analyse the contagion effects in detail. This is not done as a regular exercise, but rather as a case-by-case analysis if other indicators signal possible specific characteristics or call for additional explanations. However, network analysis methodologies, such as specific network indicators, could also be applied to conduct systematic analysis, as is done for other risk assessments (see Section 5.2).

6.2 TARGET2 incidents

When a TARGET2 incident occurs, the TARGET2 operator makes an ex post analysis of the root causes of the incident, of the measures taken and of the impact on the participants. The latter is assessed by making a granular analysis of the evolution of the cumulated intraday settlement on the incident day and on the evolution of rejection rates. This is done in particular where incidents have a broader impact on TARGET2 (i.e. both across and along the settlement chain).[48] Then, the pattern of intraday cumulated settlement on the incident day is compared to that on a normal day for each payment type – typically customer payments, interbank payments, AS transactions and T2S and TIPS liquidity transfers – and at five-minute intervals. Specific attention is given to AS settlement and interactions with T2S and TIPS in the light of their liquidity interdependency with TARGET2 (see Chart 19).

Such ex post analysis is relevant to assess how the disruption created by the incident affected the participants' ability to settle payments and the potential

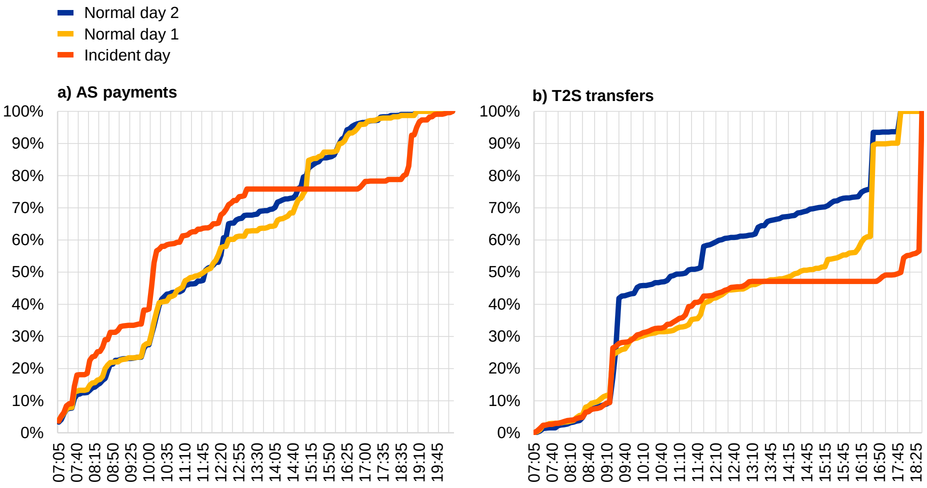
[48] For example, five major information-technology-related incidents affecting settlement in TARGET2 occurred in 2020, two of which had a broader impact.

spill-over to other FMIs. It also gives a measure of whether the contingency and resolution measures put in place by the TARGET2 Crisis Managers[49] have been effective in containing and addressing the situation. The pattern of intraday cumulated settlement gives evidence of how the traffic recovery progressed and of the incident's overall impact on settlement. Additionally, the consequences in terms of rejected transactions or additional recourse to the marginal lending facility are analysed. Finally, the analysis at short time intervals provides additional insights into pattern deviations at specific points in time into which the TARGET2 operator may perform further investigations.

Chart 19

Intraday cumulated settlement of AS payments and T2S transfers

(left panel: x-axis: TARGET2 opening hours; y-axis: cumulated value, percentages; right panel: x-axis: TARGET2 opening hours; y-axis: cumulated value, percentages)



Sources: TARGET2, TAG calculations.
Notes: Only the TARGET2 day-trade phase is considered. As most liquidity is sent to T2S at the beginning of NTS, only a fraction of the overall transfers to T2S are included in the chart in the right-hand panel.

6.3 Operational outages of participants

While the identification of critical participants focuses on the impact of a potential operational outage and system outages of TARGET2 are well identified, less is known about actual participant outages. In TARGET2, only critical participants are required to report outages to their CBs and there is no such requirement for non-critical participants. In addition, there might be an underreporting of operational outages given that participants may be concerned about reputational risks.

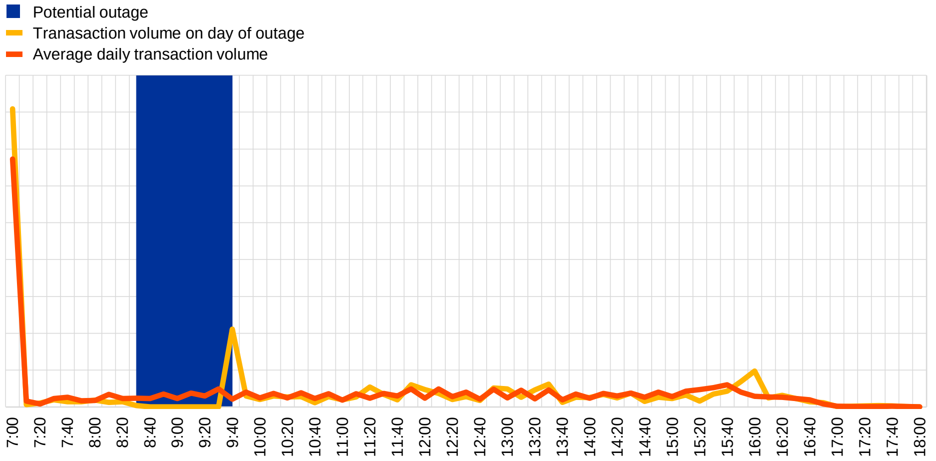
[49] Each central bank, the ECB and the providing central banks (3CB) have a crisis manager, who is informed by the respective settlement manager of their institution (responsible for the daily management of operations in TARGET2) and is involved in the event of a problem escalation.

An algorithmic methodology makes it possible to identify potential operational outages of TARGET2 participants using transaction-level data.[50] The algorithm accounts for behavioural patterns and identifies intervals where payment activity seems so low that an operational outage may be assumed. Given that the contingency measures foreseen in TARGET2[51] allow participants to initiate a limited number of transactions in the event of an outage, the methodology used works in sequential steps[52] to identify potential operational outages rather than simply identifying intervals without transactions. The identification, impact and relevance of an operational outage are strongly related to the duration of an outage. Thus, outages are identified when more than four consecutive ten-minute intervals exhibit relatively low payment activity. This approach is in line with the reporting requirements for critical participants whereby they are obliged to notify outages lasting longer than 30 minutes to their central bank. Chart 20 illustrates a participant's outage occurring between 08:40 CET and 09:30 CET on a sample day. At the identified outage intervals, payment activity is significantly lower than on an average day. After the outage there is usually a catching-up effect, as back-logged payments are sent to the system.

Chart 20

Intraday payment activity in the event of an operational outage

(x-axis: TARGET2 opening hours; y-axis: number of transactions)



Source: TARGET2, TAG calculations.
Notes: Methodology based on Glowka et al. (2018). The values of the y-axes are not reported for confidentiality reasons.

The TARGET2 operator performs a quarterly calculation of potential outages of the critical participants. This serves to monitor the risk of operational outages

50 See Glowka, M., Paulick, J. and Schultze, I. (2018), "The absence of evidence and the evidence of absence: an algorithmic approach for identifying operational outages in TARGET2", *Journal of Financial Market Infrastructures*, Volume 6, No 2/3, September, pp. 63-91.

51 More information on the contingency measures available can be found in the Information Guide for TARGET2 users, Version 15.1, European Central Bank, Frankfurt am Main, March 2022.

52 First, the low payment activity of the participant is identified when the volume of transactions of that participant over a ten-minute interval on a business day lies in the first percentile of observations of the participant in the respective ten-minute interval over the last year. Second, general (e.g. holidays) and individual payment behaviour is taken into account in order to adjust the intervals with low payment activity identified. Third, the duration of an operational outage is considered by linking consecutive ten-minute intervals with low payment activity. Last, if low payment activity is identified in four consecutive ten-minute intervals an operational outage of the participant is assumed.

affecting participants and to evaluate the performance of the algorithm. The algorithm results are cross-checked against the reported data filed in incident reports. The study is limited to the critical TARGET2 participants – as only they are obliged to report significant outages to their respective CBs. Deviations between the reported and identified data for operational outages may stem from the fact that the algorithmic approach inherently entails uncertainty or the fact that the outages were not reported. The reason for developing the approach in the first place was the absence of comprehensive and reliable information on operational outage occurrences. Besides the operational incidents communicated, the CBs use expert judgement, reporting tools, information received, as well as following up with participants to evaluate potential outages identified. In 2020 the algorithm identified a total of 72 days with a potential operational outage. On average, potential operational outages lasted for 6.6 ten-minute intervals, i.e. around one hour. There were several shorter potential outages of less than one hour (26) and a few that were longer and lasted for more than two hours (6). The longest outage lasted 18 ten-minute intervals or approximately three hours.

The results of the quarterly exercises suggest that the algorithm works very well in most circumstances, and especially in the case of long-lasting outages. The more consecutive intervals with low payment activity that are detected, the more likely it is that they constitute an actual operational outage, although, by construction, identification is difficult when the contingency measures are employed. Hence, the methodology has proven highly useful for the TARGET2 operator. The approach could also be used in other jurisdictions.[53] In the future, such tools could be employed to monitor system participants in real-time and proactively react to operational risks.

[53] The approach was also applied to Canadian large-value transfer system data (see Arjani, N. and Heijmans, R. (2020), "Is there anybody out there? Detecting operational outages from Large Value Transfer System transaction data", *Journal of Financial Market Infrastructures*, Vol. 8, Issue 4, June, pp. 23-41.)

7 Risk related to tiered participation arrangements

Tiered participation arrangements occur when a participant in an FMI offers other institutions that are not participants in the FMI itself the possibility of settling their transactions on its accounts. More generally, under PFMI Principle 19, "tiered participation arrangements occur when some firms (indirect participants) rely on the services provided by other firms (direct participants) to use the FMI's central payment, clearing, settlement, or recording facilities". On the one hand, tiered participation arrangements may be seen as beneficial for the financial system given that they ensure wider access to the services of an FMI, fostering the inclusion of smaller banks that might not be able to afford direct participation or providing access for settlement in different currencies. On the other hand, such arrangements pose certain risks for the FMI and its functioning. These risks, including credit, liquidity and operational risks, are particularly relevant when the degree of tiering in the FMI is high. In other words, the more significant (i) the proportion of the total FMI's traffic originated by indirect participants, and (ii) the concentration of the traffic originated by indirect participants in the books of a few direct participants are, the more relevant those risks.

Tiered participation arrangements may pose credit, liquidity and operational risks. Credit and liquidity risks created by tiered participation arrangements are typically addressed by private agreements between direct and indirect participants. The FMI operator is not expected to play an active role in managing them. It may, however, apply credit or position limits, in agreement with the direct participant. In contrast, operational risk is relevant for the FMI operator, as the disruption of a direct participant may affect the capacity of all its indirect participants to channel payments to the FMI. This is a concrete risk if a direct participant offers tiering services to many indirect participants, and if the traffic originating by these indirect participants is quite large.

The TARGET2 operator regularly analyses the levels of tiered participation arrangements and the related risks. The analysis is conducted on a yearly basis and is based on a set of statistical indicators identifying the traffic generated by tiered participants and the number and distribution of tiered relationships, both at aggregate and at participant level. PFMI Principle 19 states that "an FMI should identify, monitor and manage the material risks to the FMI arising from tiered participation arrangements". In particular, this means that the FMI should gather information about indirect participation, identify indirect participants responsible for a significant proportion of the transactions processed in the FMI, or of the transactions settled via the respective direct participant, review risks arising from tiered participation arrangements and take mitigating actions whenever necessary. The methodology adopted by the TARGET2 operator for the risk assessment focuses mainly on tiering on the sending side given that this is considered to pose greater risks due to the potential spill-overs to other participants that may arise if the payments from the tiered participants cannot be settled.

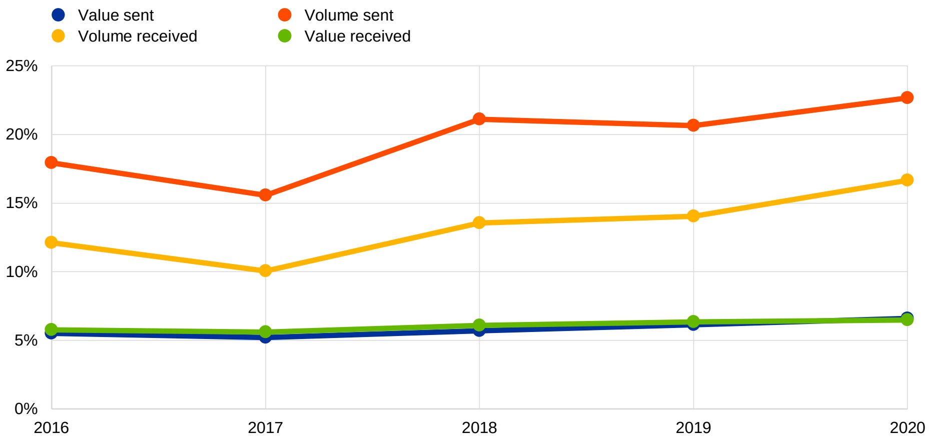
Tiered participation arrangements can occur on both the debit and the credit sides and are identified in TARGET2 by comparing a payment's sender and receiver with its originator and beneficiary and excluding intragroup transactions. To do this, the TARGET2 payment-level data are merged with the Bank Directory Plus data from SWIFT to identify and exclude intragroup transactions, i.e. those involving BICs ("tiered" BICs and "direct" BICs) belonging to the same banking group in TARGET2. This means that a payment is considered to be tiered on the sending side only if the originator and the sender belong to a different banking group. The same logic applies on the receiving side (the beneficiary and receiver belong to a different banking group). In addition, the methodology does not consider payments to be tiered if the originator parent and the beneficiary parent are the same, as this is ultimately an intragroup transaction.

The share of tiered traffic in TARGET2 has been relatively stable in value terms over time, whereas it has displayed more variation in volume terms. Between 2016 and 2020, tiering in value ranged between 5.2% and 6.6% of total TARGET2 traffic and was largely similar on the sending and the receiving sides (see Chart 21). Over the same period, tiering levels in volume terms ranged between 15.6% and 22.7% on the sending side and between 10.1% and 16.7% on the receiving side. This asymmetry suggests, first, that indirect participants typically use direct participants to settle payments more frequently on the sending side than they ask to receive on their behalf and, second, that the average tiered payment size is larger on the receiving than on the sending side. Compared with the value, tiering in volume was slightly more volatile across both the sending and receiving sides in terms of historical developments. Monitoring of the aggregate levels of tiering makes it possible for the TARGET2 operator to identify trends and to determine whether potential risks arise at platform level.

Chart 21

Tiered participation arrangements over time

(x-axis: year; y-axis: percentages, yearly average)



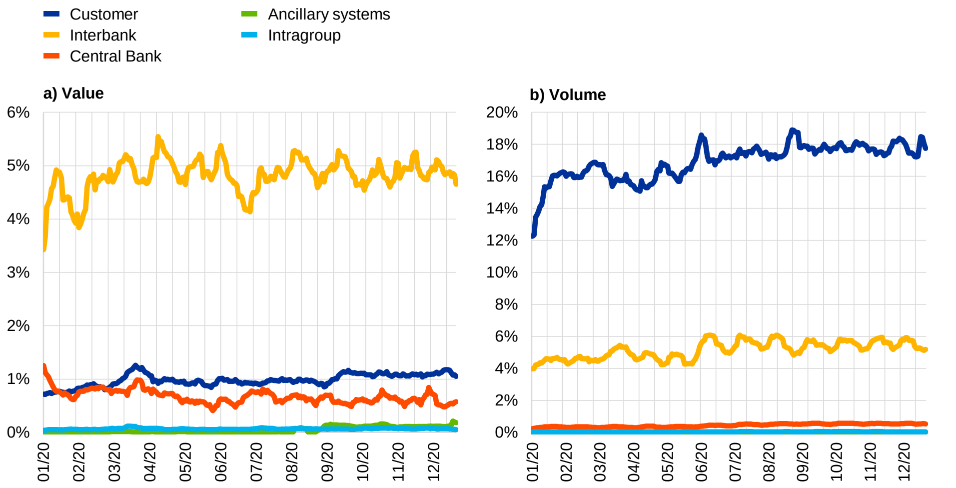
Source: TARGET2, TAG calculations.

Interbank payments account for the largest share of tiered TARGET2 traffic in value terms, whereas customer payments are predominant in volume terms. In 2020, interbank payments sent by TARGET2 participants on behalf of other institutions accounted for 4.8% of total TARGET2 traffic (see Chart 22). On the volume side, customer and interbank payments sent by TARGET2 participants on behalf of other institutions accounted for 16.9% and 5.2% of total TARGET2 traffic respectively. These results reflect the composition of the overall TARGET2 traffic.

Chart 22

Tiered participation arrangements by payment category

(left panel: x-axis: month; y-axis: percentages, 10-day moving average; right panel: x-axis: month; y-axis: percentages, 10-day moving average)



Source: TARGET2, TAG calculations.

Banking groups headquartered in the United States were the top contributors to tiered traffic in TARGET2 in value terms in 2020. Out of all the banking groups that asked direct participants to send payments on their behalf in TARGET2, these groups accounted for 28.6% of the overall tiered traffic in value terms (see Chart 23, left-hand panel). From outside the EEA, Switzerland, Canada, Japan and China also contributed to tiered traffic, but to a lesser extent. Groups located inside the EEA accounted for 21.0% of the total value. As institutions located in the EEA can also access TARGET2 directly, these results are not surprising.

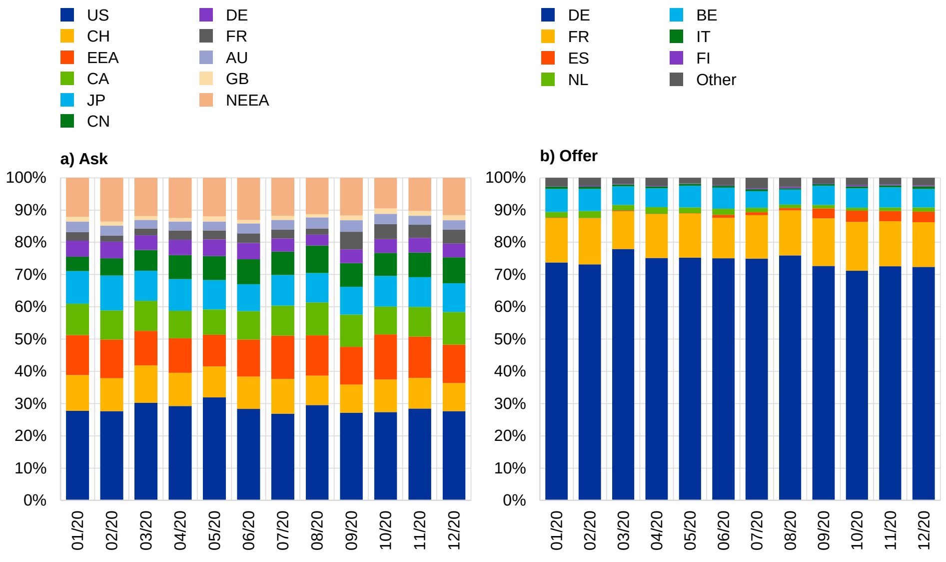
The most active groups offering tiering services in 2020 were located in Germany. Of all the banking groups offering to send payments through TARGET2 on behalf of other groups located worldwide , German groups were the most significant with 74.2%, followed by France with 13.7% and Belgium with 6.1% (see Chart 23, right-hand panel). These results are linked to many factors, including the characteristics of the national banking systems, namely its size and the presence of banking groups' headquarters, and the fact that correspondent banking services is a concentrated business.[54]

[54] See "Correspondent banking trends and developments in 2019", *MIP News*, European Central Bank, Frankfurt am Main, 6 November 2020,

Chart 23

Tiered participation arrangements by country

(left panel: x-axis: month; y-axis: percentages; right panel: x-axis: month; y-axis: percentages)



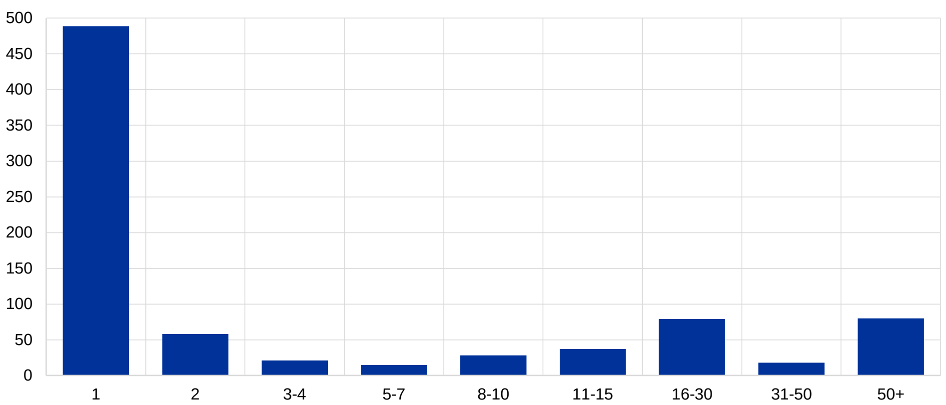
Source: TARGET2, TAG calculations.
Note: The percentages are in terms of total value.

A few banking groups channelled their payments to TARGET2 through a large number of direct participants in 2020, whereas the majority of groups used a single access point. A total of 4,768 indirect groups (corresponding to 25,276 individual participants) sent at least one payment to TARGET2 through another institution in 2020 (see Chart 24). The share of indirect participant groups using just a single point of direct entry into TARGET2 was less than 20%, while more than a third of the indirect groups connected to TARGET2 through 11 or more direct groups. The possibility of accessing TARGET2 through multiple institutions constitutes a relevant mitigation measure, especially in the event that one of the direct participants experiences an issue. This picture has been relatively stable over time.

Chart 24

Direct participants per tiered group in 2020

(x-axis: number of direct participants; y-axis: number of tiered participants)



Source: TARGET2, TAG calculations.

Overall, the yearly monitoring conducted by the TARGET2 operator shows that the traffic associated with tiered participation arrangements in TARGET2, and the risks stemming from this, are relatively limited. The risks associated to tiering are mainly linked to the value of tiered transactions given that a large amount of liquidity might become unavailable for settlement in the event of a failure of a direct participant. In this regard, it should be underlined that tiered traffic as a proportion of total TARGET2 traffic has not exceeded 6.6% in value over the last five years. Moreover, concentration risk does not appear to be relevant given that more than 80% of tiered groups use two or more direct participants as points of entry to TARGET2, thereby lowering the potential impact of a disruption of a direct participant.

8 Conclusion

As one of the world's leading payments systems, TARGET2 is subject to the regulatory standards set by the CPMI-IOSCO PFMIs. To assess the system's resilience to the various types of risks identified by the PFMIs, the TARGET2 operator has developed, over time, dedicated frameworks combining qualitative and quantitative elements. The latter are used to assess the system's compliance with specific regulatory provisions for which risk assessment needs to be supported by granular data analysis. This is in particular the case when assessing risks arising from interdependencies (Principle 3 on the comprehensive management of risks), analysing liquidity risk (Principle 7), monitoring general business risk (Principle 15), identifying the system's critical participants (Principle 17 on operational risk) and analysing the risks of tiered participation arrangements (Principle 19).

The TARGET2 operator relies on a broad and diverse analytical toolkit to support regulatory compliance. Access to TARGET2 transaction-level data, which provides an extremely rich source of information, combined with analytical expert knowledge, has allowed the TAG to develop over time different approaches based on data analytics for monitoring and assessing risk. The toolkit created by the TAG includes individual statistical indicators, as well as more complex exercises using compound indicators and specific tools, such as the TARGET2 simulator. The choice of methodological approach and the periodicity of analyses are tailored to the specific regulatory provision, the characteristics and implications of each risk and the actions that the TARGET2 operator is required to take. The complexity of the TARGET2 system and the potential methodological challenges that may need to be overcome are also taken into consideration.

The analysis of interdependencies serves to quantify the risks arising from the interconnections that TARGET2 has with other entities, which, in the case of TARGET2, are other FMIs. Interdependencies in TARGET2 are mainly of a liquidity and operational nature. Their analysis relies on a set of statistical and network indicators based on a general framework established by the CPMI. For interdependencies occurring along the settlement chain, the operator focuses on the number and traffic of other FMIs in TARGET2. Although lower than in the past, they represent a significant fraction of the overall TARGET2 daily value with an average 24.6% in 2020. The amount of liquidity sent daily from TARGET2 to T2S and TIPS is a measure of the interdependency between these systems. While in TIPS interdependency is still very low, liquidity transfers to T2S represented 7.1% of TARGET2 traffic in 2020. Network measures are used to evaluate the indirect relationships in TARGET2 among FMIs through a common participant given that these might lead to contagion effects. Overall, the connectivity of the TARGET2 network is extremely low.

Various liquidity indicators, focusing inter alia on intraday developments, and ad hoc studies on system features or participants' payments behaviour are instrumental to monitoring and analysing liquidity risk. Settlement in an RTGS system can be very liquidity intensive for participants, and the operator carefully monitors to ensure that participants have sufficient liquid resources and use them in an efficient manner. Intraday analysis of the liquidity available on participants' accounts makes it possible for the TARGET2 operator to monitor the use of the credit line, which has proved to be relatively limited and constant throughout time, implying a low intraday liquidity risk for TARGET2 participants. Regular monitoring of intraday payments behaviour at system level provides insights into the distribution of settlement during the day with the aim of avoiding concentration at specific times; at participant level, it makes it possible to identify payment-pattern deviations that might be indicative of potentially abnormal situations. The TARGET2 operator has conducted extensive analysis of the usage and effectiveness of its liquidity saving features. While limited use is currently made of these tools in TARGET2, owing inter alia to the high liquidity levels at the present time, they support the efficiency of settlement in the system.

Data analysis supports two dimensions of compliance with the general business risk requirements, namely cost recovery and fraud detection. The TARGET2 operator regularly monitors traffic developments and reviews the financial performance of the system to assess whether TARGET2 is offsetting its costs from the revenues generated from fees. Should this not be the case, mitigating action is taken. Furthermore, the TARGET2 operator has developed and implemented tools that make it possible to monitor and detect abnormal payments in the system. The methodology currently used is based on several ex post indicators that capture different aspects of potential fraudulent payments. More recently, an attempt was made to employ machine-learning techniques to assist with anomaly detection at payment level, but the approach is still in an experimental phase.

Critical credit institutions in TARGET2 are identified by combining two criteria using dedicated indicators and thresholds within the more general operational risk framework. The first criterion looks at the turnover generated by participants in the system. The second criterion assesses the impact on TARGET2 settlement of a simulated technical failure. It addresses the more general definition of criticality as the potential impact of an operational failure on others, thereby capturing the "contagion" effect. While the PFMIs give a general indication of characteristics that could make a participant critical, the identification of such participants presents methodological challenges and calls for a combination of expert knowledge, due diligence checks and practicability considerations. Critical participants in TARGET2 are identified on an annual basis and must comply with additional information security and business-continuity requirements. As part of its operational risk monitoring, the TARGET2 operator assesses the impact of TARGET2 incidents by looking at intraday cumulated settlement and identifies potential operational outages among TARGET2 participants using an algorithmic methodology.

Tiered participation arrangements in TARGET2 are assessed by looking at the entire payment chain and comparing the sender and receiver of a payment against its originator and beneficiary. The TARGET2 operator focuses its analysis of tiering mainly on the sending side, given that this is considered to pose greater risks due to the potential spill-overs that might arise if liquidity did not reach the recipients of tiered participants' payments. In value, tiering stood at 6.6% of total TARGET2 traffic in 2020, while in volume it represented 22.2% of total payments. The risks associated with tiering are mainly linked to the value of tiered payments, hence tiering risk is considered to be low in TARGET2.

Although developed with the objective of regulatory compliance, these tools have been important for monitoring the system and gaining knowledge and understanding of the system's activity over time. These indicators and the related studies offer important insights into traffic patterns, system efficiency, the effectiveness of various system features, liquidity flows, payment patterns, the behaviour of individual participants and their interconnections. They have therefore been regularly used by the TARGET2 operator in its daily activities, and, in exceptional circumstances, to deepen analysis and monitor the impact of specific events, such as incidents or functional changes in the system. Data analyses have been pivotal to supporting decision making by the TARGET2 operator, and to more general policy discussions surrounding TARGET2, its developments, its access rules and interlinkages. They have also been key to more general discussions around European FMIs, such as the recent pan-European strategy for instant payments and preparation of the T2-T2S consolidation. For the TARGET2 operator, and, more generally, for Eurosystem FMI policy making, it is therefore of the outmost importance to keep investing in these tools with a view to future developments in the payment systems landscape.

One particular challenge going forward will be the T2-T2S consolidation in November 2022 and the creation of the future TARGET system, composed of different services.[55] These developments need to be supported by solid analysis and appropriate risk assessment, hence the development and implementation of analytical tools that rely on granular information will continue to be indispensable. To this end, a new analytical environment with enhanced features, improved data access and collaborative options is being developed to support payment-level data analysis by the operator and the overseer of the future TARGET system. With the change to the new system, the current methodologies will need to be revised. Moreover, new indicators may need to be monitored, especially for the initial phase of stabilisation of the system. While the TAG is already working on both fronts to ensure that everything will be ready and on time for November 2022, the Eurosystem sees this paper as the ideal opportunity to establish a fruitful exchange with other central banks around the world on analytics for payment systems with the common objective of further improving the tools for a greater understanding of RTGS systems.

55 See ECB website: *T2-T2S consolidation: what is it?*

Annex

Table A
Liquidity management features in TARGET2

Liquidity Management Features	Description
Priorities	If payments cannot be settled immediately due to a lack of liquidity on the participant's account, payments are queued according to their priority. Participants can choose from the priorities "normal", "urgent" or "highly urgent". The default priority is "normal". The priority "highly urgent" is only allowed for certain payment types, such as FMI-related payments and TIPS/T2S liquidity transfers, and is assigned automatically by TARGET2.
Reservations	Participants may set aside amounts of liquidity for transactions with a non-normal priority (urgent or highly urgent).
Limits	Participants can set bilateral and multilateral sender limits. In general, limits establish the cumulated payment amount that a participant is willing to pay to another participant (bilateral) or to all other participants (multilateral – with no bilateral limit being set) without having received payments (that are credits) first.
Timed payments	The sender of a transaction has the possibility of setting both a specific time before which a transaction cannot be settled (the so-called earliest debit time) and a time limit after which the transaction will either remain in the queue or be rejected (the so-called latest debit time).
Liquidity pooling	For participants with more than one account, TARGET2 offers liquidity pooling services. Before using the service, the participant has to specify a hierarchical structure for the accounts to be included in the liquidity pooling arrangement. The manager of a group of accounts has the possibility of either viewing the liquidity position of all group accounts simultaneously, thereby having the benefit of information on the aggregated liquidity positions of the whole group (consolidated information functionality), or managing group accounts as a single virtual account (aggregated liquidity functionality).
Active queue management	TARGET2 offers its participants a functionality that enables them to actively manage their queued payments. They can change the priority, the earliest and/or latest time stamp or the order in the queue of each queued payment. They may also revoke payments.

Sources: TARGET2 UDFS.

Table B
Liquidity saving mechanisms (LSMs) in TARGET2

Liquidity Saving Mechanisms (LSM)	Description
ALGO1: all or nothing optimisation	Calculates, for each participant, those payments that can be executed in compliance with the participant's bilateral and multilateral limit position from all queued payments and all priorities. It settles successfully if all positions are positive, otherwise it stops when the liquidity becomes insufficient, or if the reservations are not met. This algorithm was switched off in 2009.
ALGO2: partial optimisation	Works in a similar way to ALGO1, but is able to deallocate payments (i.e. keep them in the queue) if it detects negative positions (or "uncovered positions") in calculating the total liquidity position, the aim being to turn those negative positions into positive positions. It can also end in payments being unsuccessful if bilateral/multilateral limits are breached or positions are not covered.
ALGO3: multiple optimisation	Tries to resolve all the queues with the highest possible settlement volume and low liquidity demand. It consists of two parts, one bilateral and the other multilateral. It can also end in payments being unsuccessful if bilateral/multilateral limits are breached or positions are not covered.
ALGO4: partial optimisation with ancillary system	Acts in a similar way to ALGO2 and offers the possibility of AS settlement procedure 5 (simultaneous multilateral settlement) transactions being settled. It includes any other pending transactions in its runs.
ALGO5: optimisation on sub-accounts	Is a function for resolving AS transactions within AS procedure 6 (settlement on dedicated liquidity accounts) only.

Source: TARGET2 UDFS.
Note: Algorithms 1-3 are "time triggered", while algorithms 4 and 5 are "event triggered".

Bibliography

Arjani, N. and Heijmans, R. (2020), "Is there anybody out there? Detecting operational outages from Large Value Transfer System transaction data", Journal of Financial Market Infrastructures, Vol. 8, Issue 4, June, pp. 23-41.

Bank of Finland (2009), "Product Information: Bank of Finland Payment and Settlement System Simulator BoF-PSS2", Version 2.4.0, Bank of Finland, 5 October.

Benos, E., Garratt, R. and Zimmerman, P. (2012), "Bank behaviour and risks in CHAPS following the collapse of Lehman Brothers", Working Paper Series, No 451, Bank of England, London, 21 June.

Betz, E., and Duca-Radu, I. (2019), "Unsupervised Anomaly Detection For Payment Systems At Transaction Level", 17th Payment and Settlement System Simulation Seminar, Helsinki, 29 August.

Bolt, W. and Humphrey, D. (2005), "Public good issues in TARGET, Natural monopoly, scale economies, network effects and cost allocation", ECB Working Paper Series, No 505, European Central Bank, Frankfurt am Main, July.

Committee on Payments and Settlement Systems (2008), "The interdependencies of payment and settlement systems", CPMI Papers, No 84, Bank for International Settlements, Basel, June.

"Correspondent banking trends and developments in 2019", MIP News, European Central Bank, Frankfurt am Main, 6 November 2020.

Decision of the European Central Bank of 29 July 2010 on access to and use of certain TARGET2 data (ECB/2010/9) (2010/451/EU) (OJ L 211 12.8.2010, p. 45).

Decision (EU) 2017/2080 of the European Central Bank of 22 September 2017 amending Decision ECB/2010/9 on access to and use of certain TARGET2 data (ECB/2017/29) (OJ L 295, 14.11.2017, p. 86).

Diehl, M. and Müller, A. (2014), "Analysis of the use and impacts of limits", Journal of Financial Market Infrastructures, Volume 3, Issue 1, September, pp. 33–60.

Duca-Radu, I. and Polo Friz, L. (2020), "Liquidity distribution and payments in TARGET2", Economic Bulletin, Issue 5, European Central Bank, Frankfurt am Main, August.

Duca-Radu, I. and Testi, S. (2021), "Liquidity usage in TARGET2", Economic Bulletin, Issue 3, European Central Bank, May.

"ECB takes steps to ensure pan-European reach of instant payments", MIP News, European Centra Bank, Frankfurt am Main, 24 July 2020.

Garratt, R., Antoine, M. and McAndrews, J. (2014), "Turnover in Fedwire Funds Has Dropped Considerably since the Crisis, but it's Okay", Liberty Street Economics, Federal Reserve Bank of New York, New York, 25 August.

Glowka, M. (2019), "Profiling banks: how to use cluster analysis with payment system data", The Journal of Financial Market Infrastructures, Vol. 8, No 2, December, pp. 21-45.

Glowka, M., Paulick, J. and Schultze, I. (2018), "The absence of evidence and the evidence of absence: an algorithmic approach for identifying operational outages in TARGET2", Journal of Financial Market Infrastructures, Volume 6, No 2/3, September, pp. 63-91.

Group on TARGET2 Stress Testing of the Market Infrastructure Board, Market Infrastructure and Payments Committee (2017), "Stress-Testing of liquidity risk in TARGET2", Occasional Paper Series, No 183, European Central Bank, Frankfurt am Main, February.

Holthausen, C. and Rochet, J. (2005), "Incorporating a "public good factor" into the pricing of large-value payment systems", ECB Working Paper Series, No 507, European Central Bank, Frankfurt am Main, July.

Information Guide for TARGET2 users, Version 15.1, European Central Bank, Frankfurt am Main, March 2022.

Kaliontzoglou, A. and Müller, A. (2016), "Implementation aspects of indicators related to payments timing", in Diehl, M., Alexandrova-Kabadjova, B., Heuver, R. and Martínez-Jaramillo S. (Eds.), Analyzing the Economics of Financial Market Infrastructures, Hershey, PA: Business Science Reference, pp. 169–190.

Mastropasqua, C., Intonti, A., Jennings, M., Mandolini, C., Maniero, M., Vespucci, S. and Toma, D. (2021), "T2S-TARGET2-Securities. The pan-European platform for the settlement of securities in central bank money", Markets, Infrastructures, Payment Systems series, Vol. 4, Banca d'Italia, Rome, September.

Müller, A. and Diehl, M. (2014), "Analysis of the use and impact of limits", Journal of Financial Market Infrastructures, Vol. 3, No 1, September, pp. 33-60.

Müller, A., Papsdorf, P. and Polo Friz, L. (2017), "Critical Participants in TARGET2", 15th Payment and Settlement System Simulation Seminar, Helsinki, 1 September.

Regulation of the European Central Bank (EU) No 795/2014 of 3 July 2014 on oversight requirements for systemically important payment systems (ECB/2014/28) (OJ L 217, 23.7.2014, p. 16).

Regulation (EU) 2017/2094 of the European Central Bank of 3 November 2017 amending Regulation (EU) No 795/2014 on oversight requirements for systemically important payment systems (ECB/2017/32) (OJ L 299, 16.11.2017, p. 11).

TARGET2 Annual Report 2013, European Central Bank, Frankfurt am Main, May 2014.

T2-T2S consolidation: what is it?, European Central Bank, Frankfurt am Main.

Glossary

Term	Explanation
Algorithm	An algorithm is a mathematical method used to ensure smooth, fast and liquidity-saving resolution of the payment queue, for example by taking offsetting payment flows into account.
Ancillary system (AS)	An organisation providing clearing, payment or settlement services that is established in the EEA and is subject to supervision and/or oversight by a competent authority and must comply with the oversight requirements of the location of the infrastructures offering services in euro, as amended from time to time and published on the ECB's website, in which payments or financial instruments are exchanged and/or cleared, while the resulting monetary obligations are settled in TARGET2 in accordance with the Guideline on TARGET2 and a bilateral arrangement between that organisation and the relevant Eurosystem central bank. ASs may be: retail payment systems (RPSs), large-value payment systems (LVPSs), foreign exchange (FX) systems, money market systems (MMSs), clearing houses, securities settlement systems (SSSs).
Central counterparty (CCP)	An entity that interposes itself between the counterparties to contracts traded in one or more financial markets, becoming the buyer to every seller and the seller to every buyer.
Central securities depository (CSD)	A CSD is an organisation holding securities either in certificated or uncertificated form, to enable the book-entry transfer of securities. In addition to safekeeping and administration of securities, a CSD may also provide clearing and settlement and assets servicing functions.
Credit line	Maximum collateralised overdraft position of the balance on a payment module (PM) account. The PM account holder can obtain information about changes in the credit line through the information and control module (ICM). Changes in credit lines will be executed immediately. In the event of a reduction in a credit line, the change is given "pending" status if the reduction would lead to an uncovered overdraft position. The change will be executed when the overdraft position is covered by the reduced credit line.
Continuous Linked Settlement (CLS)	CLS is a global settlement system for foreign exchange transactions that provides participants with simultaneous processing of both sides of the transaction, thereby eliminating settlement risk.
Dedicated transit account	A cash account in the RTGS system and in T2S that is held and used by the system operator concerned to transfer funds between the two. The transit account opened within T2S is referred as the RTGS dedicated transit account and the transit account opened within the RTGS system is referred as the T2S dedicated transit account.
Intraday credit	Credit extended and to be reimbursed within a period of less than one business day; in a credit transfer system with end-of-day final settlement, intraday credit is tacitly extended by a receiving institution if it accepts and acts on a payment order even though it will not receive the final funds until the end of the business day. The credit may take the form of a collateralised overdraft or of a lending operation against collateral pledge or established under a repurchase agreement.
Intraday liquidity	Funds that may be accessed during the business day, usually to enable financial institutions to make payments on an intraday basis.
Principles for Financial Market Infrastructures (PFMI)	International standards for financial market infrastructures (FMIs) issued by the Committee on Payments and Market Infrastructures (CPMI) and the International Organization of Securities Commissions (IOSCO).
Queuing	An arrangement whereby transfer orders are kept pending by the sending direct participant or by the system until they can be processed in accordance with the rules of the system.
Real-time gross settlement (RTGS) system	A settlement system in which processing and settlement take place in real time on a gross basis. An RTGS system may provide centralised queues for orders which cannot be settled at the time of submission due to insufficient funds or quantitative limits on the funds.
SWIFT	Society for Worldwide Interbank Financial Telecommunication. A cooperative organisation, created and owned by banks, operating a network designed to facilitate the exchange of payment and other financial messages between financial institutions (including broker-dealers and securities companies) throughout the world. A SWIFT payment message is an instruction to transfer funds; the exchange of funds (settlement) subsequently takes place through a payment system or through correspondent banking relationships.
TARGET2-Securities (T2S)	The set of hardware, software and other technical infrastructure components through which the Eurosystem provides services for central securities depositories (CSDs) and central banks that make it possible to conduct core, neutral and borderless settlement of securities transactions on a delivery versus payment (DvP) basis in central bank money.
TARGET Instant Payment Settlement (TIPS) service	The settlement in central bank money of instant payment orders on the TIPS platform.
Technical account	An account used for ancillary system (AS) operations as an intermediary account for the collection of debits/credits resulting from the settlement of balances or delivery versus payment (DvP) operations. The balance of this account is always zero because debits (or credits, as the case may be) are always followed by offsetting credits (or debits, as the case may be) of an overall equal amount.

Acknowledgements
We would like to thank Eirini Katsalirou and Ulrich Bindseil for their helpful comments and suggestions, and Ioana Duca-Radu for the valuable contributions she provided. We are also grateful to Luca Melzi for his excellent research assistance.
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PDF ISBN 978-92-899-5241-5, ISSN 1725-6534, doi:10.2866/011817, QB-AQ-22-043-EN-N