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Abstract

We exploit banks' early repayments of targeted longer-term refinancing operations (TLTRO) following the program's recalibration in October 2022 as a laboratory to uncover demand drivers of central bank liquidity. We formulate and estimate a discrete-time hazard model to early exit from TLTRO to identify what bank (country) characteristics drive a sticky, prolonged demand for central bank (long-term) operations as opposed to an early exit from such facilities. We also examine whether the more liquidity-risk exposed banks during the TLTRO phasing out period had a higher probability of becoming "liquidity dependent" on the ECB when exiting (Acharya et al., 2023). Finally, we discuss the policy implications of our findings, particularly in the context of the recent review of the ECB's operational framework.

Keywords: monetary policy normalisation, TLTRO, demand-driven operational frameworks, discrete-time hazard models.

JEL classification: E52, E58, G21, C41.

Resumen

En este documento se utilizan las amortizaciones anticipadas de las operaciones de financiación a plazo más largo con objetivo específico (TLTRO) que realizaron los bancos tras la recalibración de las condiciones de las TLTRO en octubre de 2022, para descubrir los factores que impulsan la demanda de liquidez del banco central. Se formula y estima un modelo de riesgos en tiempo discreto para la salida anticipada de las TLTRO, con el fin de identificar qué características de los bancos (país) impulsan una demanda persistente y prolongada de operaciones (a largo plazo) del banco central, en contraposición a una desvinculación temprana de dichas facilidades. Asimismo, se examina si los bancos con mayor exposición al riesgo de liquidez durante el período de retirada gradual de las TLTRO tenían mayor probabilidad de volverse dependientes de la liquidez del BCE en el momento de su salida. Finalmente, se analizan las implicaciones políticas derivadas de los hallazgos, particularmente en el contexto de la reciente revisión del marco operativo de la política monetaria del BCE.

Palabras clave: normalización política monetaria, TLTRO, marcos operativos basados en la demanda, modelos de riesgo en tiempo discreto.

Códigos JEL: E52, E58, G21, C41.

1 Introduction

As central banks unwind their balance sheets, determining the optimal operational framework for supplying central bank reserves and establishing their appropriate steady-state level has become one of their crucial tasks. Central banks like the ECB or the Bank of England have recently opted to transition from a system with surplus reserves to a demand-driven framework to steer interest rates,[1] that is, a framework in which the future steady-state size of the balance sheet will be determined by banks' demand for reserves. Given the high uncertainty of banks' aggregate demand for reserves over time, policy makers have placed refinancing (lending or repo) operations at the center of central bank liquidity provision under demand-driven frameworks, since they are considered the best placed to meet banks' evolving demand for reserves. (Schnabel, 2024; Saporta, 2024). They also recognised that demand-driven systems cannot fully rely on short-term lending operations to satisfy banks' reserve demand and they need to be complemented by longer-term refinancing operations. (Schnabel, 2024; Saporta, 2024).

In this context, one key question that emerges is what drives demand for participation in (long-term) refinancing operations at the bank level. How to leverage on central banks' recent experience over the transitioning (balance sheet unwinding) period to unveil what shapes demand and draw lessons for the steady-state operational frameworks? To answer this question, we exploit the recalibration of the ECB's third series of targeted longer-term refinancing operations (TLTRO) as a laboratory to uncover drivers of (long-term) central bank liquidity. Together with the ECB's asset purchase programs, TLTRO has been a major source of reserve supply for euro area banks, especially since the outbreak of the COVID-19 pandemic, reaching its peak at the end of 2021 with a total of EUR 2.2 trillion in supplied reserves.

On 27 October 2022, the ECB announced the recalibration of TLTRO, consisting of a tightening of the program's conditions, with the aim to increase the speed of the monetary policy normalisation process. The recalibration led a large part of euro area banks to accelerate their exit from TLTRO via sizable early repayments amounting to over EUR 1 trillion. Some TLTRO participating banks, however, chose to retain TLTRO funds until maturity. Although the design features of TLTRO had a particular purpose of mone-

[1] The Bank of England (BoE) has officially operated in a reserve demand-driven floor system since August 2022 while the ECB announced the changes to its operational framework in March 2024.

tary policy easing, which is not foreseen in (long-term) operations under demand-driven operational frameworks, the TLTRO recalibration offers an ideal laboratory to exploit banks' early exit behavior and understand what shapes banks' sticky, prolonged demand for long-term refinancing operations as opposed to an early exit from such facilities.[2]

To examine the factors influencing banks' accelerated exits from TLTRO, or alternatively their delayed exit decisions, we apply a *time-to-exit* or *survival analysis*, accounting for both the occurrence and timing of these exit decisions. Building on the works of Allison (1982) and Singer and Willett (1993), we formulate and estimate a discrete-time hazard model for TLTRO early exit. We then explore what bank and country characteristics influence banks' time-to-early-exit. Our findings, which shed light on the broader demand drivers for (long-term) refinancing operations, contribute in four key ways.

First, we provide evidence that design features such as maturity, pricing and type of collateral securing the lending operation influence banks' hazard to early exit and consequently emerge as key demand drivers for (long-term) liquidity via refinancing operations. With respect to maturity, our findings present evidence supporting an *NSFR value* for longer-term refinancing operations with maturity exceeding six months.

Second, turning to balance sheet characteristics, we find that a bank's supervisory significance, balance sheet capacity (stemming from the leverage ratio requirement), as well as its minimum reserves requirements also play a significant role in shaping their demand for central bank liquidity. We document that a bank's share of excess reserves or stable funding sources does not significantly explain banks' early exit decisions. In turn, when recognising the influence of claims on liquidity encumbered on reserves, such as deposits and credit lines (Lopez-Salido and Vissing-Jorgensen, 2023; Acharya and Rajan, 2024; Acharya et al., 2023), or the influence of long-term lending positions which require stable funding, both "available" excess reserves and "required" stable sources of funding emerge as key demand drivers for (long-term) refinancing operations.

Third, building on these findings and recognizing the dual function of targeted longer-term refinancing operations as both a source of central bank reserves and stable funding, we consolidate all relevant (on- and off-) balance sheet items into comprehensive indicators of bank liquidity needs. Drawing on the liquidity creation framework outlined by Berger

[2]Although TLTRO are targeted lending operations (where borrowing amounts and interest rates depend on the lending performance of participating banks) during the period under analysis, banks' lending conditions no longer influenced TLTRO terms. This lets us disregard the targeted aspect of TLTRO and instead speak for demand drivers of (long-term) refinancing operations more broadly.

and Bouwman (2009) and the composite liquidity risk exposure measure introduced by Acharya et al. (2023), we propose three liquidity position indicators. These indicators provide a holistic view of bank liquidity and distinguish between banks' short- and long-term liquidity requirements. Our results position these bank liquidity position measures as among the most influential demand drivers of (prolonged) central bank liquidity in terms of magnitude. Furthermore, by highlighting their regulatory interpretability, our findings point to a strong connection between the demand for (long-term) central bank funding and the fulfillment of regulatory liquidity ratios.

Finally, motivated by Acharya et al. (2023), we show that more liquidity-risk exposed banks during the TLTRO phasing-out period, based our bank liquidity measures, had a higher probability to become "liquidity (funding) dependent" on the ECB when exiting, by participating in standard refinancing operations. This effect is stronger the later the exit occurred. Since the phenomenon of "liquidity dependence", that is, increasing reliance on central bank liquidity as central banks reduce their balance sheets, is, in some sense, an intrinsic feature of demand-driven operational frameworks and considering that participation in standard refinancing operations was limited after the phase-out of TLTRO,[3] our motivation to test this hypothesis is to evaluate whether our liquidity position (risk) measures can serve as indicators of when reserves/stable funding scarcity emerge at the bank level. Our findings offer supporting evidence that these measures can effectively signal such bank level scarcity points.

Related literature. Our paper contributes to different strands of the literature. First, it contributes to the existing work on demand drivers of central bank liquidity. Our study analyses banks' participating behaviour in central bank facilities in the euro area, including (targeted) longer-term refinancing operations (Drechsler et al., 2016; Vergote and Sugo, 2020; Fudulache and Goetz, 2023). In contrast to these studies that focus on drivers of participation, we use the experiment of a monetary policy normalisation shock to explore the drivers of banks' exiting choices and timing from such facilities. Our study is also close to Lopez-Salido and Vissing-Jorgensen (2023), who emphasise three drivers for banks' demand for reserves in the US, namely the spread between market rates and interest rates on reserves, banks' liquidity needs, and bank balance sheet costs. Moreover, our paper relates to the existing literature emphasizing the role of liquidity regulatory

[3]See for example Hudepohl and Malderez (2024).

requirements on bank demands for central bank reserves/monetary policy operations (Kedan and Ventula Veghazy, 2021; Rezende et al., 2021).

Second, by exploiting an episode of large Eurosystem balance sheet reduction, our study adds to the growing literature on monetary policy normalization via banks. While the addressed balance sheet policies differ, our framework for conceptualizing the demand drivers of central bank reserves has parallels to that of Acharya and Rajan (2024) and Acharya et al. (2023) particularly regarding the mechanics of central bank balance sheet expansion and contraction through banks' balance sheets. Moreover, similar to Acharya et al. (2023) our findings suggest that banks exposed to liquidity risk during the TLTRO phasing out period had a higher probability to become dependent on Eurosystem liquidity when exiting. In the euro area context, our study relates to Burlon et al. (2025) who also exploit the 2022 TLTRO recalibration from a monetary policy transmission perspective. They argue that an accelerated withdrawal of central bank liquidity can have tightening effects on bank credit and economic outcomes. While we exploit the TLTRO recalibration outside a monetary policy transmission context, our approach has the advantage of characterising Eurosystem balance sheet reduction pace via banks and to uncover bank-specific factors that shape the strength and speed of the transmission of balance sheet policies.

Third, our study is linked to literature on measuring bank liquidity. Our paper draws upon the liquidity creation literature (Berger and Bouwman, 2009) to develop liquidity position (risk) indicators in a euro area context. To our knowledge, this is the first paper that replicates the Berger and Bouwman (2009) bank-level measure of liquidity creation for a comprehensive sample of euro area banks.[4] By applying this framework jointly with TLTRO we underpin the inverse liquidity creation (maturity transformation) role of targeted longer-term refinancing operations and thus the liquidity intermediation capacity of the Eurosystem balance sheet via long-term refinancing operations. We also tie our bank liquidity measures with the ones employed by Acharya et al. (2023) and argue that they could be used as relevant proxies for regulatory ratios.[5]

Fourth, our analysis contributes to the literature on TLTRO and bank behaviour and the effectiveness of TLTRO from a monetary policy perspective (Andreeva and García-

[4]Bonfim and Kim (2019) proxies liquidity creation for European and North American banks based on commercial data from Bankscope.

[5]See also Hoerova et al. (2018) and Bonfim and Kim (2019) who provide proxies for the Liquidity coverage ratio (LCR) and Net stable funding ratio (NSFR).

Posada, 2021; Da Silva et al., 2021; Altavilla et al., 2023a; Fudulache and Goetz, 2023; Barbiero et al., 2024). Our study also provides evidence for the effectiveness of the TLTRO recalibartion in terms of accelerated balance sheet reduction. More generally, by uncovering the factors that shape the ease of exit from TLTROs, our findings contribute to a better understanding of this monetary policy instrument.

Finally, from an empirical design perspective, our paper is related to studies applying survival (duration or time-to-event) analyses in empirical banking (Steven and Smith, 2001; Bonfim and Soares, 2018). We apply a survival analysis in discrete-time buiding on Allison (1982); Singer and Willett (1993). To our knowledge, our study is the first one formulating a discrete-time hazard model in a monetary policy implementation context.

The paper is organised as follows. Section 2 describes the institutional setting. Section 3 introduces the discrete-time hazard model for examining the time-to-exit TLTRO and the used data sources. Section 4 presents the main results in terms of the drivers and mitigants of banks' early exit choices. It also discusses their robustness. Section 5 examines the liquidity dependence hypothesis in the spirit of Acharya et al. (2023) for TLTRO banks. Section 6 draws policy implications and concludes.

2 Institutional setting

2.1 Tightening of TLTRO conditions

Following the high and unexpected rise in inflation that started in 2021, the ECB embarked in December 2021 on a path of monetary policy normalisation. In July 2022, the ECB had already discontinued net asset purchases under its purchase programs and started the most rapid increase of interest rates in the history of the euro area. By October 2022, the ECB had already increased key policy rates by a cumulative 125 basis points.

However, the terms and conditions of the third series of targeted longer-term refinancing operations (TLTRO) that prevailed at that time were not in line with the intended path of normalisation of monetary policy. After the end of the program's accommodative, pandemic-related conditions[6] on 23 June 2022, the interest rate on each TLTRO opera-

[6] To recall, TLTRO was a key tool of monetary policy accommodation during the COVID-19 pandemic. For details on program's recalibration as a response to the pandemic crisis and its impact on bank lending conditions, see Barbiero et al. (2021).

tion was indexed to the average applicable key ECB interest rate over the *lifetime* of the respective operation. In the context of the hiking cycle that started mid 2022, this pricing scheme had two main consequences. First, owing to the negative interest rates preceding the hiking cycle, TLTRO rates were only gradually adjusting with interest rate hikes and bank funding conditions were thus not normalising as quickly as intended. Second, the difference between excess reserves' remuneration at the (rapidly increasing) deposit facility rate and the (slowly adjusting) TLTRO borrowing rate gave rise to financial benefits for those banks which chose to keep their TLTRO borrowings as central bank reserves. Both results discouraged banks from engaging in early repayments.

As a consequence, on 27 October 2022 the ECB announced the recalibration of the TLTRO terms and conditions[7] with the aim of (i) tightening bank funding conditions via an increase in the TLTRO cost of funding and (ii) accelerating the pace of Eurosystem balance sheet normalisation by incentivizing banks to early repay. Specifically, the ECB linked the interest rate on each TLTRO operation to the average applicable policy rate over the *remaining term* of the operation, *i.e.* from recalibration until the earlier of final maturity or early repayment date. The change was implemented on 23 November 2022 and applied to the all (nine out of ten) outstanding operations. To provide more exit options to participating banks, the recalibration was accompanied by the introduction of three additional early repayment windows, one in November 2022 (the date of implementation of the recalibration) and two others in January and February 2023.[8].

Assuming that key ECB policy rates developed in line with the median expectations of the Monetary Analysts at the time of the announcement,[9] the recalibration implied an average expected increase of 1.8 percentage points in applicable TLTRO rates post-recalibration, generating an expected average increase of 38 basis points in final TLTRO rates.[10] Appendix A includes more details on the impact of the recalibration on the calculation of TLTRO rates.

This TLTRO recalibration represents an ideal laboratory for studying the main drivers behind bank demand for long-term central bank liquidity. While the recalibration triggered large early repayments, amounting to over EUR 1 trillion over the period November

[7]See the ECB Press Release of 27 October 2022.

[8]These complemented the already existing early repayment dates at quarterly frequency.

[9]See The ECB Survey of Monetary Analysts, October 2022, Aggregated Results.

[10]These averages are computed at bank level across nine remaining operations and only for participating banks in our final sample. More details on sample construction are provided in Section 3.2

2022 to December 2023, not all banks chose to exit earlier from the program and thus did not contribute to the intended accelerated path of normalisation. We further illustrate this in the following subsection.

2.2 Accelerated Eurosystem balance sheet reduction via TLTRO banks

To illustrate how the recalibration affected banks' exit pace from TLTRO, and thus Eurosystem balance sheet reduction pace via TLTRO, we define three bank-level TLTRO exit events:

Hold-to-maturity (HTM) exit. The first event is a hypothetical baseline in the absence of recalibration. It is built under the assumption that all banks would have held TLTRO positions until maturity due to continued advantageous conditions. We define an HTM exit event when at least half of a bank's TLTRO position has matured.

Realised exit. This event captures an actual realised exit from TLTRO based on both early and final maturity repayments. A realised exit event occurs at the bank level when a bank reduces its outstanding TLTRO exposure before the recalibration by more than half. Formally, a bank experiences a realised exit event when its cumulative TLTRO repayment rate measured since September 2022 (before the change in conditions) reaches more than 50%.

Early (voluntary) exit. This is our event of interest throughout the paper. It captures a voluntary and accelerated exit from TLTRO, predominantly through early repayments as a dominant strategy, rather than retaining funds until maturity. Specifically, an early exit event occurs when a bank prepays more than half of its TLTRO exposure measured before the change in conditions. Formally, a bank experiences an early voluntary exit event when its cumulative TLTRO early repayment rate measured since September 2022 reaches more than 50%.

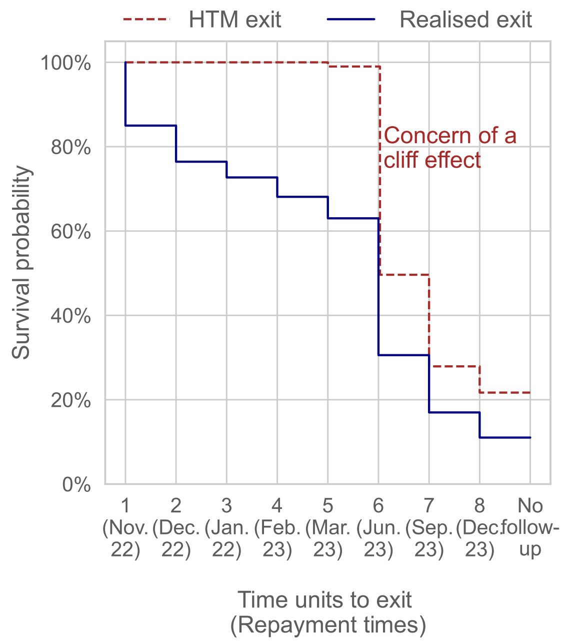
We visually inspect how the survival probability of these three exit events evolved over time. A survival probability is defined as the probability that the exit event of interest has not yet occurred by a certain repayment time. **Figure 1** shows Kaplan-Meier survival estimates (Kaplan and Meier, 1959) for the three exit events between recalibration and end-December 2023.[11]

[11] These estimates are also reported in Table C1 of Appendix C in the form of life tables, where more

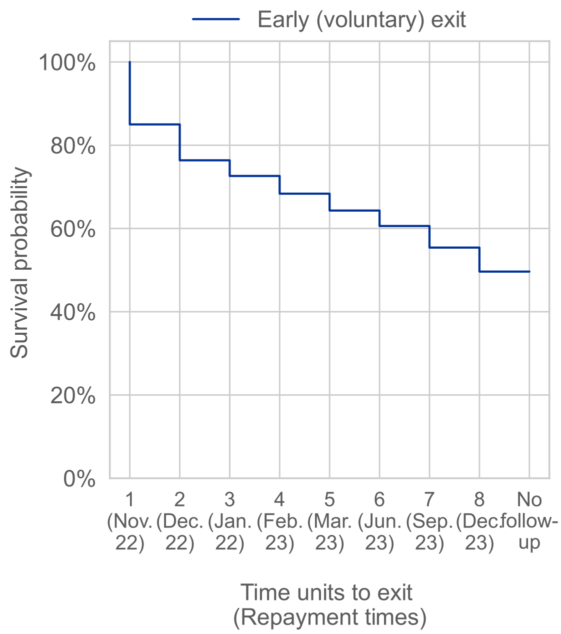
Figure 1: Kaplan-Meier suvival estimates of TLTRO exit events.

This figure illustrates the Kaplan-Meier survival probability estimates of the three TLTRO exit events. More details on their derivation are provided in Table C1 of Appendix C.

(a) HTM and Realised exit events.



(b) Early (voluntary) exit event.



Panel 1a depicts the probability of not exiting TLTRO past a certain time according to the first two event definitions, with a red dashed line and solid blue line, respectively. Two takeaways emerge. First, in the absence of early repayments, there would have been a high concentration of banks exiting the program in June 2023. This could have generated a cliff effect in money and funding markets. Second, the real situation depicts a more accelerated bank exit from TLTRO, pointing to an overall effectiveness of the policy change, with many banks responding to the change in conditions and choosing to exit before final maturity.

In Panel 1b we take a closer look at accelerated bank exits by zooming into the TLTRO early exit event. The plotted survival function represents the probability of not exiting early past a certain time. By the end of the follow-up period more than half of banks did not experience an early exit event and thus "survived" the recalibration. With this in mind, our main question becomes why certain banks experienced a longer reliance on central bank liquidity as opposed to an accelerated exit from the long-term facilities.

details on their derivation are included.

3 Time-to-exit TLTRO: Methodology and data

3.1 A discrete-time hazard model for TLTRO early exit

To examine what drives the banks' accelerated exit from TLTRO, we employ a *time-to-event analysis*, also known as *survival analysis* or *duration analysis*, where the event of interest is the *Early (voluntary) exit* defined in the previous section.

Since the Kaplan-Meier method does not allow for covariate-adjusted survival probability estimation, we formulate and estimate a regression model in which the occurrence of the early exit event depends on time and explanatory variables. Specifically, we employ a discrete-time extension of the Cox proportional hazards model (Cox, 1972), where time is measured in discrete intervals $t = 1, 2, ..., 8$, corresponding to the early repayment windows available after TLTRO recalibration: November 2022, December 2022, January 2023, February 2023, March 2023, June 2023, September 2023, and December 2023. This approach models the *hazard probability*, namely the probability that a bank experiences the early exit event at a given time, conditional on not having exited earlier. Formally, the hazard probability (or hazard function) is defined as:

$$h_{i,t} = \Pr\left(T_i = t \mid T_i \geq t, X_{i,t}\right) \tag{1}$$

where T_i is the time of early exit for bank i, and $X_{i,t}$ is a vector of explanatory variables.[12]

Model formulation. The Cox proportional hazard rate model can be generalized in discrete time as follows:

$$\frac{h_{i,t}}{1 - h_{i,t}} = \frac{h_{0,t}}{1 - h_{0,t}} \cdot e^{\beta' \cdot X_{i},t} \tag{2}$$

where $\frac{h_{i,t}}{1-h_{i,t}}$ represents the odds of early exit at time t of bank i, $h_{0,t}$ is the *baseline hazard* of early exit at time t, $\frac{h_{0,t}}{1-h_{0,t}}$ is the *baseline odds* of early exit, and β is a vector of parameters capturing the relative risk associated with the covariates of interest. Taking

[12] In this setting, the *survival probability* (or the survivor function), that is, the probability that the bank remains in TLTRO beyond time t, is not directly modeled but is derived as: $\mathrm{S}_{i,t} = \Pr\left(T_i > t \mid X_{i,t}\right) = \prod_{j=1}^{t}(1 - h_{i,j})$.

logarithms, we obtain a logistic dependence of the hazard on time and covariates:

$$\log\left(\frac{h_{i,t}}{1-h_{i,t}}\right) = f(t) + \beta' \cdot X_i, t \tag{3}$$

where $f(t)$ is the logit transformation of the baseline hazard or the *baseline logit-hazard*. We do not impose a parametric form on $f(t)$ and instead model it using time dummies, $f(t) = \alpha_t$, resulting in:

$$\log\left(\frac{h_{i,t}}{1-h_{i,t}}\right) = \alpha_t + \beta' \cdot X_i, t \text{ ; where} \tag{4}$$

$$\alpha_t = \log\left(\frac{h_{0,t}}{1-h_{0,t}}\right). \tag{5}$$

Proportionaity assumption. In our setting, exponentiated β parameters represent the shift parameters of the baseline odds of early exit associated with the covariates of interest. This implies that the odds profiles corresponding to different values of a covariate are amplifications or reductions of one another, *i.e.* they are proportional. For small hazard probabilities, which is the case in this setting, this closely approximates the proportional hazards assumption of the continuous-time Cox model.

Model estimation. For each bank, we construct a panel tracking the early exit event and the covariate values at each t until either the early exit occurs or the observation is censored. In our setting, censoring can occur for two reasons: (i) the bank exits TLTRO via the hold-to-maturity competing strategy, or (ii) the bank remains in the program until December 2023 without exiting voluntarily. We refer to this panel of all exit time-bank observations as the *survival dataset*. The *risk set* at time t includes all banks still at risk of early exit, *i.e.*, those that have not exited and are not censored prior to t.

The discrete-time hazard model is fitted by applying standard logistic regression on the survival dataset to regress the early exit event variable on (i) a set of dummy variables for the the exit (repayment) times and (ii) the set of explanatory variables included in $X_{i,t}$, using the method of maximum likelihood. Appendix B provides a detalied explanation of the discrete-time extension of the Cox model and its estimation.

Model specifications. We employ several model specifications leveraging on the rich set of explanatory variables included in $X_{i,t}$. Specifically, $X_{i,t}$ is comprised of a set of time-varying country characteristics $Y_{c(i),t}$ and a set of (time-varying) bank characteristics $Z_{i,t}$.

The set of country characteristics capture differences in credit demand and financial stress. The set of bank characteristics capture: (i) differences in TLTRO funds characteristics at the bank level (maturity profile, change in pricing following TLTRO recalibration, and collateral mobilisation); (ii) differences in bank balance sheets (banks' supervisory significance, leverage ratio, and availability of central bank reserves and stable funding), or alternatively, (iii) differences in bank liquidity positions in our preferred specifications. These variables are either constant, measured before the recalibration and labeled with (t_0) or time-varying, measured either contemporaneously or with a one month lag and labeled with (t) or ($t-1$) respectively.[13]

All specifications include country dummy variables to account for country heterogeneity. Following Fudulache and Goetz (2023), to account for heterogeneity in banks' credit worthiness, and indirectly their financing conditions, we also include three credit quality dummy variables constructed based on credit ratings of banks' long-term senior unsecured debt.[14] Results are reported on the log-odds scale with robust standard errors.[15]

3.2 Data sources and summary statistics

We combine data from several confidential and publicly available sources and databases managed by the Eurosystem. All our data are collected at monthly frequency over the period between September 2022 and December 2023, unless otherwise stated. After merging all data sources we obtain a sample of 820 euro-area TLTRO participating banks. Table 1 presents descriptive statistics of all the variables used in the time-to-exit analysis. More details on variable definitions and construction are provided in the following subection.

Proprietary confidential bank-level data governed by the Eurosystem's Market Operations Committee. . We source TLTRO take-up and early repayments data at bank/group and operation level from the Tender Operations platform (TOP) to calculate TLTRO outstanding amounts, either in full or broken down by residual maturities. This data is also used to formulate the three exit events described in Section 2.2. For bank entities that participated in groups we source information on group composition

[13]For simplicity, lagged variables are labeled with "$t-1$" instead of "$t-1$ month".

[14]Our four credit quality bins are based on the Eurosystem's credit assessment framework and are: (i) Credit quality step (CQS) 1 or 2, (ii) CQS3, (iii) Below CQS3 or non-rated.

[15]Our results do not change when we use non-robust standard errors or when we cluster them at the bank-level. Even though banks contribute multiple observations to the survival dataset, no correction for dependency among the observations of the same bank is necessary Allison (2014).

Table 1. Data Sources and Summary Statistics

This table presents the sources and descriptive statistics of the variables used in the time-to-exit TLTRO analysis and in panel regressions estimating the probability to turn to standard refinancing operations. More details on the variables construction are provided in Sections 4 and 5. Due to confidentiality reasons, Min and Max values of variables sourced from TOP (other than binary) are not shown.

Variable	Source	N	Mean	St.Dev.	Min	p25	Median	p75	Max
Panel A: Country-level variables (survival dataset)									
Firms credit demand (Diffusion index)	SDW	3,953	-6.42	9.46	-50.00	-12.90	-1.61	0.00	37.50
Country-level indicator of financial stress (CLIFS)	SDW	3,945	0.20	0.08	0.03	0.14	0.20	0.21	0.48
Panel B: Bank-level variables (survival dataset)									
TLTRO cum. repayment rate	TOP	3,953	0.22	0.28		0.00	0.10	0.40	
TLTRO cum. early repayment rate	TOP	3,953	0.18	0.25		0.00	0.00	0.33	
TLTRO early exit	TOP 0.00	3,953	0.09	0.28	0.00	0.00	0.00	0.00	1.00
TLTRO (HTM) / Total assets	TOP, iBSI	3,953	0.06	0.05		0.03	0.05	0.09	
TLTRO WAM (years)	TOP	3,953	1.17	0.39		0.85	1.10	1.35	
TLTRO HTM <6m / Total assets	TOP, iBSI	3,953	0.02	0.03		0.00	0.01	0.03	
TLTRO HTM 6m-1y / Total assets	TOP, iBSI	3,953	0.02	0.03		0.00	0.01	0.03	
TLTRO HTM >1y / Total assets	TOP, iBSI	3,953	0.02	0.03		0.00	0.01	0.02	
Δ TLTRO final rate HTM	TOP, SMA	3,953	0.42	0.09		0.37	0.42	0.48	
Govies-like collateral / TLTRO	C2D, TOP	3,953	0.24	0.40		0.00	0.04	0.31	
SSM significance	RIAD	3,953	0.15	0.36	0.00	0.00	0.00	0.00	1.00
Capital (leverage) ratio	iBSI, AC	3,953	0.10	0.03	0.00	0.08	0.10	0.11	0.34
Minimum reserves / Total Assets	LM, iBSI	3,953	0.00	0.00	0.00	0.00	0.01	0.01	0.05
Excess reserves / Total Assets	LM, iBSI	3,953	0.06	0.08	-0.01	0.01	0.04	0.08	0.71
Demandable (wholesale) deposits / Total Assets	iBSI	3,953	0.31	0.14	0.01	0.23	0.30	0.38	0.90
Unused loan commitments / Total Assets	AC, iBSI	3,953	0.05	0.06	0.00	0.02	0.04	0.07	1.68
Stable (retail) deposits / Total assets	iBSI	3,953	0.48	0.16	0.00	0.42	0.51	0.58	0.89
Bonds issued >1Y / Total assets	iBSI	3,953	0.03	0.07	0.00	0.00	0.00	0.01	0.77
Mortgage loans / Total assets	iBSI	3,953	0.27	0.16	0.00	0.15	0.30	0.39	0.75
NFC loans/Total assets	iBSI	3,953	0.19	0.10	0.00	0.13	0.18	0.24	0.75
Liquid assets ratio (LCR-like)	iBSI, LM, C2D, AC	3,953	0.40	0.59	-0.02	0.11	0.20	0.44	12.27
Stable funding ratio (NSFR-like)	iBSI, TOP	3,953	1.10	0.60		0.80	0.98	1.27	
Inverse liquidity creation ratio	iBSI, LM, C2D, AC, TOP	3,953	0.80	0.46		0.54	0.68	0.92	
Panel C: Bank-level variables (monthly panel dataset. Nov 2022-Dec 2023)									
SRO participation	TOP	11,180	0.04	0.20	0.00	0.00	0.00	0.00	1.00
MRO participation	TOP	11,180	0.01	0.11	0.00	0.00	0.00	0.00	1.00
LTRO3m participation	TOP	11,180	0.05	0.22	0.00	0.00	0.00	0.00	1.00
Time-to-exit (% Time-to-HTM exit)	TOP	11,180	0.76		0.11	0.50	1.00	1.00	

from submitted templates as part of banks' reporting obligations prior to participation. We also obtain from TOP outstanding amounts in other credit operations[16], broken down by residual maturity, which we further use when building liquidity position indicators.[17] We source from the Counterparty and Collateral database (C2D) data on outstanding amounts of government and other public sector bonds used to collateralize TLTRO borrowings. We further use the Liquidity Management platform (LM) to obtain data on bank minimum required and excess reserves held in their current accounts with the Eurosystem or at the deposit facility. Finally, we obtain quarterly data on the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) for the subsample of Spanish TLTRO participants from a regular supervisory data submission to the Eurosystem for monetary policy implementation purposes.

Other confidential bank-level sources. We additionally have access to bank balance sheet data from the ECB's individual Balance Sheet Items (iBSI). With this data we construct the majority of employed bank-specific explanatory variables. We complement this data with information on unused loan commitments sourced from Eurosystem's credit register AnaCredit (AC), which we aggregate at bank-level. For banks participating as groups in TLTROs individual participant bank-level data is aggregated.Additionally, information on bank's significance under the Single Supervisory Mechanism (SSM) is obtained from the Register of Institution and Affiliates Database (RIAD). To construct credit quality dummy variables we use information from the Centralised Securities Database (CSDB) on bank credit ratings for long-term senior unsecured debt provided by the four credit rating agencies eligible for monetary policy purposes at the date of analysis.

Publicly available data. Finally, we collect publicly available data from the ECB's Statistical Data Warehouse (SDW): (i) quarterly country-level credit demand indicators derived from the euro area Bank Lending Survey; (ii) quarterly Country-level Index of Financial Stress (CLIFS); and (iii) daily data on the deposit facility rate (DFR). We also collect data from the ECB Surveys of Monetary Analysts (SMA) on the median expectation for DFR before each repayment date until the end of the TLTRO program,[18] that

[16]Such as former TLTRO programs and other longer-term refinancing operations.

[17]We also obtain from TOP participation data on standard refinancing operations which we use to construct dependent variables in the second part of the analysis, namely our tests of central bank liquidity dependence.

[18]We use aggregated results of the ECB SMAs from October 2022, December 2022, February 2023, March 2023, June 2023, September 2023 and December 2023 available here.

we use in conjunction with TLTRO participation data to construct bank-level changes in TLTRO pricing following the recalibration.

4 Results

4.1 Baseline TLTRO exit pace

Unlike the continuous-time Cox regression model, the discrete-time modeling approach allows us to recover and examine the shape of the baseline hazard and survivor functions and not only the shift parameters associated with the explanatory variables of interest (Singer and Willett, 1993). We start our analysis by visually inspecting the shape of the baseline hazard and survivor functions.

The shape of the baseline hazard and survivor functions are important as they indicate when the risk of early exit was most likely to materialize as well as how this risk varied over time. These shapes characterize bank baseline early exit paces from TLTRO, and from a policy perspective, describe when the TLTRO recalibration was most effective in accelerating Eurosystem balance sheet reduction via banks. To recall, due to the assumption of proportionality underlying our discrete-time hazard model, the influence of explanatory variables will only shift the baseline early exit hazard but it will not alter its temporal shape.

To recover baseline hazard and survivor functions, we first estimate the coefficients α_t of the version of the model in Equation 6 which does not include any explanatory variables $X_{i,t}$. We then make use of Equation 7 and Equation 3 to obtain estimated baseline hazard and survivor functions respectively. Figure 2 plots these estimates.

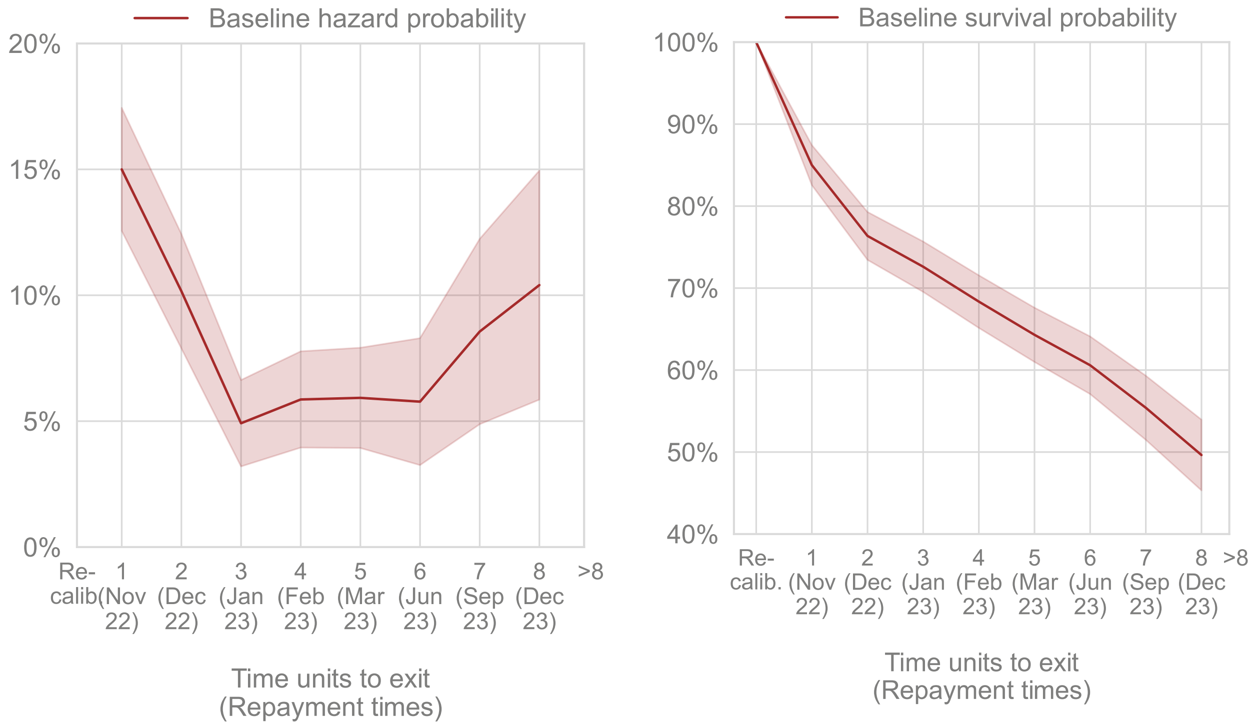
Focusing on the baseline hazard probability in Panel 2a, we observe an almost quadratic shape, with the most hazardous early exit times occurring during the first two repayment windows (November and December 2022), followed by a decrease and stabilization of the baseline hazard through June 2023, and thereafter followed by another increase in September and December 2023. This quadratic shape could be explained by the fact that with the repayment of the largest TLTRO operation in June 2023 a large share of banks dropped out of the early exit risk set.[19] As the number of "surviving banks" becomes smaller the baseline hazard probability increases, as observed in the last repayment times.

[19]See Panel C of the Life Table (Table C1 of Appendix C).

Figure 2: Baseline hazard and survivor functions of TLTRO early exit.

This figure illustrates the baseline (whole-sample) hazard and survivor functions of the TLTRO early exit event. Standard errors are obtained via the delta method.

(a) Baseline hazard function. **(b)** Baseline survivor function.



Baseline survival probability estimates, as shown in Panel 2b, are identical to the Kaplan-Meier estimates plotted in Figure 1 and reported in the Life table[20] as the effect of explanatory variables is not taken into account in either case.

Having analysed the baseline exit pace from TLTRO, the key question that arises is what factors and mechanisms contribute to shifts in this baseline behaviour and to a higher or lower prolonged demand for central bank liquidity. We now turn to the results of our model specifications including explanatory variables to identify and analyse such factors, with the goal of uncovering demand drivers of long-term central bank liquidity.

4.2 Country and TLTRO funds characteristics

Table 2 presents estimates of different versions of our model. It shows the influence of country time-varying characteristics on early exit hazard, country fixed characteristics,

[20]See Panel C of Table C1 of Appendix C. Maximum likelihood hazard probability estimates are also identical to those obtained with the Kaplan-Meier method but reported only in the Life table in Appendix C.

and banks' credit quality.[21]

In column (1), we include our two country-specific explanatory variables (*Credit demand* and *Financial stress*) which we employ in the absence of bank-level data. They are measured by the Firm credit demand diffusion index derived from the quarterly ECB Bank Lending Survey[22] and the Country-Level Index of Financial Stress (CLIFS)[23] also published quarterly by the ECB. We use CLIFS as a proxy for banks' need to hold liquidity as a precaution against market stress or funding uncertainty. We find a statistically significant negative association between both country-level variables and the early exit hazard. This points to a longer time-to-exit for banks facing higher credit demand and greater uncertainty or stress. [24]

In columns (2)-(6) we augment our regression specifications with the introduction of bank-level TLTRO funds characteristics. We are interested in four features of TLTRO funds: (i) a bank's funding reliance on TLTRO; (ii) their maturity structure; (iii) changes in the cost of funding following the recalibration, as well as (iv) mobilised collateral in exchange of TLTRO funds. All employed TLTRO-related explanatory variables are predefined before the recalibration, meaning that they are either constructed under the baseline scenario that TLTRO funds would have been held until maturity or fixed before the recalibration. Their construction is thus not influenced by banks' exit behaviour.

In column (2) we include an explanatory variable (*TLTRO HTM amounts / Total assets*) to capture bank funding reliance on TLTRO over time under the hold-to-maturity (HTM) assumption. We do not find that funding reliance on TLTRO over time is associated with an earlier or later exit from TLTRO.

To examine the influence of TLTRO funds' maturity profile, in column (3) we include as an explanatory variable the residual weighted average maturity of TLTRO funds (*TLTRO WAM*, measured in years before recalibration). We find that a higher residual

[21] As explained in Section 3, all regression specifications include a set of (i) exit time dummy variables, (ii) country dummmy variables, and (iii) credit quality dummy variables.

[22] With respect to credit demand, the diffusion index refers to the weighted difference between the share of banks reporting an increase in loan demand and the share of banks reporting a decline. For more details see User guide to the euro area bank lending survey.

[23] The CLIFS includes six, mainly market-based, financial stress measures that capture three financial market segments: equity markets, bond markets and foreign exchange markets. For further details, see Duprey, T. and Klaus, B., "Dating systemic financial stress episodes in the EU countries", Working Paper Series, No 1873, ECB, December 2015.

[24] However, as we will see later in the analysis, the statistically significant effect of *Financial stress* seems to be confounded by other bank characteristics, and the result does not hold when we control for balance sheet characteristics in Section 4.3.

Table 2. Early exit hazard, country and TLTRO fund characteristics.
This table reports results from logistic regressions applied to the survival dataset, estimating the discrete-time hazard probability to exit early from TLTROs via maximum likelihood. In the variable notation, (t_0) is used to label explanatory variables measured before the announcement date of the TLTRO change, while (t) is used to label time-varying variables, measured contemporaneously with each repayment date. All regressions include repayment time, country and credit quality fixed effects. Robust standard errors reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All coefficients are reported on the logit scale.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			TLTRO early exit			
Credit demand (t)	-0.031***	-0.031***	-0.031***	-0.029***	-0.033***	-0.035***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Financial stress (t)	-2.873***	-2.873***	-2.873***	-1.957**	-3.266***	-3.688***
	(0.897)	(0.897)	(0.897)	(0.992)	(1.098)	(1.117)
TLTRO HTM (t) / Total assets (t0)		-2.279	-1.501			
		(1.673)	(1.693)			
TLTRO WAM (t0) (years)			-0.546***			
			(0.182)			
TLTRO HTM <6m (t) / Total assets (t0)				5.663**	5.664**	6.163***
				(2.309)	(2.317)	(2.294)
TLTRO HTM 6m-1y (t) / Total assets (t0)				-4.578*	-6.205**	-5.773**
				(2.711)	(2.884)	(2.866)
TLTRO HTM >1y (t) / Total assets (t0)				-9.852***	-11.428***	-11.216***
				(3.553)	(3.751)	(3.710)
Δ TLTRO final rate HTM (t)					1.728**	1.585**
					(0.739)	(0.742)
Govies-like collateral / TLTRO (t0)						0.468***
						(0.132)
Exit (repayment) time dummies	x	x	x	x	x	x
Country dummies	x	x	x	x	x	x
Credit quality dummies	x	x	x	x	x	x
Observations	3,945	3,945	3,945	3,945	3,945	3,945

maturity of TLTRO funding is associated with a higher probability to retain TLTRO funds until maturity.

To examine the influence of TLTRO funds' maturity profile, in column (3) we include as an explanatory variable the residual weighted average maturity of TLTRO funds (*TLTRO WAM*, measured in years before recalibration). We find that a higher residual maturity of TLTRO funding is associated with a higher probability to retain TLTRO funds until maturity.

In column (4) we break down TLTRO HTM funding reliance into three residual maturity buckets: (i) *TLTRO HTM* $< 6m$ / *Total assets*, which captures TLTRO HTM funding over time with a residual maturity below six months; (ii) *TLTRO HTM* $6m$-$1y$ / *Total assets*, which captures TLTRO funding with a residual maturity between six months and one year; and (iii) *TLTRO HTM* $> 1y$/ *Total assets*, capturing TLTRO HTM funding maturing in more than one year time. We find that having a high share of TLTRO funds with less than six months residual average maturity is associated with a faster exit from TLTRO, while having a high share of TLTRO funds with more than six months remaining maturity and even more so, more than one year maturity, is associated with a delay in exiting from the targeted operations.

These results are more insightful when linked with bank liquidity regulatory requirements, specifically the fulfillment of the net stable funding ratio (NSFR). Given that TLTRO funding is considered stable funding for NSFR purpuses with residual maturity greater than one year, and to a lesser extent between six months and one year, our results suggest an *NSFR value* of TLTRO/central bank funding with a residual maturity above six months. Our results suggest that an absence of NSFR value in TLTRO funding increases banks' early exit hazard while the presence of NSFR value in TLTRO funding increases the probability of retaining TLTRO funds for longer. Our results also provide evidence that the higher the NSFR value is the larger this effect is, as reflected by the higher magnitudes of the coefficient of *TLTRO HTM* $> 1y$ / *Total assets* compared to the one of *TLTRO HTM* $6m - 1y$ / *Total assets*.

Additionally, we examine how differences in TLTRO cost of funding influence early exit hazard. We include in Column (5) Δ *TLTRO final rate HTM* as a covariate. This variable captures the impact of the recalibration on final TLTRO interest rate at the bank level assuming that all banks kept TLTRO funds until maturity. It is constructed as explained in Appendix A, however it is no longer fixed at announcement date, it is time-varying and updates according to monetary policy path (DFR) expectations before each repayment date. We find that a stronger tightening of the TLTRO conditions is associated with a higher early exit hazard, as indicated by the positive, statistically significant coefficient. This finding further supports the effectiveness of the policy change to incentivize a more accelerated exit.

Finally, turning to the link between mobilised collateral and early exit hazard, we include in Column (6) *Govies-like collateral / TLTRO*, which refers to the amount of government bonds and other similar asset types mobilised as collateral in exchange of TLTRO before recalibration. Our results suggest that having more govies-like bonds pledged as collateral before the policy change increased banks' hazard to exit early from TLTRO, hinting to a decrease in the relative attractiveness of central bank reserves injected via TLTRO relative to government bonds. Similar to Lopez-Salido and Vissing-Jorgensen (2023); Vissing-Jorgensen (2023), our results point to the fact that TLTRO-injected reserves and government bonds may also interact through their respective convenience yield in monetary policy normalisation times. Banks that use more govies-like bonds as collateral having a higher tendency to exit early may be an indication that these bonds were further released to the market, which underscores a potential effect of the TLTRO recalibration on safe assets release and on alleviating collateral scarcity.[25]

4.3 Bank significance and balance sheet characteristics

In Table 3 we supplement our regression specifications with the introduction of further bank characteristics: bank significance and several balance sheet characteristics measured with one month lag. In all specifications, in addition to controlling for time, country and credit quality fixed effects, we control for the country time-varying characteristics and TLTRO funding conditions analyzed in the previous section.

In Column (1) we examine the influence of banks' significance under the Single Supervisory Mechanism (SSM) on the early exit hazard by including *SSM significance* as an explanatory variable. This variable takes on a value of *1* if a bank is a significant insti-

[25]Furthermore, since Eurosystem borrowing against high-quality liquid assets (HQLA) such as govies-like collateral does not bring any NSFR benefits (Vergote and Sugo, 2020), this finding also highlights the role of a broad collateral framework for the *NSFR value* that could be generated via long-term operations with residual maturity above six months.

tution (under direct ECB supervision) and *0* if it is a less significant institution (outside direct ECB supervision).[26] We find that being a significant institution for supervisory purposes is associated with a faster TLTRO exit. This result is not surprising, as SSM significance relates to bank size and its access to capital markets, which in turn provides more options to exit TLTRO and more interest to ensure a diversified investor base. This finding could also relate to significant banks' way of signaling a "fortress balance sheet" (Acharya and Rajan, 2024) to their investor base, supervisors and even credit rating agencies. Given that potential risks stemming from bank reliance on TLTRO funding and their exit strategies were part of supervisory scrutiny,[27] these results could also be suggestive of a *potential fear of stigma* by significant banks had they not exited TLTRO after recalibration.

In Column (2) we include *Capital (leverage) ratio* as an explanatory variable. This variable is computed as *Capital and reserves / (Total assets + Unused Loan commitments)* and is meant to proxy the *Leverage ratio* under the Basel III regulatory framework. The Leverage ratio regulation requires banks to hold capital against all on- and off- balance sheet exposures, regardless of their risk, in the form of a minimum Leverage ratio of 3%. It reflects banks' capacity to expand their balance sheet, including via central bank liquidity. The statistically significant negative coefficients in Column (2) suggest that a higher leverage ratio (*i.e.* more balance sheet space) is associated with a higher probability to stay in TLTRO operations until maturity. Conversely, a lower leverage ratio increases an early exit hazard. Similar to Lopez-Salido and Vissing-Jorgensen (2023); Andreeva et al. (2025), our results suggest that banks' balance sheet capacity, stemming from the leverage ratio requirement, affects demand for central bank liquidity.

Recognizing the dual role of targeted longer-term central bank operations for banks' liquidity management as both a source of central bank reserves and a source of stable funding, we assess the link between a banks' reserve and stable funding availability and their capacity or willingness to exit early. Focusing on central bank reserves, in Column (3) we add *Minimum reserves / Total Assets* and *Excess reserves / Total Assets* as explanatory variables. With these two variables we want to differentiate between mandatory reserves that banks need to hold and central bank reserves held in excess of minimum requirements; both as a share of total assets.

[26]For more details on banks supervisory significance see What makes a bank significant?

[27]See ECB Banking Supervision: SSM supervisory priorities for 2023-2025.

Table 3. Early exit hazard, bank significance and balance sheet characteristics.
This table reports results from logistic regressions applied to the survival dataset, estimating the discrete-time hazard probability to exit early from TLTROs via maximum likelihood. In the variable notation, (t_0) is used to label explanatory variables measured before the announcement date of the TLTRO change, while $(t-1)$ is used to label time-varying variables, measured with one moth lag with respect to each repayment date. All regressions include repayment time, country and credit quality fixed effects and additional controls as indicated. Robust standard errors reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All coefficients are reported on a logit scale.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:			TLTRO early exit			
SSM significance (t0)	0.610***	0.461**	0.398**	0.422**	0.416**	0.347*
	(0.196)	(0.198)	(0.199)	(0.206)	(0.203)	(0.202)
Capital (leverage) ratio (t-1)		-8.658***	-8.163***	-8.596***	-9.651***	-8.264***
		(2.140)	(2.051)	(2.057)	(2.316)	(2.094)
Minimum reserves / Total Assets (t-1)			-58.768***	-57.183***	-51.947**	-49.336**
			(20.882)	(21.896)	(20.670)	(20.076)
Excess reserves / Total Assets (t-1)			1.27	2.304**		
			(0.816)	(0.912)		
Demandable (wholesale) deposits / Total Assets (t-1)				-1.992***		
				(0.597)		
Unused loan commitments / Total Assets (t-1)				-3.079**		
				(1.311)		
Stable (retail) deposits / Total Assets (t-1)					0.945*	1.899***
					(0.484)	(0.522)
Bond issued (>1Y) / Total Assets (t-1)					1.602	2.232**
					(0.993)	(1.028)
Mortgage loans / Total Assets (t-1)						-2.273***
						(0.538)
NFC loans / Total Assets (t-1)						-2.032***
						(0.001)
Exit (repayment) time dummies	x	x	x	x	x	x
Country dummies	x	x	x	x	x	x
Credit quality dummies	x	x	x	x	x	x
Country and TLTRO funds characteristics	x	x	x	x	x	x
Observations	3,945	3,944	3,944	3,944	3,944	3,944

We find that a higher *Minimum reserves / Total Assets* is statistically related with a later exit from TLTRO, in line with a higher demand for reserves stemming from the need to fulfill minimum reserve requirements. At the same time, a higher share of minimum reserves could also be a reflection of different business models. Regarding excess reserves, one may expect their share to be associated with a faster exit from operations, since ultimately TLTRO funds can only be repaid via central bank reserves. However, we do not find a statistically significant effect on the early exit hazard.

We further build on the idea that in order to assess how "spare" or "available" excess reserves really are, we need to recognise the influence of *Claims on liquidity* encumbered on these reserves, such as demandable (uninsured) deposits and credit lines (Acharya and Rajan, 2024; Acharya et al., 2023). In Column (4) we control for demandable deposits and unused loan commitments, by including *Demandable (wholesale)deposits / Total Assets* and *Unused loan commitments / Total Assets* as covariates. Our variable of demandable deposits captures wholesale deposits, as opposed to retail, stable deposits, since we do not have information on their insured versus uninsured status.[28] After adjusting for the influence of claims on liquidity, we find that the amount of excess reserves as a share of total assets has now a positive statistically significant coefficient, doubled in size, which indicates that the more "available" excess reserves with respect to claims on liquidity are, the higher banks' hazard of early exiting. Moreover, both *Demandable (wholesale) deposits / Total Assets* and *Unused loan commitments / Total Assets (t-1)* have statistically significant negative coefficients, indicating that both types of claims on liquidity are associated with a longer time-to-exit TLTRO. Similar to Lopez-Salido and Vissing-Jorgensen (2023), in whose framework deposits constitute a demand curve shifter, we also find that the share of demandable deposits is a shifter of the baseline early exit hazard. Importantly, our result on deposits does not follow from banks' liquidity needs for reserves requirements, which are also determined by the amount of deposits, since we continue to control for minimum reserves required as a share of total assets.

Finally, to examine the link between the availability of stable funding and banks' early/late exit decision from TLTRO, we use in Column (5) *Stable (retail) deposits / Total Assets* and *Bonds issued* $(> 1Y)$ */ Total Assets* as covariates, where *Stable (retail)*

[28] In addition, instead of credit lines we control for a broader measure of loan commitments which includes all off-balance sheets credit exposures reported to the European credit register AnaCredit, not just credit lines.

deposits refer to deposits from households and non-financial corporations, while *Bonds issued (>1Y)* refers to bonds issued with an original maturity higher than one year. Only the stable deposits category appears statistically related to the early exit hazard. This association does not appear to be statistically strong, since the significance level of the corresponding coefficient is close to 10%. Interestingly, the coefficients of both variables become strongly statistically significant and of large magnitude when controlling for *Mortgage loans / Total Assets* and *NFC loans / Total Assets* in Column (6), *i.e.*, when recognizing the existence of balance sheet items such as long-term loans that require stable funding.

Interestingly, also, *Stable (retail) deposits / Total Assets* and *Demandable (wholesale) deposits / Total Assets* have opposite signs in the different employed specifications. This suggests that deposit composition matters: wholesale deposits tend to be associated with a later exit because they require more reserves and weigh on their availability. Conversely, retail, stickier deposits are associated with a faster exit as they constitute a comparable source of funding to TLTROs from a funding stability perspective.

4.4 Bank liquidity positions

4.4.1 Measuring bank liquidity positions

The results in Section 4.3 suggest that banks' excess reserves or stable sources of funding in isolation cannot fully explain demand for central bank liquidity. To capture banks' liquidity needs both for demandable liabilities or off-balance sheet exposures and, on a longer-term basis, for stable funding we define *composite measures of banks' liquidity positions*. With these measures, our goal is to account for all relevant on- and off- balance sheet items and TLTRO funds characteristics to gain a deeper insight into the relationship between these composite measures and demand for central bank liquidity.

We build on two measures of bank liquidity (risk) developed in the literature, namely the *Liquidity creation* measure proposed by Berger and Bouwman (2009) (hereinafter BB framework) and the *Claims to potential liquidity* measure proposed by Acharya et al. (2023) (hereinafter ACRS framework).*Liquidity creation* is a comprehensive measure of a bank's overall ability to finance relatively illiquid assets with relatively liquid liabilities. The more liquidity a bank is creating, the larger its maturity transformation role is.

Claims to Potential liquidity represent a composite measure of liquidity risk,[29] proposed by the authors to examine vulnerabilities when transitioning from QE to QT.

By classifying all bank balance sheet and off-balance sheet activities as liquid, semiliquid, or illiquid, Berger and Bouwman (2009) propose four comprehensive measures of bank liquidity creation, which differ in the way loans are classified, *i.e.* by their liquidity or by their maturity ("cat" vs "mat" liquidity creation measures) and based on weather off-balance sheet activities are included or excluded from the classification ("fat" vs "non-fat" measures). We build on their "mat fat" classification, which we adapt to available data for euro area banks,[30] and obtain the following categories:

- *Illiquid assets.* This category comprises loans to non-financial corporations (NFC) and households (HH) established in the euro area with an original maturity greater than one year; as well as all loans granted outside the euro area, which we assume are also granted on a longer-term basis.

- *Liquid assets.* This category consists of cash, excess reserves and unencumbered government and other public sector (govie-like) security holdings. When excluding encumbered govie-like securities holdings, we only exclude securities mobilised as Eurosystem collateral, *e.g.* in exchange of TLTRO.

- *Liquid liabilities.* Consistent with the previous section, we proxy the category of liquid, runnable liabilities with wholesale (demandabble) deposits, as opposed to retail deposits which we consider sticky/stable.

- *Illiquid liabilities.*[31] We classify the stable sources of funding employed as explanatory variables in the previous section (retail stable deposits and bond issuances with an original maturity larger than one year) as illiquid. We also include in this category TLTRO funds with a residual maturity of more than six months, *i.e.* funds considered "stable" for regulatory (NSFR) purposes.

- *Off-balance sheet items.* In our setting this category includes only *Illiquid guarantees* comprised of *Unused loan commitments* as defined in Section 4.3.

[29]In turn, this measure builds on Acharya and Rajan (2024) and the literature on banks as liquidity providers (Kashyap et al., 2002).

[30]For simplicity we disregard the classification of semi-liquid assets and liabilities, the remaining categories in Berger and Bouwman (2009), since they will be assigned with a zero weight.

[31]Note that the BB framework also includes equity, which we exclude, since we control for the Capital (leverage) ratio in all the remaining specifications employing measures of bank liquidity positions.

Following the BB framework, we assign weights to these categories: $1/2$ to Illiquid assets, Liquid liabilities and Illiquid guarantees; and $-1/2$ to Liquid assets and Illiquid liabilities. By summing up the five categories with their corresponding weights, we obtain our proxy of the "mat fat" Liquidity Creation measure:

$$\begin{aligned} \textit{Liquidity Creation} = {} & 1/2 \cdot \textit{Illiquid assets} + 1/2 \cdot \textit{Liquid (Demandable) liabilities} + \ldots \\ & 1/2 \cdot \textit{Unused loan commitments} - 1/2 \cdot \textit{Illiquid (Stable) liabilities} - \ldots \\ & 1/2 \cdot \textit{Liquid assets}. \end{aligned} \tag{6}$$

By rearranging terms, we break down the *Liquidity Creation* measure from Equation 6 into two components, with the objective of differentiating between maturity transformation on the short- and long-term of the balance sheet: *Liquid assets gap* and *Stable funding gap.* The former captures liquidity created via the short term side of the balance sheet, or short-term liquidity needs:

$$\begin{aligned} \textit{Liquid assets gap} = {} & 1/2 \cdot \textit{Liquid (Demandable) liabilities} + 1/2 \cdot \textit{Unused loan commitments} \ldots \\ & - 1/2 \cdot \textit{Liquid assets}, \end{aligned} \tag{7}$$

while the latter captures liquidity created via the longer-term side of the balance sheet, or the long-term liquidity (or rather funding) needs:

$$\textit{Stable funding gap} = 1/2 \cdot \textit{Illiquid assets} - 1/2 \cdot \textit{Illiquid (Stable) liabilities}. \tag{8}$$

By expressing these two components as ratios instead of differences and after inverting we obtain our first two liquidity position measures:

$$\textit{Liquid assets ratio} = \frac{\textit{Liquid assets}}{\textit{Liquid (wholesale) liabilities} + \textit{Unused loan commitments}} \tag{9}$$

$$= \frac{\textit{Liquid assets}}{\textit{Claims on Liquidity (ACRS)}} \tag{10}$$

$$\approx \frac{1}{\textit{Claims to Potential Liquidity (ACRS)}} \tag{11}$$

$$\textit{Stable funding ratio} = \frac{\textit{Illiquid (stable) liabilities}}{\textit{Illiquid assets}}. \tag{12}$$

The denominator of the *Liquid assets ratio* in Equation 10 includes *Claims on liquidity* as defined by Acharya and Rajan (2024); Acharya et al. (2023) and discussed in Section 4.3. Thus, the *Liquid asset ratio* we derive from the BB framework is conceptually equivalent to *1/ Claims to Potential Liquidity* from the ACRS framework (Equation 11).[32]

Expressing *Liquidity creation* from Equation 6 as a ratio instead of a difference between positive and negative weight categories and inverting yields our third composite liquidity position measure to capture a bank's overall liquidity position on both the short- and long-term sides of the balance sheet:

$$\textit{Inverse Liquidity creation ratio} = \frac{\textit{Illiquid (stable) liabilities} + \textit{Liquid assets}}{\textit{Illiquid assets} + \textit{Liquid (wholesale) liabilities} + \textit{Unused loan commitments}}. \tag{13}$$

Table C2 from Appendix C summarises the construction of the three liquidity position ratios based on our replication of the BB and ACRS frameworks. Figure 3 shows the evolution of our three liquidity position since the Covid-19 pandemic crisis outbreak and their cross-sectional dispersion.[33]

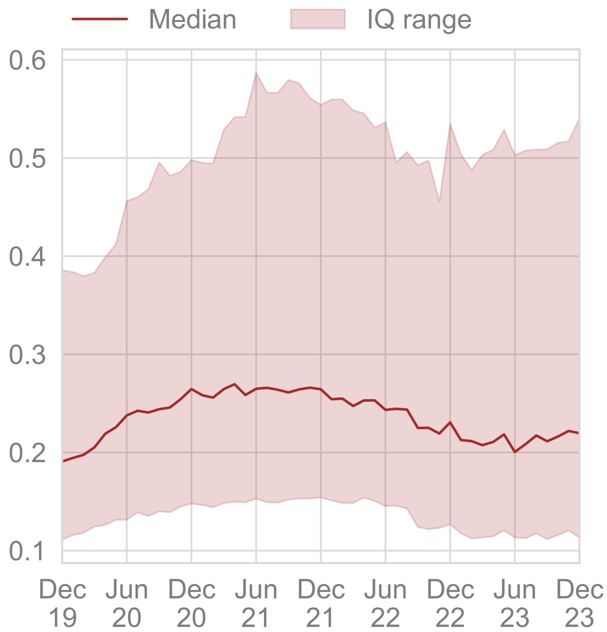
Focusing on the time series, we observe that during the pandemic crisis and until the start of monetary policy normalisation, TLTRO improved banks' liquidity positions according to all three indicators. Keeping in mind the dual function of targeted longer-term refinancing operations in providing a source of liquid assets and a source of stable funding, the different panels illustrate the capability of longer-term refinancing operations to reduce maturity transformation by banks and transfer the liquidity creation role to the Eurosystem, either through each function individually (panels 3a and 3b) or jointly (panel 3c). We observe a correction in the three ratios around the start of the tightening cycle, albeit followed by their stabilisation. The evolution of the three ratios does not suggest aggregate risks during the TLTRO phasing-out period due to the still abundant aggregate level of excess reserves in the system and possibly due to banks' overall ability to access stable sources of funding, such as deposits. However, turning to the cross-sectional

[32]In the ACRS framework, the denominator of the *Claims to Potential Liquidity* consists of *Reserves* and *Eligible assets* for exchange with the Fed for reserves. In our case, the *Liquid assets* category comprises in addition to (excess) reserves only a subset of eligible assets as collateral that can be used in exchange of reserves with the Eurosystem, namely *Govies-like securities.* Nevertheless, both *Potential*

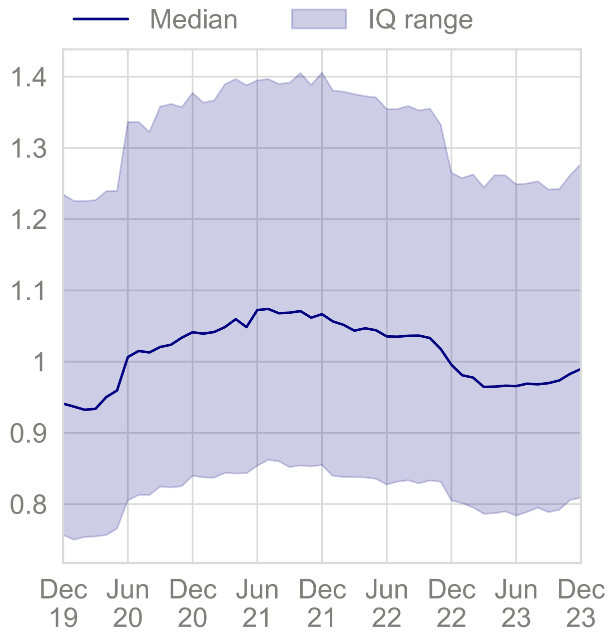
Figure 3: Bank liquidity positions measures: Summary of time series and cross-sectional dispersion.

This figure illustrates the evolution and cross-sectional dispersion of the three liquidity position measures over the period December 2019 - December 2024. A summary of their construction is provided in Table C2 from Appendix C.

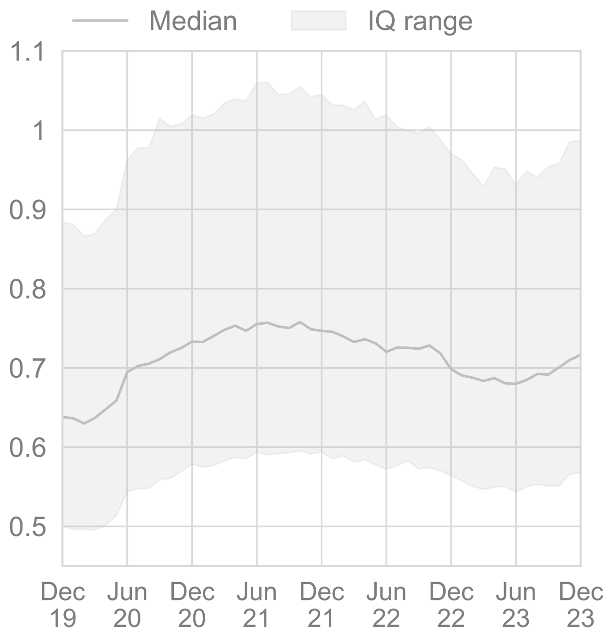
(a) Liquid Assets Ratio



(b) Stable funding ratio



(c) Inverse Liquidity Creation Ratio



dispersion of the three measures the picture is quite different. dispersion This highlights a high degree of heterogeneity in banks' liquidity (funding) positions and potentially masking some risks in the cross-section of banks associated with TLTRO phasing-out.

4.4.2 Regulatory meaning

Could our liquidity position indicators be interpreted in a regulatory context? We argue that the *Liquid assets ratio* and the *Stable assets ratio* are conceptually similar in construction to liquidity regulation ratios under the Basel regulatory framework, namely the *Liquidity coverage ratio (LCR)* and *Net stable funding ratio (NSFR)*.

The *LCR* is defined as the stock of high-quality liquid assets (HQLA) divided by the net liquidity outflows under a severe 30-day stress scenario. Our *Liquid assets ratio* uses a slightly different denominator, as we include stocks of claims on liquidity rather that net flows (as used in the regulatory ratio). This difference is palpable in our lower levels compared to *LCR*, with the *Liquid assets ratio* having values below 1 for certain banks. However, assuming that all claims on liquidity would be fully called upon (they would have a 100% run-off rate) our *Liquid asset ratio* can be seen as a stressed version of the *LCR*.

Similarly, the *NSFR* is computed as the sum of liabilities weighted by their degree of long-term reliability (available stable funding) divided by the sum of assets weighted by factors that reflect their liquidity characteristics and residual maturities over a medium-term horizon (required stable funding). Our *Stable funding ratio* also follows a maturity-based classification inspired by the BB framework for the asset side as well as a funding stability-based classification for the liabilities side, albeit it uses simpler weights than those used in the regulatory context.

We make use of quarterly regulatory data available for Spanish banks from our sample to validate this prior. Figure 4 plots the *Liquid assets ratio* and *Stable funding ratio* against the *LCR* and *NSFR* respectively at the end of Q3 2022, *i.e.* before the recalibration. The scatter plots and the fitted regression lines show a clear positive relation. This strong association is also confirmed when employing panel regressions over our survival analysis period (Q3 2022 - Q4 2023) and controlling for bank fixed effects (see Table C3

Liquidity and *Liquid assets* categories are conceptually very similar.

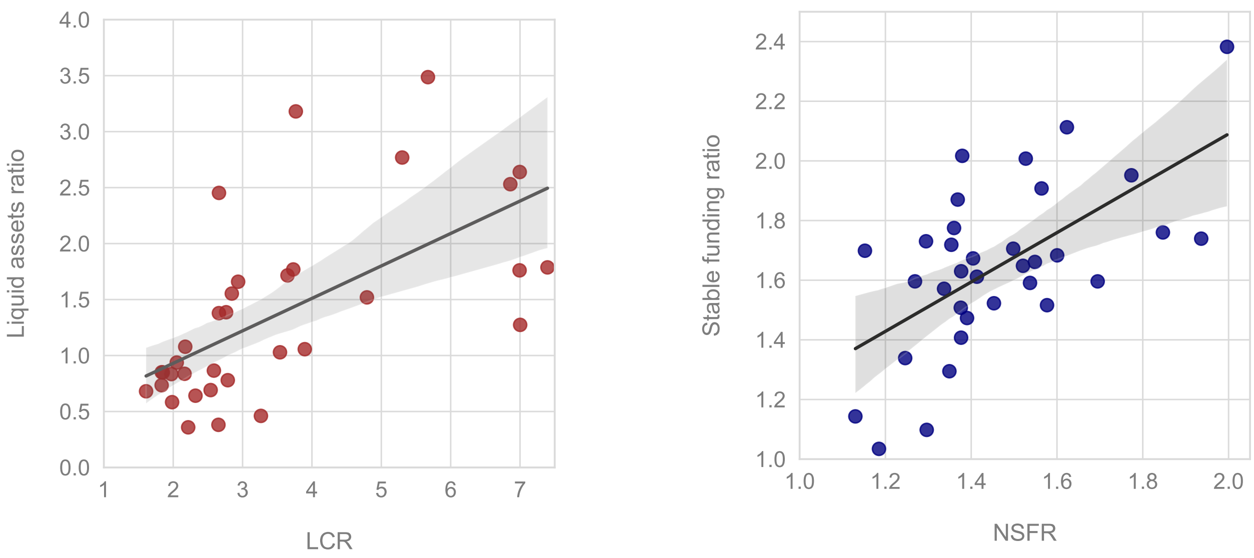
[33] We also present the descriptive statistics of the three measures over the survival dataset in Table 1.

in Appendix C). Importantly, when further assessing the interplay with the early exit hazard our measures will allow us to gain further insights between bank's regulatory incentives and demand for central bank liquidity.

Figure 4: Liquidity position measures and liquidity regulatory ratios for the sub-sample of Spanish TLTRO participating banks.

This figure illustrates the relationship between the Liquid assets ratio and the Liquidity Coverage Ratio (LCR) (Panel a) and between the Stable funding ratio and the Net Stable Funding Ratio (NSFR) (Panel b). The lines represent the linear fit.

(a) Liquid assets ratio and LCR **(b)** Stable funding ratio and NSFR



4.4.3 Bank liquidity differentials and early exit hazard

How do banks' liquidity positions relate to their ease of exiting from TLTRO? In Table 4 we show the relation between our three liquidity position indicators and TLTRO early exit hazards. In all specifications, in addition to controlling for exit time, country and bank credit quality fixed effects, we control for country time-varying characteristics, TLTRO funds characteristics, SSM significance, Capital (leverage) ratio and minimum reserves required. In all specifications, we employ the three ratios in logs, given their positive skewness (recall Table 1) and with a 1-month lag.

Table 4 suggests a strong positive association between both the *log(Liquid assets ratio)* and *log(Stable funding ratio)* and the early exit hazard, either when plugged in isolation (Columns (1) and (2)) or jointly (Column (3)). The positive link between banks' liquidity (funding) positions on both short-term and long-term sides of the balance sheet and a

Table 4. Early exit hazard and bank liquidity positions.
This table reports results from logistic regressions applied to the survival dataset, estimating the discrete-time hazard probability to exit early from TLTROs via maximum likelihood. In the variable notation, (t_0) is used to label explanatory variables measured before the announcement date of the TLTRO change, while ($t-1$) is used to label time-varying variables, measured with one moth lag with respect to each repayment date. All regressions include repayment time, country and credit quality fixed effects and additional controls as indicated. Robust standard errors reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All coefficients are reported on the logit scale.

	(1)	(2)	(3)	(4)
Dependent variable:	TLTRO early exit			
Log (Liquid assets ratio) (t-1)	0.397*** (0.088)		0.297*** (0.093)	
Log (Stable funding ratio) (t-1)		0.661*** (0.183)	0.469*** (0.177)	
Log (Inverse liquidity creation ratio) (t-1)				0.785*** (0.197)
Exit (repayment) time dummies.	x	x	x	x
Country dummies.	x	x	x	x
Credit quality dummies.	x	x	x	x
Country and TLTRO funds characteristics.	x	x	x	x
Supervisory significance, capital (leverage) ratio and minimum reserves.	x	x	x	x
Observations	3,923	3,944	3,923	3,944

faster exit from TLTRO is supported when plugging overall liquidity position measure *log (Inverse liquidity creation)* in Column (4).

Given the regulatory interpretation of the *Liquid asset ratio* and *Stable funding ratio* as *LCR-like* and *NSFR-like* ratios, the results also point to a faster exit from TLTRO associated to stronger regulatory liquidity positions or, alternatively, a prolonged demand for TLTRO associated with the fulfillment of regulatory liquidity ratios. Thus, similar to Kedan and Ventula Veghazy (2021) (who provide evidence of an LCR-induced demand for central bank reserves), our results uncover both an LCR-induced and NSFR-induced demand for reserves and funding provided via (targeted) longer-term refinancing operations. The NSFR-induced demand for central bank funding result reinforces the previous results in Section 4.2 where the case is made for an *NSFR-value* of central bank funding with more than six months maturity.[34]

4.5 Summary of drivers and mitigants of TLTRO early exit

Having uncovered the drivers behind the time-to-exit from TLTRO, we now turn to determine the magnitude of each driver and assessing their relative importance. A useful feature of our framework is the odds-proportionality assumption which allows us to derive the magnitudes of variable coefficients on the odds scale and assess which variables shift the baseline odds (and hazard) of early exit more.

We revisit Columns (3) and (4) of Table 4, where we use bank liquidity positions instead of individual balance sheet characteristics. We reformulate those regressions using standardized continuous explanatory variables,[35] to facilitate the comparison of the magnitudes of their effects. To recall, exponentiated coefficients represent the shift parameters of the baseline odds of early exit associated with each analyzed driver. It is straitforward to obtain percentage change in the odds of exiting early for a 1-standard deviation (unit) increase in each variable by subtracting 1 from exponentiated coefficients and multiplying by 100. In Figure 5, we plot estimated effects of each variable on the odds of an early exit together with their standard errors.[36]

Panel 5a shows estimated effects for the *Liquid assets ratio* and *Stable funding ratios* specification. Being a significant bank compared to a less significant one (potentially signaling a "fortress balance sheet") increases the odds of an early exit by 50%. Moving to drivers and mitigants measured with continous variables, the estimates place the *TLTRO HTM* $> 1y$ / *Total assets* (interpreted as TLTRO funding with maximum NSFR-value) and *Liquid assets ratio* (interpreted as an *LCR-like* ratio) as the primary drivers of central bank liquidity. These are followed by *Stable funding ratio* (interpreted as an *NSFR-like* ratio) and Δ *TLTRO final rate HTM* (capturing the actual impact of the recalibration

[34] Market intelligence also suggests banks' search for term liquidity with regulatory value. In particular, the Money Markets Contact Group banks emphasised that TLTRO early repayment considerations centered around the loss of NSFR value (that would decline with diminishing time to maturity of TLTRO funds) and leverage ratio considerations (as also highlighted in Section 4.3). See for example the summary of their meetings from 2022 and 2023 available here.

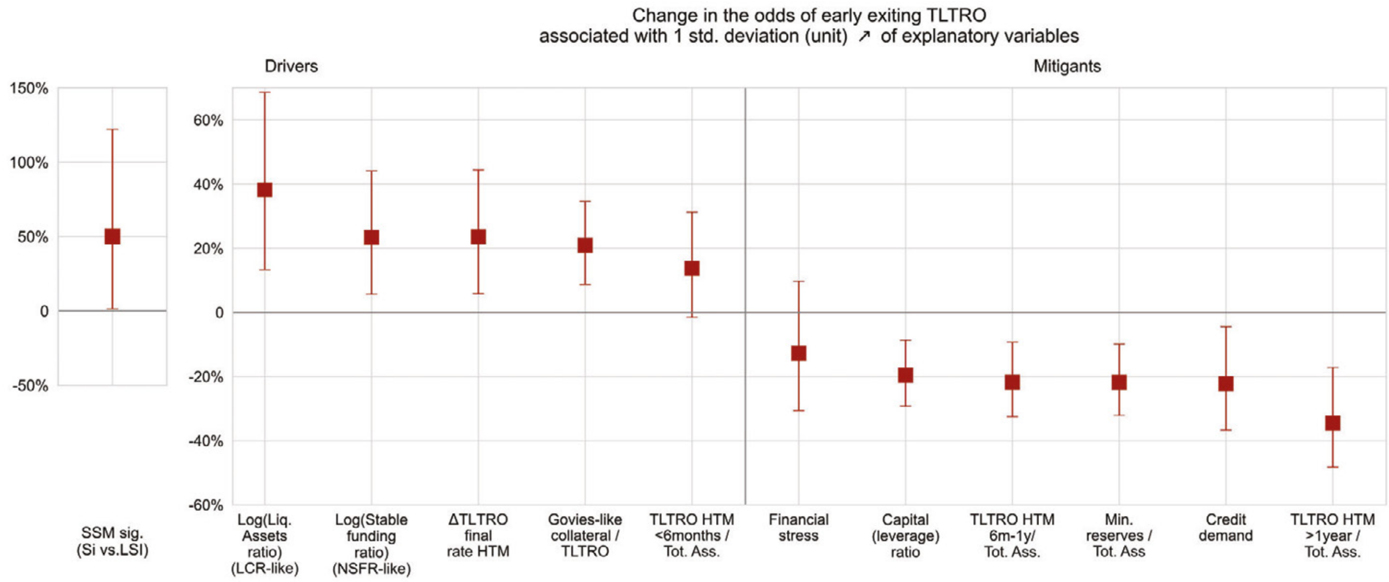
[35] In addition to the country and credit quality fixed effects which we do not report, the only discrete (dummy) explanatory variable is *SSM significance*.

[36] We also report the exponentiated coefficients, *i.e.* on the odds scale, of the reformulated regressions in Table C4 from the Appendix C.

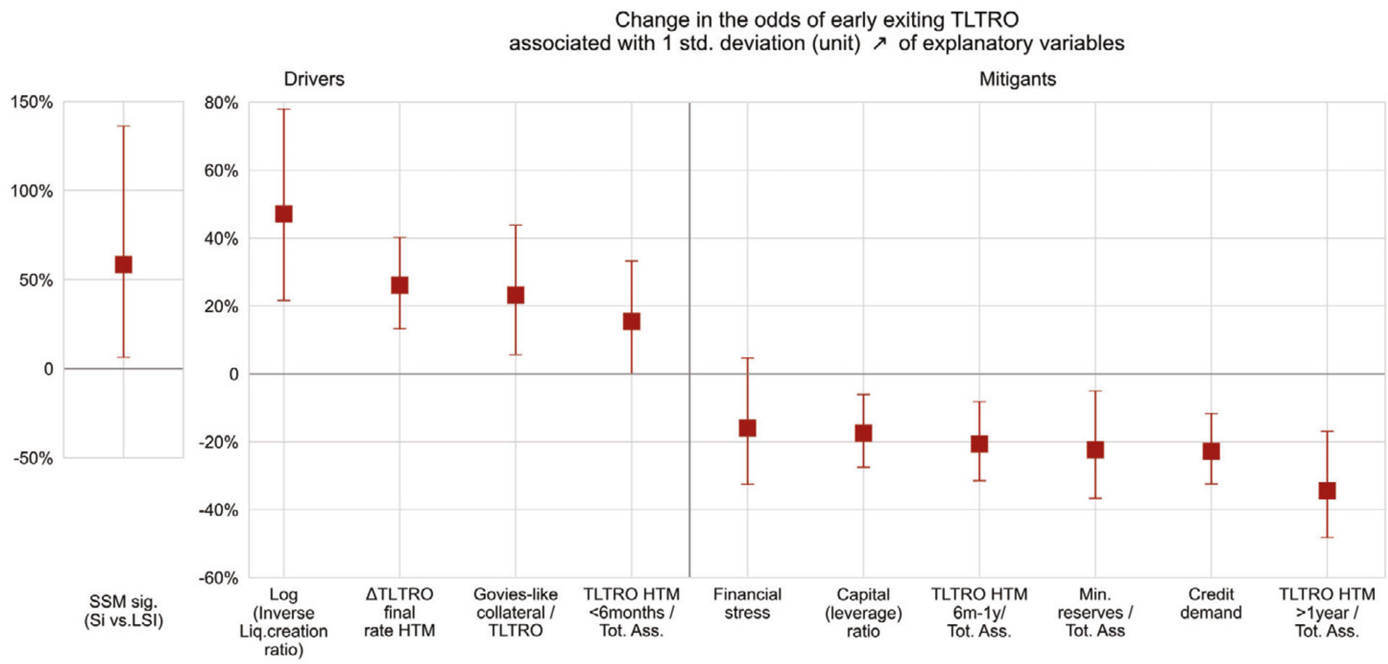
Figure 5: Drivers and mitigants of TLTRO early exit.

This figure plots the percentage change in the odds of exit early associated with one-standard-deviation (unit) increase in each explanatory variable from our preferred specifications, together with the standard errors, in decreasing order.

(a) Specification with Liquid assets ratio and Stable funding ratio.



(b) Specification with Inverse liquidity creation ratio.



on TLTRO rates). One standard deviation increase in *TLTRO HTM > 1y / Total assets* decreases the odds of an early exit by 34.5%, while one standard deviation increase in a bank's *Liquid assets ratio* is associated with an increase in the odds of 32%. One standard deviation increase in both the *Stable funding ratio* and Δ*TLTRO final rate HTM* is associated with an increase in the odds of about 24%.

Additionally important drivers that stand out in terms of magnitude are *Capital (leverage) ratio*, *TLTRO HTM 6m-1y / Total assets*, *Minimum reserves / Total Assets*, and *Credit demand*; all positioned more or less at the same level. One standard deviation increase in these variables is associated with a decrease the odds of exiting early by 19.6%, 21.7%, 21.8% and 23%, respectively. As for variables associated with an increase in the odds of an early exit, the *Govies-like collateral / TLTRO* also has a comparable magnitude (21%).

For Panel 5b we employ the overall liquidity position measure. In this case, *Inverse liquidity creation ratio* is the most important driver. A standard deviation increase in the *Inverse liquidity creation ratio* is associated with a 47.2% increase in the odds of an early exit. Panel 5b mirrors the relative order of other estimated effects in Panel 5a, with the exception of *Capital (leverage) ratio*, which appears to have higher relative importance (-22.7% in magnitude). In both panels, country-level *Financial stress* no longer has a significant differential impact, unlike the specifications employed in Table 2 where we were not controlling for many bank characteristics employed in our preferred specifications.

4.6 Robustness

In this Section we examine the sensitivity and robustness of our findings, as suggested by our two preferred specifications to different modeling choices.

Alternative time dependency of the hazard. First, we are concerned that parametrizing banks' baseline hazard profile using time dummy variables may not be parsimonious. We assess the sensitivity of our results when adopting a particular shape of the baseline hazard. Figure 2a suggests a quadratic shape and hence we re-estimate our preferred specification by including both exit times and exit times squared, instead of the set of dummy variables. The results, reported in Columns (1) and (2) of Table C5 in Appendix C remain consistent when we impose this alternative quadratic time dependence of the hazard.

Time-invariant bank-characteristics. Second, we are concerned that time-varying bank-specific explanatory variables employed in the regressions, may be a consequence rather than a driver of an early exit hazard (even if measured with a 1-month lag) given that they are not predefined before recalibration. To address this concern we re-estimate our preferred specifications by replacing all time-varing (non-predefined) bank characteristics with their value before recalibration. We present these results in Columns (3) and (4) of Table C5 from Appendix C and continue to find the same associations between the explanatory variables and the hazard to early exit.

Alternative censoring. Third, we are concerned that our results may be sensitive to the right censoring of a high number of banks in June 2023, since they are no longer at early exit risk, owing to the final maturity date of the highest TLTRO operation. To address this concern, we re-estimate earlier regression models without censoring banks that are no longer at early exit risk.[37] The results of this re-estimation (reported in Columns (3) and (4) of Table C5 from Appendix C) are robust to this alternative censoring.

Alternative link between the early exit hazard and explanatory variables. Fourth, our results are also robust when employing a complementary log-log link between early exit hazard probability and explanatory variables instead of the logit link.

$$\log\left[-\log(1-h_{i,t}]\right) = \alpha_t + \beta' \cdot X_i, t \tag{14}$$

Results remain consistent when we estimate our preferred specifications with complementary log-log regressions, as reported in Columns (1) and (2) of Table C6.[38]

Unobserved heterogenity. Finally, we are concerned about the influence of unobserved bank characteristics that may cause some banks to be more prone to early exit than others. To address this concern, we re-estimate the two logistic regressions by adding a bank random effect. The random intercept can be thought of as the combined effect of possible omitted bank-specific (time-constant) covariates. Results are presented in Columns (3) and (4) of Table C6 from Appendix C. The same associations between explanatory variables and the hazard to early exit remain when controlling for unobserved bank heterogeneity.

[37] Under both the main analysis and this sensitivity check, banks that completely exited (fully reimbursed their TLTRO) are not part of the survival dataset.

[38] Note that for the complementary log-log link of the hazard with explanatory variables, the likelihood of the data may be also written with the likelihood function in Equation 8.

5 "Liquidity dependence" hypothesis: Probability to turn to standard refinancing operations

Acharya et al. (2023) provide an explanation as to why, despite ultra-large injections of central bank reserves in the US banking sector, liquidity stress episodes (such as the September 2019 repo rate spike, the March 2020 *dash for cash*, or the March 2023 US regional banks collapse), continued to occur, requiring even larger central bank interventions. Their explanation is based on Acharya and Rajan (2024), who note that QE-injected reserves are financed on banks' balance sheets with demandable deposits from non-banks,*i.e* an offsetting claim on liquidity. This in turn makes QE liquidity-neutral for banks, as no "spare" liquidity is supplied. Thanks to these reserves, as the ultimate liquid asset, banks have a natural advantage in combining different claims on liquidity, such as demandable deposits and credit lines (Kashyap et al., 2002) and may have more incentives to write even more claims on liquidity when flooded with low-yielding reserves. Building on this theoretical foundation, Acharya et al. (2023) show that QE leads to an expansion of banks' claims on liquidity. Because reserves do not always remain where liquidity claims are issued, certain banks faced heightened liquidity risks during periods of quantitative tightening, necessitating greater central bank liquidity intervention ex-post. This underscores the phenomenon of *liquidity dependence*.

Our findings, showing that our *Liquid asset ratio* (equivalent to *1/Claims to potential liquidity* as proposed by Acharya et al. (2023) to measure liquidity risk exposure) has a strong association with TLTRO early exit hazard, suggest that banks with higher liquidity risk exposure tended to rely on TLTRO for longer and may have required additional central bank support upon exiting. Could our results be indicative of a "liquidity dependence" phenomenon for late exiters?

Unlike Acharya and Rajan (2024), our liquidity dependence hypothesis does not originate from the mechanical effect on banks' balance sheets of QE-injected reserves, *i.e.* "liquidity neutrality" of central bank reserves. If anything, in the case of TLTRO, the mechanical effect when injecting reserves via targeted long-term refinancing operations would be one of inverse liquidity creation as discussed in Section 4.4.1. However, regardless of how reserves are injected, banks have a natural advantage in combining different claims on liquidity (Kashyap et al., 2002; Acharya and Rajan, 2024), and they may also do so on the back of TLTRO-injected reserves. For instance, Fudulache and Goetz (2023) find that, following TLTRO take-up during the second series of the program, euro area banks issued more *wholesale deposits* (which are typically demandable and uninsured) and hence an offsetting claim on liquidity. Consequently, some TLTRO banks might face heightened exposure to liquidity risks during the phase-out period, necessitating central bank liquidity support upon exit. As banks also adjust their (stable) funding structures following TLTRO participation (Altavilla et al., 2023; Fudulache and Goetz, 2023), this liquidity dependence hypothesis could be extended to a *funding dependence* hypothesis. This would apply to banks that may lack sufficient stable funding sources to finance their long-term assets when exiting.

To test this hypothesis, we follow Acharya et al. (2023), who examine whether banks with greater liquidity risk became dependent on the Fed during two episodes of QT.[39] In the TLTRO unwinding case, we investigate whether TLTRO banks with higher liquidity risk exposure are related in the cross-section with banks that were more likely to turn to Eurosystem standard refinancing operations (SRO) during the TLTRO phasing-out period. To measure liquidity risk exposure we go beyond the *Claims to potential liquidity* measure and use the inverse of all our three liquidity position ratios as measures of liquidity risk, in logs.[40] Econometrically, we employ the following ordinary least squares panel regressions at bank-month level over the period between November 2022 and December 2023 for the sample of TLTRO participants used in the time-to-exit analysis:

$$\text{SRO}_{i,t} = \alpha_i + \beta \text{ Liq. risk}_{i,t} + X'_{i,t-1}\gamma + \delta_{c,t} + \kappa_{ssm,t} + \mu_{cq,t} + \epsilon_{i,t}; \tag{15}$$

where, in the different specifications the dependent variable is a dummy variable indicating participation in (i) Eurosystem main refinancing operation (MRO), (ii) regular longer-term operation with three-month maturity (3mLTRO); or (iii) either MRO or 3mLTRO. The explanatory variables of interest are liquidity risk indicators, namely the negative logarithm of our three lagged liquidity position measures.[41] $X'_{i,t-1}$ is a set of control vari-

[39] Acharya et al. (2023) show that banks with higher liquidity risk exposure during the Covid shock (via both credit lines and uninsured demandable deposits) are related in the cross section with banks that went to the discount window for more central bank support. They find that banks with higher liquidity risk exposure in March 2023, especially due to demandable uninsured deposits also increased "other" borrowings, including from the discount window.

[40] Consistent with the survival analysis and Acharya et al. (2023), we employ logs of the three liquidity risk indicators instead of the actual ratios given their skewed distribution.

[41] Our (unreported) results do not change if instead of bank liquidity position indicators we use the

ables comprised of banks' exit path from TLTRO, measured by *TLTRO repayment rate*, their *Capital (leverage) ratio* and *Minimum reserves/Total assets.* α_i, $\delta_{c,t}$, $\kappa_{ssm,t}$ and $\mu_{cq,t}$ represent bank fixed effects, country-month fixed effects, SSM significance-month fixed effects and credit quality-month fixed effects, respectively.

We report the results of this regression in Panel A of Table 5. We first examine the link between MRO participation and *-Log(Liquid assets ratio)* and *-Log(Stable funding ratio)* (Column (1)) and *Log(Liquidtiy creation ratio)* (Column (2)). We find a positive statistical relationship between MRO participation and *-Log(Liquid assets ratio)* and *Log(Liquidity creation ratio)*, while *-Log(Stable funding ratio)* does not seem to explain MRO participation. When assessing the link between 3mLTRO participation and the same explanatory liquidity risk variables (Columns (3) and (4)) we find that both the *-Log(Stable funding ratio)* and *Log(Liquidity creation ratio)* are statistically related to the 3mLTRO participation, unlike *-Log(Liquid assets ratio).*

These findings are sensible given that the *Liquid asset ratio* reflects, by construction, a bank's liquidity position (risk) on the short-term side of the balance sheet. On the other hand, the *Stable funding ratio* reflects a bank's longer-term liquidity needs. This highlights the *term* value of 3mLTRO operations relative to MRO (weekly) operations for banks requiring longer-term liquidity, despite the fact that the 3mLTRO operation does not provide any regulatory (NSFR) benefit. It also uncovers that the demand for both short-term and longer-term central bank liquidity is driven by the origin of a bank's liquidity mismatch, *i.e.* whether from reserves or sources of stable funding availability.

Our results remain consistent when we do not distinguish between any of the two SRO (Columns (5) and (6)), and find that higher liquidity risk exposure, according to all three measures, statistically explain the probability of SRO participation over the TLTRO phasing-out period.

We further test if these relations are stronger for TLTRO later exiters. We interact our explanatory variables with a *Time-to-exit* variable, which we define as the time units until the *Early exit* event normalised by the time units until the hypothetical (*HTM) exit* event. For TLTRO late- or non-exiters the *Time-to-exit* is set to 1. We report the results in Panel B of Table 5. We find that the relationship between MRO participation and *-Log(Liquid assets ratio)* is stronger the later TLTRO exit occurred (Column (1)).

distance to their pre-pandemic levels to obtain liquidity risk build-up measures during the TLTRO injection/withdrawal phases (since end December 2019).

Table 5. Liquidity risk exposure, time-to-exit TLTRO and recourse to standard refinancing operations (SRO).

This table reports results from OLS regressions at the bank-month level, where the dependent variable is a dummy variable, indicating participation in MRO (Columns (1)-(2)), in the 3mLTRO (Columns (3)-(4)) or participation in any of the two standard refinancing operations (Columns (5)-(6)). All explanatory variables are measured with one month lag, with the exception of the TLTRO repayment rate. In Panel B, the Time-to-exit refers to the time units until early exit normalised by the time units until the hypothetical hold-to-maturity exit event. All regressions include fixed effects and further controls as indicated. Standard errors are clustered at the bank level and reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Liquidity positions and demand for SRO						
Dependent variable:	MRO participation		3mLTRO participation		SRO participation *(MRO or 3mLTRO)*	
-Log(Liquid assets ratio) (t-1)	0.022**		0.001		0.024**	
	(0.009)		(0.004)		(0.010)	
-Log(Stable funding ratio) (t-1)	0.053		0.057**		0.080**	
	(0.033)		(0.023)		(0.033)	
Log(Liquidity creation ratio) (t-1)		0.076**		0.060***		0.118***
		(0.030)		(0.021)		(0.031)
R^2	0.453	0.453	0.374	0.375	0.467	0.467
Panel B: Interactions with time-to-exit TLTRO						
-Log(Liquid assets ratio) (t-1)	-0.015		-0.001		-0.014	
	(0.013)		(0.004)		(0.01)	
-Log(Liquid assets ratio) (t-1) × Time-to-exit	0.045**		0.002		0.047**	
	(0.019)		(0.007)		(0.020)	
-Log(Stable funding ratio) (t-1)	0.088		-0.022		0.087	
	(0.092)		(0.027)		(0.093)	
-Log(Stable funding ratio) (t-1) × Time-to-exit	-0.042		0.093**		-0.008	
	(0.105)		(0.046)		(0.105)	
Log(Liquidity creation ratio) (t-1)		0.022		-0.027		0.011
		(0.060)		(0.017)		(0.060)
Log(Liquidity creation ratio) (t-1) × Time-to-exit		0.067		0.109***		0.134*
		(0.077)		(0.038)		(0.078)
R^2	0.454	0.453	0.375	0.375	0.468	0.468
Bank fixed effects	x	x	x	x	x	x
Country × Month fixed effects.	x	x	x	x	x	x
SSM sign. × Month fixed effects.	x	x	x	x	x	x
Credit quality × Month fixed effects.	x	x	x	x	x	x
TLTRO repayment rate, capital ratio, minimum reserves required.	x	x	x	x	x	x
Observations	10,150	10,184	10,150	10,184	10,150	10,184
Number of banks	807	808	807	808	807	808

We also find a stronger relationship between 3mLTRO participation and *-Log(Stable fundingratio)*, in Column (3), or *Log(Liquidity creation ratio)*, in Column 4, for banks with a longer dependence on TLTRO. When we do not distinguish between the type of standard operation we only find a stronger relationship between any SRO participation and *-Log(Liquid assets ratio)* (Column (5)) or *Log(Liquidity creation ratio)* (Column 6), with the latter one being statistically weaker.

Overall, our findings indicate that higher liquidity risk exposure, measured as the inverse of our three liquidity position indicators, is linked to a greater likelihood of recourse to central bank liquidity during the TLTRO phasing-out period. Observed associations are stronger for banks exiting the TLTRO program later, supporting the liquidity (funding) dependence hypothesis for late exiters. While TLTRO unwinding was not associated with aggregate liquidity stress and the aggregate reliance on standard refinancing operations remained limited during the analyzed period;[42] as the ECB continues to reduce its balance sheet and excess liquidity, or as bank access to stable funding sources becomes constrained, demand for central bank liquidity (funding) may increase again. In this context, our findings suggest that the three measures of bank liquidity position (risk) are not only significant drivers of prolonged TLTRO reliance; they may also be viewed as key demand drivers for short- and long-term central bank liquidity going forward and consequently, key indicators of the point when reserves/stable funding sources may become scarce at the bank-level.

6 Conclusion and policy implications

Motivated by the recent policy and academic interest in central bank balance sheet normalisation and "steady-state" operational frameworks, in this paper we exploit the October 2022 TLTRO recalibration via a time-to-exit TLTRO analysis and present novel empirical evidence on the demand drivers for (long-term) central bank liquidity.

We first incorporate design features such as maturity, pricing, and collateral, as well as balance sheet characteristics such as capital (leverage) ratios and minimum reserve requirements, which we identify as significant central bank liquidity demand drivers. Since a bank's share of excess reserves or stable funding is not (strongly) linked to banks'

[42]The maximum peak of participation in SRO following the revision of TLTRO conditions in November 2022 reached EUR 34 billion at the end of 2024.

early/late exit decisions, we then draw on the existing literature to develop three bank liquidity position indicators that demonstrate a strong relationship with the demand for prolonged central bank liquidity. By uncovering their link to liquidity regulatory ratios our findings suggest a strong connection between the demand for (long-term) central bank funding and the fulfillment of regulatory liquidity ratios.

We also show that these liquidity position measures were associated with a higher probability to participate in the ECB's standard refinancing operations (SRO) during the TLTRO phasing-out period and this association was stronger for TLTRO late exiters. Moreover, since our liquidity position measures offer the advantage of distinguishing between short-term and long-term bank liquidity needs, our framework not only identifies the factors influencing the ease of exit from TLTRO but also offers a bank-level approach to monitor demand for both short-term and longer-term refinancing operations going forward.

Our findings have important policy implications, particularly relevant to the euro area. They inform the ongoing discussions on steady-state operational frameworks with demand-driven floors, such as the ECB's new operational framework. Within this framework, SRO are intended to play a central role in meeting banks' liquidity needs and ensure a smooth implementation of monetary policy. At a later stage, these operations will be complemented by new structural long-term refinancing operations, which will aim to substantially meet the banking sector's structural liquidity needs without affecting the monetary policy stance. Importantly, despite the different purpose of TLTRO compared to structural long-term refinancing operations, our findings provide valuable insights not only towards key elements of the operational framework but also for the design and activation timing of these structural long-term operations, envisaged to be calibrated in 2026. While the empirical exercise we conduct does not aim to provide a full quantification of bank-level demand for future structural long-term operations, it underpins the key drivers of such demand. Moreover, the estimated odds ratios reported in Section 4.5 quantify the relative importance of these drivers, helping policymakers to better understand which design features may matter most when calibrating the operation.

From an operations design perspective, understanding the demand drivers for both short-term and long-term central bank liquidity provision is crucial to ensure that the conditions for structural long-term operations (such as maturity, pricing, and collateral) are not excessively attractive such that they trigger low participation in SRO. The complementary provision of short-term reserves through SRO and long-term reserves via structural lending operations aims to prevent the need for frequent rollovers of large structural liquidity amounts on a weekly or monthly basis (Schnabel, 2024) and thus should not result in an overly extensive liquidity creation role for the Eurosystem.

The effective calibration of long-term operations should also carefully consider interactions between demand reserves and liquidity regulation requirements. The regulatory interpretability of our liquidity position ratios coupled with the evidence for an *NSFR value* of operations with maturities exceeding six months, suggest a link between the demand for (long-term) central bank funding and the fulfillment of regulatory liquidity ratios. Since the aim of liquidity regulation was to reduce reliance on central bank funding (Hoerova et al., 2018), our findings raise important questions from a monetary policy and financial stability perspective on the appropriate levels of desired central bank liquidity for the fulfillment of regulatory objectives. Thus, policy discussions should also address whether over-reliance on central bank funding for regulatory purposes should be curtailed *e.g.* through appropriate pricing or limits, while ensuring that no stigma is attached to these operations.

From a timing perspective, our liquidity position measures, distinguishing between short-term and long-term bank liquidity needs, could be used as monitoring indicators to identify when reserves or stable funding become scarce at the bank level, and by extension when demand for short-term versus long-term operations might increase. Consequently, they can help pinpoint optimal moments for activating the new structural long-term refinancing operations.

Finally, from a monetary policy transmission perspective, our time-to-exit analysis from TLTRO uncovers bank-specific factors that shape the speed of balance sheet reduction policies. Identified heterogenities in the ease of exiting TLTRO may have implications for how the TLTRO phasing-out transmitted to lending policies and to real outcomes. In addition, the implications outlined for the operational framework may also be relevant from a monetary policy transmission perspective. As lending conditions are influenced by how reserves are supplied to the banking system (Altavilla et al., 2023b), the impact of central bank liquidity on bank intermediation will critically hinge on the future instruments used to provide liquidity and their respective design.

References

Acharya, Viral V., Rahul S. Chauhan, Raghuram Rajan and Sascha Steffen. (2023). "Liquidity Dependence and the Waxing and Waning of Central Bank Balance Sheets". NBER Working Paper Series, 31050, National Bureau of Economic Research. http://dx.doi.org/10.3386/w31050

Acharya, Viral V., and Raghuram Rajan. (2024). "Liquidity, Liquidity Everywhere, Not a Drop to Use - Why Flooding Banks with Central Bank Reserves May Not Expand Liquidity". *Journal of Finace*, 79(5), pp. 2943-2991. https://doi.org/10.1111/jofi.13370

Allison, Paul D. (1982). "Discrete-time methods for the analysis of event histories". *Sociological Methodology*, 13, pp. 61-98. https://doi.org/10.2307/270718

Allison, Paul D. (2014). *Event History and Survival Analysis*. Quantitative Applications in the Social Sciences, 2nd ed. SAGE Publications. https://doi.org/10.4135/9781452270029

Altavilla, Carlo, Francesca Barbiero, Miguel Boucinha and Lorenzo Burlon. (2023a). "The Great Lockdown: Pandemic response policies and bank lending conditions". *European Economic Review*, 156(104478). https://doi.org/10.1016/j.euroecorev.2023.104478

Altavilla, Carlo, Massimo Rostagno and Julian Schumacher. (2023b). "Anchoring QT: Liquidity, credit and monetary policy implementation". CEPR Discussion Paper Series, 18581, Centre for Economic Policy Research. https://ideas.repec.org/p/cpr/ceprdp/18581.html

Andreeva, Desislava C., and Miguel García-Posada. (2021). "The impact of the ECB's targeted long-term refinancing operations on banks' lending policies: The role of competition". *Journal of Banking & Finance*, 122(105992). https://doi.org/10.1016/j.jbankfin.2020.105992

Andreeva, Desislava, Anna Samarina and Lara Sousa Faria. (2025). "Leverage Actually: The Impact on Banks' Borrowing Costs in Euro Area Money Markets". ECB Working Paper Series, 3016, European Central Bank. http://dx.doi.org/10.2139/ssrn.5123501

Barbiero, Francesca, Miguel Boucinha and Lorenzo Burlon. (2021). "TLTRO III and bank lending conditions". Economic Bulletin Articles, 6, European Central Bank. https://ideas.repec.org/a/ecb/ecbart/202100062.html

Barbiero, Francesca, Lorenzo Burlon, Maria Dimou and Jan Toczynski. (2024). "Targeted monetary policy, dual rates, and bank risk-taking". *European Economic Review*, 170(104889). https://doi.org/10.1016/j.euroecorev.2024.104889

Berger, Allen N., and Christa H. S. Bouwman. (2009). "Bank Liquidity Creation". *The Review of Financial Studies*, 22(9), pp. 3779-3837. https://doi.org/10.1093/rfs/hhn104

Bonfim, Diana, and Moshe Kim. (2019). "Liquidity Risk and Collective Moral Hazard". *International Journal of Central Banking*, 15(2), pp. 101-150. https://www.ijcb.org/journal/ijcb19q2a4.htm

Bonfim, Diana, and Carla Soares. (2018). "The Risk Taking Channel of Monetary Policy: Exploring All Avenues". *European Economic Review*, 50(7), pp. 1507-1541. https://doi.org/10.1111/jmcb.12500

Burlon, Lorenzo, Alessandro Ferrari, Stephen Kho and Nikoleta Tushteva. (2025). "Why Gradual and Predictable? Bank Lending During the Sharpest Quantitative Tightening Ever". ECB Working Paper Series, 3010, European Central Bank. http://dx.doi.org/10.2139/ssrn.5091139

Cox, David R. (1972). "Regression Models and Life-Tables". *Journal of the Royal Statistical Society. Series B (Methodological)*, 34(2), pp. 187-220. https://doi.org/10.1111/j.2517-6161.1972.tb00899.x

Da Silva, Emilie, Vincent Grossmann-Wirth, Benoît Nguyen and Miklos Vari. (2021). "Paying Banks to Lend? Evidence from the Eurosystem's TLTRO and the Euro Area Credit Registry". SSRN. http://dx.doi.org/10.2139/ssrn.3956108

Drechsler, Itamar, Thomas Drechsel, David Marques-Ibanez and Philipp Schnabl. (2016). "Who Borrows from the Lender of Last Resort?". *Journal of Finance*, 71(5), pp. 1933-1974. https://doi.org/10.1111/JOFI.12421

Fudulache, Adina-Elena, and Martin R. Goetz. (2023). "Long-Term Deposit Funding and Demand for Central Bank Funds: Evidence from Targeted Longer-Term Refinancing Operations". Deutsche Bundesbank Discussion Paper Series, 12/2023, Deutsche Bundesbank. https://doi.org/10.2139/ssrn.4537002

Hoerova, Marie, Caterina Mendicino, Kalin Nikolov, Glenn Schepens and Skander Van den Heuvel. (2018). "Benefits and costs of liquidity regulation". ECB Working Paper Series, 2169, European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2169.en.pdf

Hudepohl, Tom, and Suzanne Malderez. (2024). "The use of the Eurosystem's monetary policy instruments and its monetary policy implementation framework in 2022 and 2023". ECB Occasional Paper Series, 355, European Central Bank. https://doi.org/10.2866/786599

Kaplan, Edward L., and Paul Meier. (1959). "Nonparametric Estimation from Incomplete Observations". *Journal of the American Statistical Association*, 53, pp. 457-481. https://doi.org/10.1080/01621459.1958.10501452

Kashyap, Anil K., Raghuram Rajan and Jeremy Stein. (2002). "Banks as Liquidity Providers: An Explanation for the Coexistence of Lending and Deposit-Taking". *The Journal of Finance*, 57(1), pp. 33-73. https://doi.org/10.1111/1540-6261.00415

Kedan, Danielle, and Alexia Ventula Veghazy. (2021). "The Implications of Liquidity Regulation for Monetary Policy Implementation and the Central Bank Balance Sheet Size: An Empirical Analysis of the Euro Area". ECB Working Paper Series, 2515, European Central Bank. http://dx.doi.org/10.2139/ssrn.3797135

Lopez-Salido, David, and Annette Vissing-Jorgensen. (2023). "Reserve Demand, Interest Rate Control, and Quantitative Tightening". SSRN. http://dx.doi.org/10.2139/ssrn.4371999

Rezende, Marcelo, Mary-Frances Styczynski and Cindy M. Vojtech. (2021). "The Effects of Liquidity Regulation on Bank Demand in Monetary Policy Operations". *Journal of Financial Intermediation*, 46(100860). https://doi.org/10.1016/j.jfi.2020.100860

Saporta, Victoria. (2024). "Let's get ready to repo!". Speech given at Association for Financial Markets in Europe (AFME), London 22 July 2024. https://www.bankofengland.co.uk/-/media/boe/files/speech/2024/july/lets-get-ready-to-repo-speech-by-victoria-saporta

Schnabel, Isabel. (2024). "The Eurosystem's operational framework". Speech at the Money Market Contact Group meeting, 14 March 2024. https://www.ecb.europa.eu/press/key/date/2024/html/ecb.sp240314~8b609de772.en.html

Singer, Judith D., and John B. Willett. (1993). "It's about Time: Using Discrete-Time Survival Analysis to Study Duration and the Timing of Events". *Journal of Educational Statistics*, 18(2), pp. 155-195. https://doi.org/10.2307/1165085

Steven, Ongena, and David C. Smith. (2001). "The duration of bank relationships". *Journal of Financial Economics*, 61(3), pp. 449-475. https://doi.org/10.1016/S0304-405X(01)00069-1

Vergote, Olivier, and Tomohiro Sugo. (2020). "Who Takes the Ecb's Targeted Funding?". ECB Working Paper Series, 2439, European Central Bank. http://dx.doi.org/10.2139/SSRN.3644249

Vissing-Jorgensen, Annette. (2023). "Balance sheet policy above the effective lower bound". Paper presented at the ECB Forum on Central Banking, 26-28. June 2023, Sintra, Portugal. https://www.ecb.europa.eu/press/conferences/ecbforum/shared/pdf/2023/VissingJorgensen_paper.pdf

Appendix A Impact of recalibration on TLTRO rates

This appendix details the impact of the TLTRO recalibration on the final TLTRO interest rates at the announcement date, under the assumption that all banks would hold their TLTRO funds until final maturity. For simplicity of notatios, we also assume that all lending performance targets set under the TLTRO program were met by all banks, that is, the ECB policy rate applicable to all banks and in all calculations is the lowest one, namely the deposit facility rate (DFR).[43]

In the following notations:

- $t_{j,0}$ refers to the time of entry in operation j (*i.e.* the settlement date);
- $t_{j,p}$ refers to the time of exit from operation j (*i.e.* the early repayment date or final maturity); In the computations below we however assume that that $t_{j,p}$ is always the final maturity date of operation j ;
- TLTRO final rate$_j$ refers to the interest rate applied for the life of a TLTRO operation j, namely from $t_{j,0}$ to $t_{j,p}$;
- r_k refers to the TLTROIII interest rate over a period k;
- SIRP refers to the Special Interest Rate Period and means the period from 24 June 2020 to 23 June 2021; over this period, the applicable TLTRO interest rate was 50 basis points below the average DFR, which equaled -1%;
- pre-SIRP refers to the period between an operation's settlement ($t_{j,0}$) and 24 June 2020, where applicable;
- ASIRP refers to the Additional Special Interest Rate Period, which is the period from 24 June 2021 to 23 June 2022. Over ASIRP, the applicable TLTRO interest rate was also 50 basis points below the average DFR, which also equaled -1%;
- SIRP-ASIRP refers to the period between the start of the SIRP and the end of the ASIRP, namely the period spanning from 24 June 2020 to 23 June 2022;

[43]If participating banks did not outperform their lending benchmarks, a linear combination between the DFR and the interest rates on the main refinancing operations (MRO rate) applied, which in turn depended on bank-specific lending outcomes with respect to these targets. For more details on the TLTRO interest rates computations please see Decision (EU) 2019/1311 of the European Central Bank of 22 July 2019 on a third series of targeted longer-term refinancing operations (ECB/2019/21).

- post-ASIRP refers to the period starting with the end of ASIRP, namely the period spanning from 23 June 2022 until the time of exit from an operation ($t_{j},_{p}$);

- ASIRP-Nov22 refers to the period from the end of ASIRP period, that is 23 June 2022 until the time of exit from an operation ($t_{j},_{p}$);

- post-Nov22 refers to the period from 23 November 2022 until the time of exit from an operation ($t_{j},_{p}$);

- t_1 is the start of the SIRP, that is 24 June 2020;t_2 is the end of the ASIRP, that is 23 June 2022; t_3 is the start date of the implementation of the new TLTRO conditions, that is November 2022;

- $N(t_k, t_l)$ refers to the number of days between t_k and t_l, and

- $\overline{\text{DFR}}(t_k, t_l)$ refers to the average DFR rate between times t_k and t_l;

- $\text{TLTRO}_{i,j}$(Sep.22) refers to the outstanding TLTRO amount of bank i in operation j at the end of September 2022, *i.e.* prior to the recalibration;

- TLTRO_i(Sep.22) refers to the total outstanding TLTRO amount of bank i at the end of September 2022, *i.e.* prior to the recalibration.

Before the calibration, the final interest rate on each operation j was computed as follows:

$$\begin{aligned}
\text{TLTRO final rate}_j =& \frac{N(t_{j,0}, t_1)}{N(t_{j,0}, t_{j,p})} \times r_{\text{pre-SIRP}} + \frac{N(t_1, t_2)}{N(t_{j,0}, t_{j,p})} \times r_{\text{SIRP-ASIRP}} + \dots \\
& \frac{N(t_2, t_{j,p})}{N(t_{j,0}, t_{j,p})} \times r_{\text{post-ASIRP}} \qquad (1) \\
=& \frac{N(t_{j,0}, t_1)}{N(t_{j,0}, t_{j,p})} \times \overline{\text{DFR}}(t_{j,0}, t_{j,p}) + \frac{N(t_1, t_2)}{N(t_{j,0}, t_{j,p})} \times (-1\%) + \dots \\
& \frac{N(t_2, t_{j,p})}{N(t_{j,0}, t_{j,p})} \times \overline{\text{DFR}}(t_{j,0}, t_{j,p}) \qquad (2)
\end{aligned}$$

The recalibration consisted of the split of the last interest rate segment of the pricing $(t_2, t_{j},_{p})$ into two legs:

- The first leg (t_2, t_3) that ended on the date of recalibration on 23 November 2022, *i.e.* that spanned the ASIRP-Nov22 period defined in the notations above. The interest rate applicable over this leg was indexed to the average DFR during that period.

- The second leg $(t_3, t_{j,p})$ starting with the date of recalibration and lasting until the repayment of the operations, *i.e.* spanning the post-Nov22 period defined in the notations above. The TLTRO interest rate applicable over this leg was indexed to the average DFR during that period.

After the recalibration, the final interest rate on each operation j was computed as follows:

$$\begin{aligned}
\text{TLTRO final rate}_j =& \frac{N(t_{j,0},t_1)}{N(t_{j,0},t_{j,p})} \times r_{\text{pre-SIRP}} + \frac{N(t_1,t_2)}{N(t_{j,0},t_{j,p})} \times r_{\text{SIRP-ASIRP}} + \dots \\
& \frac{N(t_2,t_3)}{N(t_{j,0},t_{j,p})} \times r_{\text{ASIRP-Nov22}} + \frac{N(t_3,t_{j,p})}{N(t_{j,0},t_{j,p})} \times r_{\text{post-Nov22}} \qquad (3) \\
=& \frac{N(t_{j,0},t_1)}{N(t_{j,0},t_{j,p})} \times \overline{\text{DFR}}(t_{j,0},t_{j,p}) + \frac{N(t_1,t_2)}{N(t_{j,0},t_{j,p})} \times (-1\%) + \dots \\
& \frac{N(t_2,t_3)}{N(t_{j,0},t_{j,p})} \times \overline{\text{DFR}}(t_2,t_3) + \frac{N(t_3,t_{j,p})}{N(t_{j,0},t_{j,p})} \times \overline{\text{DFR}}(t_3,t_{j,p}) \qquad (4)
\end{aligned}$$

Thus, the recalibration yielded the following:

- At the **operation level**, for each operation $j = 2, \cdots, 10$:

$$\Delta\text{TLTRO rate post-Nov.22}_j = \overline{\text{DFR}}(t_3,t_{j,p}) - \overline{\text{DFR}}(t_{j,0},t_{j,p}) \qquad (5)$$

$$\begin{aligned}
\Delta\text{TLTRO final rate}_j =& \Bigg[\frac{N(t_2,t_3)}{N(t_{j,0},t_{j,p})} \times \left[\overline{\text{DFR}}(t_{j,0},t_3) - \overline{\text{DFR}}(t_{j,0},t_{j,p})\right] + \\
& \frac{N(t_3,t_{j,p})}{N(t_{j,0},t_{j,p})} \times \left[\overline{\text{DFR}}(t_3,t_{j,p}) - \overline{\text{DFR}}(t_{j,0},t_{j,p})\right]\Bigg] \qquad (6)
\end{aligned}$$

- At the **bank level**, for each bank i in our sample:

$$\Delta\text{TLTRO rate post-Nov.22}_i = \sum_{j=2}^{10} \text{TLTRO post Nov22}_j \cdot \frac{\text{TLTRO}_{i,j}(Sep.22)}{\text{TLTRO}_i(Sep2.2)} \qquad (7)$$

$$\Delta\text{TLTRO final rate}_i = \sum_{j=2}^{10} \text{TLTRO final rate}_j \cdot \frac{\text{TLTRO}_{i,j}(Sep.22)}{\text{TLTRO}_i(Sep.22)} \qquad (8)$$

Appendix B Discrete-time extension of the Cox proportional hazard model

Notations. In our setting, time takes discrete values $t = 1, 2, ..., 8$, corresponding to the early exit (repayment) times available to banks after recalibration, namely November 2022, December 2022, January 2023, February 2023, March 2023, June 2023, September 2023 and December 2023.

We observe 820 participating banks in TLTRO, indexed by $i = 1, ..., 820$. We also observe a $K \times 1$ vector of country-specific and bank-specific explanatory variables $X_{i,t}$ which can be constant or time-varying. We denote by $\gamma_{i,t}$ the event indicator describing whether bank i experiences an early exit at time t.

Let t_i be the point in time when either the early exit event occurred for bank i or the observation is censored. Censoring means that a bank is observed at t_i but not at $t_i + 1$. In our setting, censoring may happen for one of two reasons: the bank is no longer at early exit risk because it already exited via the hold-to-maturity competing strategy or the bank was still at risk but it did not experience the early exit event by the end of the study. Additionally, let δ_i be a censoring variable which takes a value equal to 1 if a bank observation is uncensored and 0 if censored. Finally, we denote by T_i the discrete random variable that indicates the uncensored early exit time for bank i.

Survival dataset and risk set. We pool all bank observations with their early exit indicator variable $\gamma_{i,t}$ and covariates of interest $X_{i,t}$ from $t = 1$ until t_i, that is, the point at which either the early exit event occurred for bank i or the observation is censored. We refer to this pool as the *survival dataset*. We refer to the set of banks included in the survival dataset, *i.e.* "survivor" banks in each time period, as the *risk set*.[44]

Formulating the model. An early exit event at bank level given observed characteristics $X_{i,t}$ can be characterized in two different ways: its hazard and survival probabilities.

The discrete-time **hazard probability** (or hazard function) is the conditional probability that a TLTRO early exit occurred for bank i at time t given that the event had

[44] Panel C of the Life Table (Table C1 of Appendix C) reports the number of banks at early exit risk at each discrete-time period in our model.

not already occurred, *i.e.* the bank is still at risk of early exit:

$$h_{i,t} = \Pr\left[T_i = t | T_i \geq t, X_{i,t}\right] \tag{1}$$

The discrete-time **survival probability** (or survivor function) $S_{i,t}$ is the probability that bank i will survive (*i.e.* remain in TLTRO) beyond an exit time t. In our model this is not modeled explicitly. It can however be derived from hazard probabilities:[45]

$$S_{i,t} = \Pr\left[T_i > t | X_{i,t}\right] \tag{2}$$

$$= (1 - h_{i,1}) \cdot (1 - h_{i,2}) \cdot ... \cdot (1 - h_{i,t-1}). \tag{3}$$

We follow Cox (1972) to specify how the discrete-time hazard of our event of interest depends on time t and the set of explanatory variables $X_{i,t}$. Specifically, the Cox proportional hazard rate model can be generalized in discrete time as follows:

$$\frac{h_{i,t}}{1 - h_{i,t}} = \frac{h_{0,t}}{1 - h_{0,t}} \cdot e^{\beta' \cdot X_i, t} \tag{4}$$

where $\frac{h_{i,t}}{1-h_{i,t}}$ represents the odds of early exit at time t of bank i, $h_{0,t}$ is the *baseline hazard* of early exit at time t (and remains in general unspecified), $\frac{h_{0,t}}{1-h_{0,t}}$ is the *baseline odds* of early exit, and β is a vector of parameters capturing the relative risk associated with the covariates of interest. Taking the logarithm of both sides of Equation 4 we obtain a logistic dependence of the hazard on time and explanatory variables (Cox, 1972; Allison, 1982; Singer and Willett, 1993):

$$\log\left(\frac{h_{i,t}}{1 - h_{i,t}}\right) = f(t) + \beta' \cdot X_i, t \tag{5}$$

where $f(t)$ is the logit transformation of the baseline hazard or the *baseline logit-hazard.*

Following Cox (1972); Allison (1982); Singer and Willett (1993) we do not assume a specific functional form for the temporal shape of the baseline logit-hazard. Instead, we allow for time-variation in the hazard by setting $f(t) = \alpha_t$ $(t = 1, 2, ..., 8)$. α_t are constant

[45] In the case of Kaplan-Meier estimates survival probabilities were also derived from hazard probabilities, as explained in Table C1 of Appendix C.

for each exit (repayment) time. The discrete-time hazard model then becomes:

$$\log\left(\frac{h_{i,t}}{1-h_{i,t}}\right) = \alpha_t + \beta' \cdot X_i, t \text{ ; where} \tag{6}$$

$$\alpha_t = \log\left(\frac{h_{0,t}}{1-h_{0,t}}\right). \tag{7}$$

Proportionality assumption. As noted by Singer and Willett (1993) the discrete-time hazard model has the attributes of: (i) a baseline risk profile given by the baseline hazard (odds) of event occurrence, and (ii) a vector of shift parameters that capture the effects of different covariates on the baseline profile on a logistic scale. In our setting, exponentiated β parameters represent the shift parameters of the baseline odds of early exit associated with the covariates of interest.

These attributes imply that the odds profiles corresponding to different values of a covariate are amplifications or reductions of one another, *i.e.* they are proportional. This proportional-odds consequence of the discrete-time hazard model is equivalent to the proportional hazards assumption in the Cox regression model. However, when the magnitude of hazard probabilities is small the odds of an event occurring is approximately equal to the probability of it occuring. Hence when this is the case the proportional-odds assumption is approximately equal to a proportional-hazards assumption.

Estimating the model. Allison (1982) notes that the likelihood of the model represented by Equation 6 may be written as:

$$L = \prod_{i=1}^{n} \left[\Pr(T_i = t_i\right]^{\delta_i} \left[\cdot[\Pr(T_i > t_i)\right]^{1-\delta_i}, \tag{8}$$

where each of the two probabilities in Equation 8 can be expressed as a function of the hazard probability $h_{i,t}$:

$$\Pr(T_i = t) = h_{i,t} \cdot \prod_{j=1}^{t-1}(1 - h_{i,j}) \tag{9}$$

$$\Pr(T_i > t) = \frac{h_{i,t}}{1-h_{i,t}} \cdot \prod_{j=1}^{t}(1 - h_{i,j}). \tag{10}$$

Substituting the two probabilities in Equation 8 and taking logarithms yields the log-likelihood function:

$$\log L = \sum_{i=1}^{n} \delta_i \log\left(\frac{h_{i,t_i}}{1-h_{i,t_i}}\right) + \sum_{i=1}^{n}\sum_{j=1}^{t_i} \log(1-h_{i,j}). \tag{11}$$

After further manipulation of the first term by introducing the early exit indicator $\gamma_{i,t}$, Allison (1982) also notes that the log-likelihood function can be re-written as follows:

$$\log L = \sum_{i=1}^{n}\sum_{j=1}^{t_i} \gamma_{i,t} \log\left(\frac{h_{i,j}}{1-h_{i,j}}\right) + \sum_{i=1}^{n}\sum_{j=1}^{t_i} \log(1-h_{i,t}). \tag{12}$$

The above derivation is equivalent to the log-likelihood function for the regression analysis of a dichotomous dependent variable. In our case this corresponds to the early exit indicator variable $\gamma_{i,t}$ but only for bank level observations comprised between t and t_i, *i.e.* the observations captured by the survival dataset.

To estimate the parameters of the discrete-time hazard model in Equation 6 we use the appropriate data structure, *i.e* the survival dataset, and apply standard logistic regression to regress the early exit event variable on (i) a set of dummy variables for the the exit (repayment) times and (ii) the set of explanatory variables included in $X_{i,t}$, using the method of maximum likelihood.

Appendix C Additional Tables

Table C1. TLTRO Life tables

This table summarizes the exit behaviour from TLTROs of a sample of 820 banks at each repayment time following the recalibration until end 2023. The exit behaviour descriptive statistics are based on the three TLTRO exit events described in Section 2, namely the Hold-to-maturity (HTM) exit event, which assumes that that all banks keep their TLTRO funds until maturity (Panel A), the Realised exit event (Panel B) and the Early (voluntary) exit event (Panel C). In each panel, the estimated hazard and survival probabilities are derived with the Kaplan-Meier method. The hazard probability in each period is given by the number of exiters in the given period divided by the number of surviving banks at the beginning of the period (number at risk). For each period, the survival probability is the product of the complement of hazard probabilities until that period.

Panel A: Hold-to-maturity exit event					
Months/ quarters to HTM exit	HTM exit time	No of banks at risk of HTM exit	No of HTM exiters	Estimated hazard probability	Estimated survival probability
1	Nov-22	820	0	0.0%	100.0%
2	Dec-22	808	0	0.0%	100.0%
3	Jan-23	808	0	0.0%	100.0%
4	Feb-23	808	0	0.0%	100.0%
5	Mar-23	805	8	1.0%	99.0%
6	Jun-23	794	396	49.9%	49.6%
7	Sep-23	393	172	43.8%	27.9%
8	Dec-23	220	49	22.3%	21.7%
Panel B: Realised exit event					
Months/ quarters to realised exit	Realised exit time	No of banks at risk of realised exit	N0 of actual exiters	Estimated hazard probability	Estimated survival probability
1	Nov-22	820	123	15.0%	85.0%
2	Dec-22	685	69	10.1%	76.4%
3	Jan-23	615	30	4.9%	72.7%
4	Feb-23	585	37	6.3%	68.1%
5	Mar-23	548	41	7.5%	63.0%
6	Jun-23	505	260	51.5%	30.6%
7	Sep-23	243	108	44.4%	17.0%
8	Dec-23	134	47	35.1%	11.0%
Panel C: Early (voluntary) exit event (Event of interest)					
Months/ quarters to early exit	Early exit time	N0 of banks at risk of early exit	No of early exiters	Estimated hazard probability	Estimated survival probability
1	Nov-22	820	123	15.0%	85.0%
2	Dec-22	680	69	10.2%	76.4%
3	Jan-23	610	30	4.9%	72.6%
4	Feb-23	580	34	5.9%	68.4%
5	Mar-23	540	32	5.9%	64.3%
6	Jun-23	329	19	5.8%	60.6%
7	Sep-23	222	19	8.6%	55.4%
8	Dec-23	173	18	10.4%	49.6%

Table C2. Construction of liquidity position measures

This table summarises the construction of the three liquidity position measures based on the Berger and Bouwman (2009) framework for bank liquidity creation (BB framework) and the Claims to Potential Liquidity measure by Acharya et al. (2023) (ACRS framework).

Panel A: ASSETS (BB framework)	
Illiquid assets **(weight = $\frac{1}{2}$)** Loans to NFC and HH euro area ¿1Y Loans outside the euro area	**Liquid assets** **(weight = - $\frac{1}{2}$)** Cash Excess liquidity with the Eurosystem (Unencumbered) Govies-like securities holdings
Panel B: LIABILITIES AND EQUITY (BB framework)	
Liquid (Demandable) liabilities **(weight = $\frac{1}{2}$)** Money market deposits (interbank and from MMFs) Other wholesale deposits	**Illiquid (Stable) liabilities and equity*** **(weight = -$\frac{1}{2}$)** Sight and time retail deposits TLTROs >6m Other central bank long-term operations ¿6m Debt issuance >1Y *Capital and reserves*
Panel C: OFF-BALANCE SHEET ACTIVITIES (BB framework)	
Unusued loan commitments **(weight = $\frac{1}{2}$)**	
Panel D: LC CAT/MAT FAT (BB framework) and Inverse liquidity creation measure	
Mat fat Liquidity Creation (BB)	$\frac{1}{2}$·Illiquid assets + $\frac{1}{2}$·Liquid liabilities + $\frac{1}{2}$·Unused loan commitments - $\frac{1}{2}$·Illiquid liabilities -$\frac{1}{2}$·Liquid assets
Inverse liquidity creation ratio	*(Iliquid liabilities+ Liquid assets)/(Iliquid assets+Liquid liabilities + Iliquid guarantees)*
Panel E: Liquid assets ratio and Stable funding ratio	
Liquid assets gap	$\frac{1}{2}$·liquid liabilities + $\frac{1}{2}$·Unused loan commitments - $\frac{1}{2}$·Liquid assets
Liquid assets ratio	***Liquid assets / (Liquid liabilities + illiquid guarantees)*** ***= 1 / Claims to Potential Liquidity (ACRS)***
Stable funding gap	$\frac{1}{2}$· Illiquid assets - $\frac{1}{2}$·Illiquid liabilities and equity
Stable funding ratio	***Illiquid liabilities / Illiquid assets***

Table C3. Liquidity position measures and regulatory ratios for the subsample of Spanish participating banks

This table reports results from an OLS regression at the bank-quarter level over the period Q3 2022-Q42023. The dependent variables in each panel are the liquidity profile measures constructed on the basis of the Berger and Bouwman (2009) framework for bank liquidity creation (BB framework) and the *Claims to Potential Liquidity* measure by Acharya et al. (2023) (ACRS) while the explanatory variables are the liquidity regulatory ratios, namley the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The sample of banks is restricted to Spanish TLTRO participating banks, for which we obtain the LCR and NSFR values. All regressions include fixed effects as indicated. Standard errors are clustered at the bank level and reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1%, respectively.

Panel A: Liquid assets ratio and LCR		
	(1)	(2)
Dependent variable:	Liquid assets ratio (Liquid assets / Claims on liquidity)	
LCR	0.529*** (0.033)	0.369*** (0.087)
Bank fixed effects		x
Time (Quarter) fixed effects	x	x
R-squared	0.63	0.76
Observations	203	203
Number of banks	34	34

Panel B: Stable funding ratio and NSFR		
	(1)	(2)
Dependent variable:	Stable funding ratio (Stable funding / Illiquid assets)	
NSFR	0.607*** (0.097)	0.688*** (0.171)
Bank fixed effects		x
Time (Quarter) fixed effects	x	x
R-squared	0.53	0.90
Observations	203	203
Number of banks	34	34

Table C4. Drivers and mitigants of TLTRO early exit (magnitudes)

This table reports results from logistic regressions applied to the survival dataset, estimating the discrete-time hazard probability to exit early from TLTROs via maximum likelihood. In the variable notation, (t_0) is used to label explanatory variables measured before the announcement date of the TLTRO change, $(t-1)$ is used to label time-varying variables, measured with one moth lag with respect to each repayment date, while (t_0) is used to used to label time-varying variables, pre-defined before recalibration and measured contemporaneously . All regressions include repayment time, country and credit quality fixed effects and additional controls as indicated. Robust standard errors reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All numerical variables are scaled by their standard deviation. All coefficients are reported on the odds scale.

	(1)	(2)
Dependent variable:	TLTRO early exit	
Credit demand (t)	0.777**	0.776**
	(0.082)	(0.080)
Financial stress (t)	0.872	0.841
	(0.102)	(0.094)
TLTRO HTM <6m (t) / Total assets (t0)	1.137*	1.154*
	(0.083)	(0.085)
TLTRO HTM 6m-1y (t) / Total assets (t0)	0.783***	0.793***
	(0.059)	(0.059)
TLTRO HTM >1y (t) / Total assets (t0)	0.655***	0.656***
	(0.078)	(0.079)
Δ TLTRO final rate HTM (t)	1.236***	1.233***
	(0.098)	(0.097)
Govies-like collateral / TLTRO (t0)	1.210***	1.261***
	(0.066)	(0.068)
SSM significance (t0)	1.501**	1.586**
	(0.300)	(0.323)
Capital (leverage) ratio (t-1)	0.804***	0.773***
	(0.052)	(0.053)
Minimum reserves / Total Assets (t-1)	0.782***	0.825***
	(0.057)	(0.054)
Log (Liquid assets ratio) (t-1)	1.382***	
	(0.140)	
Log (Stable funding ratio) (t-1)	1.234***	
	(0.098)	
Log (Inverse liquidity creation ratio) (t-1)		1.472***
		(0.143)
Exit time (repayment) dummies	x	x
Country dummies	x	x
Credit quality dummies	x	x
Observations	3,944	3,944

Table C5. Robustness: Alternative time dependency, time-invariant bank characteristics and alternative censoring

This table reports results from logistic regressions applied to the survival dataset, estimating the discrete-time hazard probability to exit early from TLTROs via maximum likelihood. In columns (1), (2), (5) and (6) the last five regressors are time-varying, while in Columns (3) and (4) they are time-invariant. All regressions include repayment time, country and credit quality fixed effects as indicated. Robust standard errors reported in parentheses. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All coefficients are reported on the logit hazards scale.

	(1)	(2)	(3)	(4)	(5)	(6)
	Alternative time dependency		*Time-invariant bank characteristics*		Alternative censoring	
Dependent variable:			TLTRO early exit			
Credit demand (t)	-0.016 (0.010)	-0.016 (0.010)	-0.030*** (0.011)	-0.027** (0.011)	-0.032*** (0.011)	-0.033*** (0.011)
Financial stress (t)	0.273 (1.000)	0.116 (0.985)	-1.483 (1.293)	-1.942 (1.256)	-2.332* (1.274)	-2.690** (1.230)
TLTRO HTM< 6m (t) (t0) / Total assets	4.388* (2.345)	4.808** (2.346)	4.059* (2.378)	4.166* (2.369)	6.177*** (2.299)	6.652*** (2.298)
TLTRO HTM 6m-1y (t) / Total assets (t0)	-9.000*** (2.803)	-8.519*** (2.769)	-9.292*** (2.914)	-8.744*** (2.893)	-8.383*** (2.893)	-7.872*** (2.872)
TLTRO HTM >1y (t) / Total assets (t0)	-13.328*** (3.743)	-13.308*** (3.771)	-13.379*** (3.825)	-13.452*** (3.848)	-13.806*** (3.904)	-13.806*** (3.934)
Δ TLTRO final rate HTM (t)	2.678*** (0.793)	2.641*** (0.788)	2.349*** (0.778)	2.102*** (0.762)	3.256*** (0.704)	3.260*** (0.701)
Govies-like collateral / TLTRO (t0)	0.486*** (0.131)	0.578*** (0.131)	0.458*** (0.133)	0.556*** (0.133)	0.437*** (0.130)	0.536*** (0.128)
SSM significance (t0)	0.476** (0.197)	0.528*** (0.201)	0.439** (0.201)	0.454** (0.203)	0.381* (0.199)	0.434** (0.203)
Capital (leverage) ratio (t-1) *Capital (leverage) ratio (t0)*	-6.085*** (2.011)	-7.297*** (0.002)	-7.477*** (1.944)	-8.449*** (0.002)	-7.545*** (2.056)	-8.793*** (0.002)
Minimum reserves / Total Assets (t-1) *Minimum reserves / Total Assets (t0)*	-69.746*** (21.845)	-55.581*** (20.191)	-65.699*** (22.240)	-45.838** (19.982)	-68.658*** (21.288)	-53.816*** (19.556)
Log (Liquid assets ratio) (t-1) *Log (Liquid assets ratio) (t0)*	0.269*** (0.090)		0.315*** (0.095)		0.279*** (0.091)	
Log (Stable funding ratio) (t-1) *Log (Stable funding ratio) (t0)*	0.515*** (0.175)		0.472*** (0.164)		0.489*** (0.172)	
Log (Inverse liquidity creation ratio) (t-1) *Log (Inverse liquidity creation ratio) (t0)*		0.777*** (0.196)		0.787*** (0.188)		0.772*** (0.197)
Exit time	-1.205*** (0.152)	-1.221*** (0.152)				
Exit time squared	0.124*** (0.017)	0.126*** (0.018)				
Exit time (repayment) dummies			x	x	x	x
Country dummies	x	x	x	x	x	x
Credit quality dummies	x	x	x	x	x	x
Observations	3,923	3,944	3,913	3,945	4,518	4,539

Table C6. Robustness: Alternative link with bank characteristics and unobserved heterogeneity

This table reports results from complementary log-log (Columns (1) and (2)) and logistic (Columns (3) and (4)) estimating the discrete-time hazard probability to exit early from TLTROs. All regressions include exit time, country and credit quality fixed effects and bank random effects as indicated. In Columns (1) and (2) robust standard errors are reported in parentheses while in Columns (4) and (5) standard errors are clustered at the bank level. *, **, *** mean significance at 10%, 5%, and 1% percent, respectively. All coefficients are reported on the logit hazards scale.

	(1)	(2)	(3)	(4)
	C log-log link		Unobserved heterogenity	
Dependent variable:	TLTRO early exit			
Credit demand (t)	-0.025**	-0.024**	-0.025*	-0.025*
	(0.010)	(0.010)	(0.014)	(0.014)
Financial stress (t)	-1.801	-2.150*	-0.611	-0.895
	(1.197)	(1.140)	(1.881)	(2.008)
TLTRO HTM <6m (t) / Total assets (t0)	3.655*	4.107*	2.495	2.771
	(2.210)	(2.231)	(3.501)	(3.694)
TLTRO HTM 6m-1y (t) / Total assets (t0)	-8.917***	-8.436***	-17.936**	-18.856**
	(2.820)	(2.786)	(7.848)	(9.265)
TLTRO HTM >1y (t) / Total assets (t0)	-12.486***	-12.527***	-20.941***	-22.309**
	(3.580)	(3.607)	(7.773)	(9.606)
Δ TLTRO final rate HTM (t)	1.801**	1.779**	3.102**	3.382**
	(0.707)	(0.700)	(1.420)	(1.642)
Govies-like collateral / TLTRO (t0)	0.411***	0.504***	1.076*	1.379*
	(0.112)	(0.110)	(0.620)	(0.782)
SSM significance (t0)	0.369**	0.415**	0.770*	0.949*
	(0.182)	(0.185)	(0.432)	(0.512)
Capital (leverage) ratio (t-1)	-6.353***	-7.709***	-13.221**	-16.463**
	(1.901)	(0.002)	(6.107)	(0.008)
Minimum reserves / Total Assets (t-1)	-67.278***	-53.514***	-123.096**	-105.085**
	(20.201)	(18.639)	(48.811)	(50.535)
Log (Liquid assets ratio) (t-1)	0.273***		0.478**	
	(0.085)		(0.201)	
Log (Stable funding ratio) (t-1)	0.408**		0.956**	
	(0.159)		(0.479)	
Log (Inverse liquidity creation ratio) (t-1)		0.724***		1.483**
		(0.175)		(0.643)
Exit time (repayment) dummies	x	x	x	x
Country dummies	x	x	x	x
Credit quality dummies	x	x	x	x
Bank random effect			x	x
Observations	3,923	3,944	3,923	3,944

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