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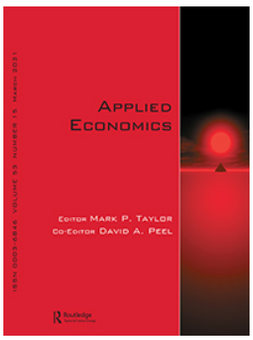

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The impact of central bank liquidity support on banks' sovereign exposures

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ABSTRACT

We empirically analyse the relationship between longer term central bank liquidity support and banks' exposures to governments, using difference-in-differences panel regressions and propensity score matching on a large sample of banks in the euro area. The research question is whether the liquidity operations, which were introduced to prevent disorderly deleveraging, can also be linked to unintended changes in banks' asset allocations, in particular to carry trades in government bonds. The results show that unconditional and conditional refinancing operations have a different effect on banks' government exposures. Unconditional longer-term refinancing operations went together with more carry trades in stressed countries, i.e. banks borrowing more while increasing their holdings of government bonds. In contrast, refinancing operations that were conditional on banks' lending were not associated with such carry trades, highlighting the benefits of conditionality attached to long-term refinancing operations.

KEYWORDS

Central bank liquidity; banking; financial intermediation; monetary transmission

JEL CLASSIFICATION

E52; G11; G32

I. Introduction

Following the emergence of financial market tensions in 2007, Eurosystem liquidity support to banks expanded considerably in order to prevent disorderly deleveraging and to support lending to the real economy. The longer-term refinancing operations (LTROs) in particular allowed banks to replace the dried up wholesale funding with central bank funding and were crucial in containing the systemic threat posed by the crisis (Giannone et al. 2012). While the relatively long-term liquidity support programmes prevented a serious credit crunch in the euro area, they may have had other effects on banks' balance sheets, such as reducing the pressure on banks to restructure their balance sheets and become self-financing again (see for instance Reichlin 2014). Central bank funding could also have encouraged risk shifting and *carry trades* through government bond purchases (Drechsler et al. 2016). The latter is the focus point of our paper. In particular, we empirically investigate whether exposures to governments of banks that were heavily dependent on the liquidity support by the Eurosystem developed differently compared to banks with low central bank dependence, controlling for the confounding factors over the period.

We test the association between banks' sovereign exposures and liquidity support, by specifically focusing on two of the longer term refinancing programmes of the ECB: (i) 36 month-refinancing operations (VLTROs) and (ii) targeted long-term refinancing operations (TLTROs) with a maturity of 4 years. The operations had different purposes. The VLTROs addressed the longer-term funding needs of banks facing a freeze of the money market, while the TLTROs' explicit aim was to support credit supply, as the conditions were dependent on the lending growth of the borrowing bank. By distinguishing between the effects of these two types of refinancing operations on bank behaviour, our paper adds value to the literature, which usually either analyses the effects of the aggregate central bank liquidity supply or just one type of liquidity operation (see the literature overview in the next section). Moreover, we control for the expanded Asset Purchase Programme (APP) of the ECB, which was announced in January 2015. Asset purchases by the central bank can affect the balance sheet of banks by changing the composition and size of their assets and liabilities.

One of the difficulties in this literature is the two-way causality between borrowing from the central bank on the one hand and bank balance

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sheet developments on the other. The financial position of the banking sector will determine the decision by the central bank to provide liquidity support, while at the same time the liquidity operations of the central bank may impact bank balance sheets. Moreover, for individual banks, the amount they borrow from the central bank will not only affect their balance sheets, but their actual (and expected future) balance sheet developments will determine how much they borrow. Therefore, active balance sheet movements as a result of the borrowing operations should be distinguished from changes that are due to other confounding factors that drive both the bidding in the operations and the balance sheets of banks. Ignoring these factors would mean that a balance sheet development that is being driven by some omitted variable is misinterpreted as a strategic action taken by banks.

We take these issues into account in difference-in-differences panel regressions for a large sample of banks in the euro area, where we regress indicators of government exposures on the use of the two longer-term refinancing operations. The difference-in-differences approach is aimed at identifying central bank borrowing as the distinguishing driver of government exposures, by controlling for other confounding factors such as bank and country-specific characteristics and cyclical developments. Endogeneity is taken into account by using a time-invariant dummy that classifies high and low borrowing banks. Empirical tests are performed to assess whether endogeneity is biasing the results. While mean difference tests suggest that there are differences in sovereign exposures in the pre- and post-treatment sample, the tests of the parallel trend assumption are always positive. Considering that the model variables are in terms of growth rates instead of levels, the parallel trend assumption test seems to be more informative. Furthermore, by including control variables such as the business cycle that may also impact balance sheets, we seek to measure active instead of passive changes in exposures to governments. As a robustness test, potential selection bias is accounted for by propensity score matching techniques. Despite the various tests and alternative approaches that we apply to address endogeneity, we acknowledge that this issue cannot be solved completely.

We run several regressions where the dependent variable is a particular form of government exposure, based on predictions from the theoretical literature on the influence of central bank financing on banks' asset allocation. The regression outcomes indicate that central bank borrowing can be associated with changes of banks' government exposures, which differ between the two types of refinancing operations. We find that unconditional longer term central bank borrowing (VLTROs) went together with increased sovereign exposures. Banks in stressed countries that borrowed in excess of the sample median in the VLTROs were more likely to increase government lending and holdings of government bonds. We find this effect both for the total sovereign bond exposures and for domestic sovereign bonds, which suggests that banks did not primarily purchase bonds of their own government. The opposite is found for the TLTROs, which were designed specifically to support credit provision to the non-financial corporate sector. Overall, the findings provide mixed support for the (theoretical) assumptions in the literature on the impact of central bank funding on banks' sovereign exposures. The findings mainly underscore the benefits of having conditionality attached to long-term refinancing operations.

The rest of this paper is organized as follows. Section 2 provides an overview of the literature dealing with the link between bank behaviour and central bank funding and formulates the hypothesis we test. Section 3 describes our sample of banks and the various central bank refinancing operations. In Section 4 we provide tentative graphical evidence for changes in bank exposures to governments. The regression model is specified in Section 5 and Section 6 presents the estimation results. Section 7 provides robustness checks. Section 8 concludes.

II. Literature review and hypotheses

In this section, we give a short literature review and derive our hypotheses.

Literature

There are a number of contributions focusing on the effects of central bank borrowing on bank

intermediation activity. Darracq-Paries and De Santis (2015) provide empirical evidence suggesting that the VLTROs supported economic growth, lending to firms and inflation, indicating that they helped to avoid a major credit crunch. García-Posada and Marchetti (2016) likewise show that VLTROs had a positive moderate-sized effect on the supply of bank credit to firms and also found that the operations in fact decreased the probability of renewing old lending relationships, which the authors interpret as evidence that funds were not used for loan evergreening. De Haan, van den End, and Vermeulen (2017) find evidence suggesting that VLTROs mitigated the negative effects of wholesale liquidity supply shocks on euro area bank lending to the non-financial sector. Likewise, for Italy, Casiraghi et al. (2016) find that the 3 year LTROs have had a beneficial impact on credit supply and money market conditions. Using data for Portugal, Alves, Bonfim, and Soares (2016) show that the ECB's monetary policy framework allowed banks to promptly obtain sufficient liquidity without major implications on funding costs and that, even though funding with the central bank increased dramatically over the course of a few months, credit flows to firms remained broadly stable. Andrade et al. (2019) found that the VLTROs enhanced loan supply in France and that most of the effects came from the first operation in which more constrained banks bid most. Carpinelli and Crosignani (2017) found for Italy that banks which were more affected by the dry-up in market liquidity used the central bank liquidity to restore credit supply, while less affected banks increased their holdings of high-yield government bonds. With respect to the TLTROs, Altavilla, Canova, and Ciccarelli (2020) find that interest rates on loans to non-financial corporations (NFCs) were lowered more by participating banks than by non-participating banks. Since many studies have already looked into the effects on credit supply, our paper focusses on the effects on the bank exposure to government bonds that may be associated with central bank borrowing.

Related empirical studies find that central bank funding encouraged risk shifting and *carry trades* through government bond purchases by – weakly capitalized – banks (Acharya and Steffen, 2015; Drechsler et al. 2016). This could be motivated by collateral trading, whereby central bank funding incentivizes banks to buy government bonds and pledge them as collateral for central bank loans. Van der Kwaak (2017) models this collateral effect in a New-Keynesian model, showing that LTROs raise the collateral value of government bonds which induces banks to shift into government bonds and shed private loans. Crosignani, Faria-e-Castro, and Fonseca (2020) find evidence for this behaviour by Portuguese banks in response to the VLTROs, and Altavilla, Pagano, and Simonelli (2017) show similar behaviour for the euro area. Carpinelli and Crosignani (2017) find that Italian banks that were less affected by financial market stress increased their holdings of high-yield government bonds. Such strategies contribute to an increased home bias of bank exposures and so increase the concentration in banks' asset portfolios (Reichlin 2014). Home bias in sovereign bond holdings may result from these carry trades of banks for several reasons, such as moral suasion or financial repression by governments, or the informational advantage of domestic banks with regard to their sovereign (Andreeva and Vlassopoulos 2019; Saka 2020).

Hypotheses

Based on the literature, we formulate our hypotheses on the behaviour of banks in response to their borrowing in the two longer-term central bank refinancing operations. We thereby distinguish between 'high borrowing' and 'low borrowing' banks, i.e. banks with high dependence on the Eurosystem and banks with low central bank dependence, respectively.

H1: Carry trades: high borrowing banks show higher exposures to government debt than low borrowing banks (Acharya and Steffen, 2015; Drechsler et al. 2016).

We measure carry trade behaviour of banks by the exposures to government debt over main assets ratio (*GOV*). *H1* assumes that this ratio increases more (or decreases less) for high borrowing banks compared to low borrowing banks, as high borrowers will use central bank funding to buy government bonds to set up carry trades.

H2: Changes in sovereign bond holdings associated with high central bank borrowing differ

between banks in stressed and non-stressed countries (Acharya and Steffen, 2015; Drechsler et al. 2016; Crosignani, Faria-e-Castro, and Fonseca 2020).

H2 assumes that especially high-borrowing banks in stressed countries purchase more sovereign bonds.

H3: Changes in sovereign bond holdings associated with high central bank borrowing differ between domestic and foreign government bonds (Andreeva and Vlassopoulos 2019).

H3 assumes that home bias exists with regards to government bond holdings.

III. Data

In this section, we discuss our data sample, the refinancing operations, and our definition of low versus high borrowing banks.

Sample

The main data source of the bank variables that we use is the ECB's individual balance sheet and interest rates statistics (IBSI). This unique data source contains monthly stocks and flows for assets and liabilities for individual monetary financial institutions (MFIs) over the period August 2007 to October 2017. When we have multiple MFIs belonging to a head institution, we aggregate the balance sheet variables to the head level. To adjust for structural breaks, we exclude banks that show an extreme change of total assets in the sample period (more than a 50% change in main assets over a one year period), as these are most likely due to bank restructurings, mergers, etc., unrelated to central bank funding. The data are also winsorized by limiting extreme outliers (at the top and bottom 1% of the distribution). The final dataset contains 117 banks in 14 euro area countries. Our variables of interest that capture bank's government exposures and different balance sheet ratios are described in Appendix A.

Refinancing operations

In normal times, central banks use refinancing operations as a monetary policy tool to steer interest rates and to manage interbank liquidity. During the crisis, the Eurosystem introduced LTROs to support the functioning of the interbank market.

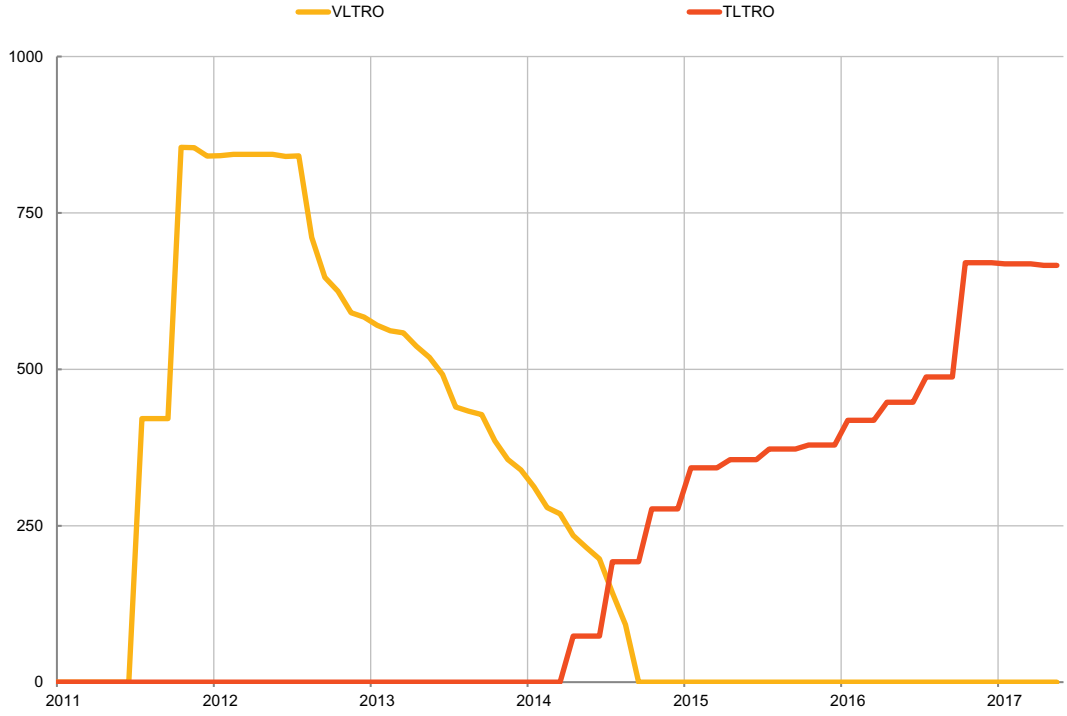

Figure 1. Long-term refinancing operations by the Eurosystem. (aggregate across sample, outstanding amounts, EUR billions) Source: ECB Liquidity operations data for sample of euro area banks.

The Eurosystem allotted two 3 year operations (VLTROs) in December 2011 and February 2012.[1] While these operations were successful in providing a backstop to the interbank market and preventing a disorderly deleveraging, persistently weak credit developments, growth and inflation prompted the central bank to announce TLTROs as part of a broader credit easing package in June 2014. These operations had a maturity of up to 4 years and the amount borrowed was conditional on banks' lending to non-financial corporations (NFCs) and households (excluding mortgages). Moreover, in the second round of targeted operations (announced in March 2016), the interest rate on the TLTRO was made dependent on new lending. This implied that banks which supplied more new loans paid a lower rate. The total amount of borrowing in these operations for our sample of banks is shown in Figure 1.

Of the 117 banks in the sample, 58 banks are defined as high borrowers in the VLTRO and 57 are high borrowers in the TLTRO. There are 49 banks that are classified as high in neither operation and 47 that are classified as high borrowers in both, leaving 11 that are only high borrowers in the VLTRO and 10 that are classified as high borrowers only in the TLTRO. In the stressed countries, there is a large overlap between VLTRO and TLTRO-borrowers; all banks that are classified as high-TLTRO-borrower were also a high-VLTRO-borrower.

High versus low borrowing banks

We compare the indicators of banks with high dependence on the Eurosystem to those of banks with low central bank dependence. To identify high borrowing banks, we generate a dummy variable which equals 1 if bank i is in the top half of the sample in terms of borrowing in each operation (defined as central bank borrowing over main assets in excess of the median of the whole sample of banks, averaged over time). To get an idea of the amount of borrowing relative to total assets, Table 1 gives summary statistics for the usage of VLTROs and TLTROs for all banks in our sample and also for banks in stressed versus other countries.[2] Table 1 shows that higher borrowing banks are concentrated in stressed countries (mean borrowing is much higher than in non-stressed countries for the refinancing operations). Furthermore, panel B shows that banks that borrowed more in the operations tended to have higher CDS spreads, lower capital ratios and lower return on equity (ROE) as compared to other banks.

Table 1. Summary of bank borrowing from the Eurosystem.

Panel A. as a percentage of total bank assets			
		VLTRO	TLTRO
Total	p25	0.00	0.00
	Median	0.00	0.00
	p75	0.78	0.66
	Mean	0.68	0.44
	St. dev	1.11	0.67
Stressed	p25	0.78	0.13
	Median	1.71	1.00
	p75	3.10	1.49
	Mean	1.91	0.99
	St. dev	1.31	0.80
Non stressed	p25	0.00	0.00
	Median	0.00	0.00
	p75	0.22	0.36
	Mean	0.22	0.24
	St. dev	0.54	0.48
Panel B. Characteristics according to borrowing			
		VLTRO	TLTRO
CDS	High borrower	283.3	275.8
	Low borrower	139.7	141.7
CET 1 ratio	High borrower	11.4	11.2
	Low borrower	11.6	12.2
ROE	High borrower	1.3	1.6
	Low borrower	3.6	3.0

Note: CDS, CET 1 ratio and ROE are the averages across the whole sample for each group.

IV. Graphical evidence

In this section, we provide some first graphical evidence of the responses of the government exposure to central bank liquidity support for high borrowing versus low borrowing banks. Figures 2 and 3 represent year-on-year rates of growth, so that lines above (below) the zero axis represent rates of increase (decrease).

Figure 2, panels 1–3 indicate that VLTROs were associated with carry trades, particularly in the first phase of these liquidity operations. The government bond ratio of high borrowing banks increased clearly more than the ratio of low borrowing banks between early 2012 and early 2013. This difference is larger for the total (domestic and foreign) government

[1]Most of the borrowings from the previously introduced 12 month operation shifted to the 36 month operation.
[2]'Stressed countries' are the economies that suffered the most during the euro debt crisis, i.e. the so-called GIIPS countries (Greece, Ireland, Italy, Portugal, Spain) and Slovenia. The other countries included in our sample are: Austria, Belgium, Germany, Finland, France, Luxembourg, Malta and the Netherlands.

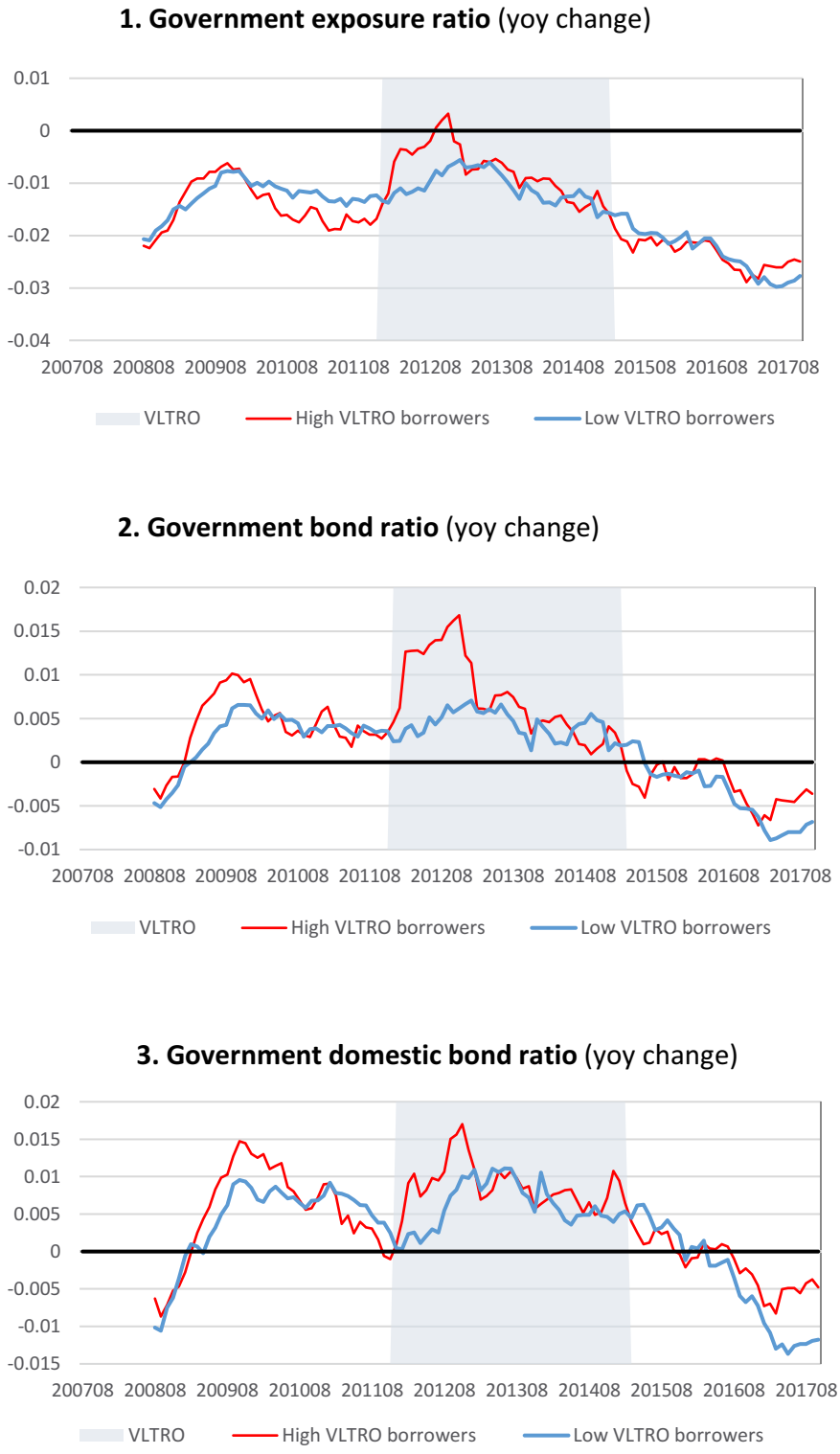

Figure 2. Effect of VLTROs on government exposure ratios.

bond ratio than for the domestic bond ratio, indicating that low borrowers purchased less foreign bonds than high borrowing banks. At the peak of the carry trade, end of 2012, the bond ratio of high borrowing banks expanded over 15% year-on-year.

In the later stages of the VLTROs, the difference between government exposure ratios of high and low borrowing banks disappeared. For both groups of banks, however, the growth of the bond ratio remained positive during the VLTROs. This is a

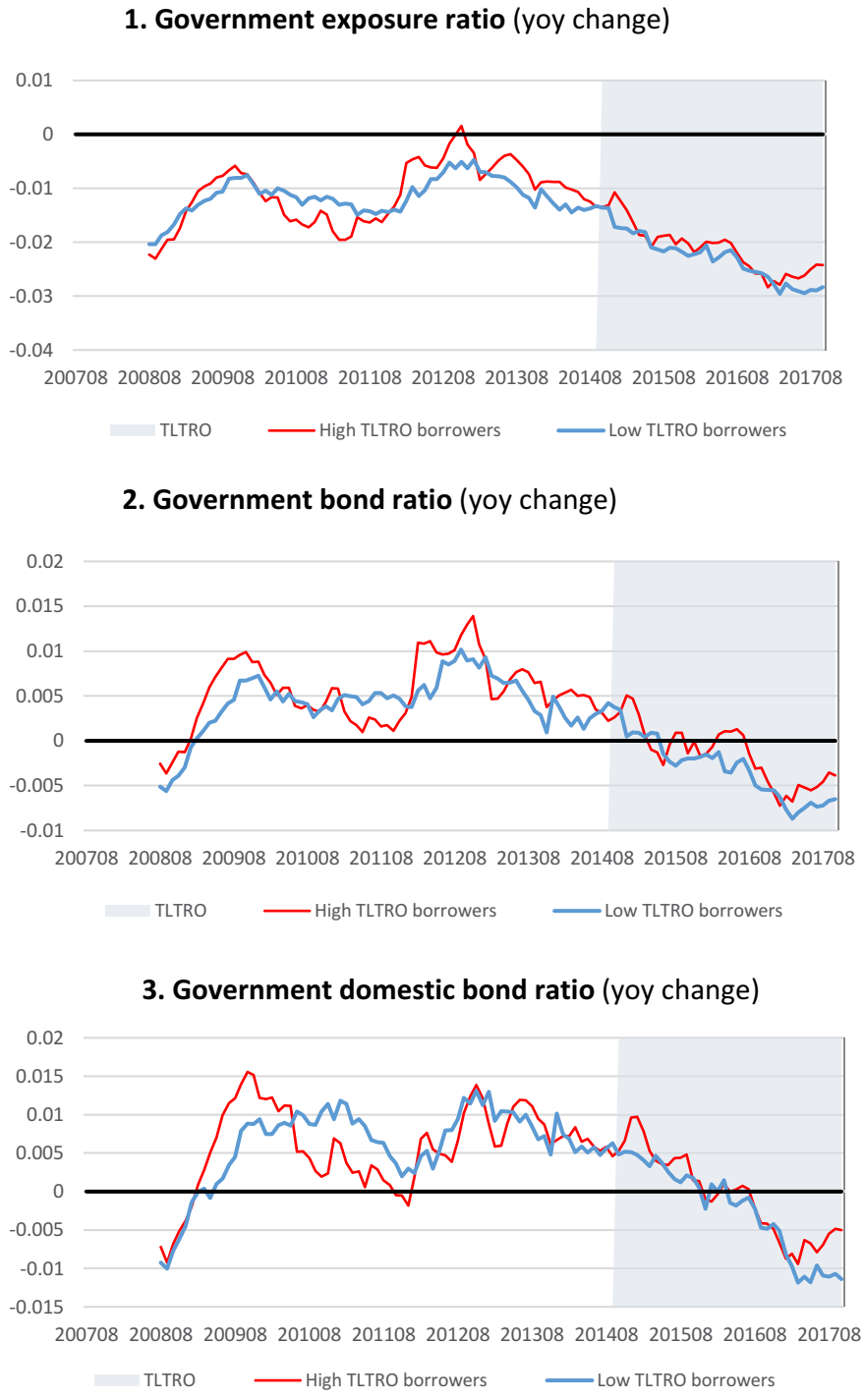

Figure 3. Effect of TLTROs on balance sheet indicators.

notable difference compared to the negative growth rate of the total government exposures ratio, which includes also loans to governments. This indicates that banks switched from government lending to sovereign bond purchases in the VLTRO-period.

Figure 3, panels 1–3 indicate that for the TLTROs there is no strong initial evidence for a change in behaviour across both groups of banks with respect to carry trades. Only at the end of the sample period, from 2017 onward, the bond ratio of high borrowing banks increased more than the ratio of low borrowing banks. Particularly from mid-2016 to the end of the sample period, TLTROs did not seem to incentivize carry trades, since the growth rate of the government bond ratio of banks became negative. This was also true for the total exposures to

Table 2. Summary statistics model variables before VLTRO and TLTRO.

Panel A – Before VLTRO											
	LTD	MM	LA	WS	LEV	GOV	GOVB	GOVDB	ROA	Size	CDS
Min	0.00	−0.95	0.00	0.11	0.01	0.00	0.00	0.00	−4.93	0.00	29.44
Median	1.26	0.44	0.21	0.67	0.07	0.08	0.05	0.03	0.28	0.00	135.41
Mean	30.42	0.40	0.23	0.65	0.08	0.11	0.06	0.05	0.17	0.01	219.44
Max	7451.0	1.63	0.87	1.00	0.24	0.65	0.34	0.33	1.79	0.07	1729.16
St. dev.	199.49	0.53	0.15	0.24	0.04	0.11	0.06	0.06	0.89	0.01	272.06
Panel B – Before TLTRO											
	LTD	MM	LA	WS	LEV	GOV	GOVB	GOVDB	ROA	Size	CDS
Min	0.00	−0.95	0.00	0.11	0.01	0.00	0.00	0.00	−4.93	0.00	29.44
Median	1.34	0.40	0.21	0.68	0.06	0.07	0.04	0.02	0.28	0.00	151.73
Mean	23.30	0.36	0.23	0.66	0.07	0.10	0.06	0.04	0.15	0.01	234.65
Max	7451.0	1.63	0.87	1.00	0.24	0.65	0.34	0.33	1.79	0.07	1729.16
St. dev.	133.17	0.51	0.14	0.24	0.04	0.11	0.06	0.05	0.90	0.01	263.15

governments, for which the ratio declined over the whole TLTRO-period (Figure 3, panel 3).

Robust associations based on graphical analysis are not warranted without controlling for confounding factors, such as macroeconomic developments. Therefore, in the next section, we outline the empirical strategy used to isolate the association between central bank borrowing and banks' strategies.

Table 3. Test outcomes for mean differences and parallel trends.

Panel A. Mean tests before VLTRO (based on the variables in terms of annual changes)			
	GOV	GOVB	GOVDB
		All	
Mean low borrowers	0.004	−0.013	0.003
Mean high borrowers	0.005	−0.014	0.004
P value from difference test	0.131	0.060	0.010
		Stressed	
Mean low borrowers	0.0005	−0.0002	−0.0002
Mean high borrowers	0.0079	−0.0074	0.0069
P value from difference test	0.0008	0.0063	0.0000
Panel B. Test for parallel trend assumption (baseline model)			
Full sample	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	0.0009	0.0011	0.0008
	(0.001)	(0.001)	(0.001)
Bank level controls	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	163	163	163
R2	0.554	0.512	0.526
Stressed countries	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	−0.0011	−0.0012	−0.0013
	(0.002)	(0.002)	(0.001)
Bank level controls	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	103	103	103
R2	0.632	0.563	0.619

Note: the test for the parallel trend assumption is based on coefficient (β) of the interaction between a deterministic time trend and the treatment indicator (*Liquidity operation*). This interaction term replaces the interaction term (*Liquidity operation*Post*) in the benchmark model (1). ***, **, * indicate that the parallel trend assumption is rejected on a 1%, 5%, 10% significance level. The model is estimation for the period before the VLTROs, which were introduced in December 2011. Bank levels controls include LTD, MM, LA, WS, ROA, SIZE, CDS.

V. Model

To identify more formally the differential correlation of targeted and untargeted long-term refinancing operations with balance sheet ratios, we estimate a difference-in-differences model (similar to Popov and Van Horen 2015) for balance sheet adjustments by bank i,

$$Y_{it} = \beta\ (Liquidity\ operation_i * Post_t)\ + \gamma\ X_{it} + \varphi_i + \eta_t * \lambda_{jt} + \varepsilon_{it} \quad (1)$$

where Y_{it} is one of the three ratios of sovereign bond holdings to total main assets for bank i, as defined in Section 2.2. In the regressions, we include the 1 month ahead year-on-year changes of Y_i to avoid endogeneity between a bank's usage of central bank refinancing and changes in sovereign exposures and because of the presence of a unit root in the exposure levels. $Liquidity\ operation_i$ is the identifying dummy variable which equals 1 if bank i is in the top half of the sample in terms of central bank borrowing (as percentage of main assets, averaged over time) and 0 otherwise. As the median level of borrowing by banks is zero in both operations, this corresponds to borrowers and non-borrowers. In the robustness section, we also show the results where high and low borrowing is defined as a dummy variable which equals 1 if bank i is in the top quartile of the sample in terms of

Table 4. Estimation outcomes (baseline model, full sample).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	0.0007	−0.0110	−0.0085
	(0.011)	(0.011)	(0.009)
Bank level controls:			
LTD	−0.0013****	−0.0007***	−0.0006***
	(0.000)	(0.000)	(0.000)
MM	0.0549	0.0598*	0.0379
	(0.043)	(0.031)	(0.029)
LA	0.0408	0.0064	0.0303
	(0.033)	(0.033)	(0.028)
WS	0.0324	0.0217	0.0440
	(0.096)	(0.071)	(0.068)
CAP	−0.209*	−0.154	−0.0739
	(0.110)	(0.146)	(0.127)
ROA	−0.0002	−0.0003	−0.000419
	(0.001)	(0.001)	(0.00233)
Size	2.543***	2.773***	2.104
	(0.745)	(0.807)	(0.684)
CDS	−0.0000	0.0000	0.0000
	(0.000)	(0.000)	(0.000)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	508	508	508
R2	0.548	0.519	0. 519
Panel B. TLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	0.0114	0.0223	0.0098
	(0.010)	(0.016)	(0.013)
Bank level controls:			
LTD	• −0.0013****	−0.0007***	−0.0006***
	(0.000)	(0.000)	(0.000)
MM	0.0565	0.0642**	0.0402
	(0.042)	(0.031)	(0.027)
LA	0.0425	0.0102	0.0321
	(0.033)	(0.032)	(0.027)
WS	0.0316	0.0238	0.0460
	(0.095)	(0.072)	(0.068)
CAP	−0.228**	−0.187	−0.0875
	(0.107)	(0.132)	(0.125)
ROA	−0.0002	−0.0003	−0.0000
	(0.000)	(0.001)	(0.001)
Size	2.136***	1.979*	1.750*
	(0.954)	(0.972)	(0.947)
CDS	−0.0000	0.0000	0.0000
	(0.000)	(0.000)	(0.000)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	508	508	508
R2	0.550	0.524	0. 519

Note: standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 5. Estimation outcomes (baseline model, stressed countries).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	0.0596***	0.0331***	0.0222*
	(0.009)	(0.010)	(0.012)
Bank level controls:			
LTD	−0.0014****	−0.0008***	−0.0007***
	(0.000)	(0.000)	(0.000)
MM	0.0549	0.0598*	0.0379
	(0.043)	(0.031)	(0.029)
LA	0.0717	0.0078	0.0279
	(0.048)	(0.037)	(0.031)
WS	0.0108	−0.0196	0.0255
	(0.110)	(0.081)	(0.0794)
CAP	−0.262*	−0.253*	−0.123
	(0.127)	(0.141)	(0.149)
ROA	−0.0001	−0.0003	−0.0001
	(0.001)	(0.001)	(0.001)
Size	3.527**	2.549	3.154*
	(1.471)	(1.584)	(1.562)
CDS	−0.0000	0.0000	0.0000
	(0.000)	(0.000)	(0.000)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	303	303	303
R2	0.567	0.523	0. 523
Panel B. TLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	−0.0523***	−0.0255	−0.0295**
	(0.013)	(0.015)	(0.013)
Bank level controls:			
LTD	• −0.0014****	−0.0008***	−0.0007***
	(0.000)	(0.000)	(0.000)
MM	0.0717	0.0784*	0.0477
	(0.048)	(0.037)	(0.033)
LA	0.0438	0.0144	0.0279
	(0.039)	(0.039)	(0.031)
WS	0.0108	−0.010	0.0255
	(0.110)	(0.081)	(0.079)
CAP	−0.262*	−0.253*	−0.123
	(0.127)	(0.141)	(0.149)
ROA	−0.000	−0.0003	−0.0000
	(0.000)	(0.001)	(0.001)
Size	3.527***	2.549	3.154*
	(0.954)	(1.584)	(1.562)
CDS	−0.0000	0.0000	0.0000
	(0.000)	(0.000)	(0.000)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	303	303	303
R2	0.567	0.523	0. 513

Note: standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

central bank borrowing. The dummy in each case is time-invariant, so that the influence of balance sheet changes over time on the demand for central bank liquidity is excluded. The regression is run separately for VLTROs and TLTROs (hence, Liquidity operation is either VLTRO or TLTRO).

To capture the time period of each operation, we include a dummy variable *Post* for either VLTRO or TLTRO.[3] For VLTROs *Post* takes a value of 1 from December 2011 to January 2015. For TLTRO *Post* takes a value of 1 from September 2014 to the end of the sample period. As robustness check, in Section 7 another dummy is included to control for the effect of the APP on the balance sheets of the banks.

Vector X_{it} includes time-varying bank level control variables and φ_i are bank-specific fixed effects that control for unobserved time-invariant bank characteristics. In X_{it} we include time-varying measures that capture bank solvency or credit risk

[3]Dummies for the duration of the other programmes are included as controls, to isolate the effect of the programme included in the interaction term.

(measured by CDS spread), bank size (main assets as share of the total banking sector), bank profitability (return on assets), loan to deposit ratio (LTD), mismatch ratio (MM), liquid asset ratio (LA), wholesale funding ratio (WS), and capital ratio (CAP).

η_t are time-specific fixed effects, λ_{jt} are country-specific fixed effects that together fully control for all time variant characteristics across countries. The interaction between these two variables controls for all changes in macroeconomic conditions at the country level that could impact banks' behaviour and their balance sheets.[4] ε_{it} is a residual.

The coefficient of interest is β, the partial-correlation between VLTRO borrowing (or TLTRO) and the balance sheet ratio. This approach assumes a treatment and comparison group and identifies the treatment effect – in this case high central bank borrowing – through the inter-temporal variation between the groups (Abadie 2005). By controlling for these observable and unobservable characteristics we increase the chance of identification of the VLTRO or TLTRO as the distinguishing factor behind the differential balance sheet behaviour of the bank and not the initial financial conditions of the bank, for instance. The model is estimated using OLS, and to address concerns regarding inconsistent standard errors owing to serial correlation, we cluster standard errors at the bank level. Table 2, panels A and B present summary statistics of the model variables before the VLTROs and TLTROs, respectively.

VI. Results

For the difference-in-differences framework, it is crucial to provide evidence that low borrowing banks can actually serve as a valid counterfactual. To this end, Table 3, Panel A provides mean difference tests to assess whether the high borrowing banks differ from the low borrowing banks with respect to the outcome variables in the period prior to the first policy change, i.e. before the VLTROs. The mean difference tests for the full sample of banks suggest that there is no significant difference between holdings in government bonds (*GOV*), but we reject the assumption that they are equal in stressed countries. We find that our other measures of sovereign exposures are statistically different from each other. Given that the variables are included in terms of annual growth rates, mean difference tests are likely less telling than parallel trend assumptions. The assumption that the outcome variables of the treatment and control groups have parallel trends before treatment is tested by including the interaction between the treatment indicator Liquidity operation and a deterministic trend in Equation (1), instead of the interaction term (Liquidity operation*Post). The outcomes of this test – based on the model estimated in the period before the VLTROs – are shown in Table 3, panel B. The results indicate that all outcome variables have parallel trends before treatment.

The estimation outcomes of the baseline model are shown in Table 4, with panel A and panel B showing the outcomes associated with the VLTROs and TLTROs, respectively, for the full sample. Table 5 shows the outcomes for banks in stressed countries as defined in Section 3.

For the full country sample, the carry trade hypothesis *H1* cannot not be accepted. The β coefficients of variables *GOV, GOVB* and *GOVDB* are not significant, both with regard to the VLTROs and TLTROs (columns 1–3 in Table 4). It indicates that these is no significant difference between high and low borrowing banks with regard to changes in their sovereign exposures. This could indicate that the banks had sufficient opportunities to use the central bank liquidity, for instance in the form of lending to households and firms.

However, in the stressed country sample the results do indicate that the VLTROs were an incentive for carry trades. The β coefficients of *GOV, GOVB* and *GOVDB* are significant and positive with regard to the VLTROs in this sub-sample (columns 1–3 in Table 5). Hence, banks in stressed countries that were high bidders in the VLTROs did increase their exposures to governments significantly more than low bidding banks in those countries. Hence, hypotheses 1 and 2 (i.e. changes in government exposures are more likely for banks in stressed countries) can be accepted with regard to the VLTROs. We find this effect both for the total sovereign bond exposures and for domestic sovereign bonds, which suggests that banks did

[4]We also estimated regressions with macroeconomic variables instead of country time dummies, but this alternative did not change the results substantially.

not primarily purchase bonds of their own government (the significance of β is even less for *GOVDB* than for *GOVB*). This suggests that hypothesis 3 cannot be accepted.

In contrast to the effect of VLTROs, the TLTROs seemed to have a significantly negative effect on *GOV* and *GOVDB* in the stressed country sample (and a negative, but insignificant effect on *GOVB*). This indicates that banks in stressed countries that were high bidders in the TLTROs did reduce their government loan and domestic bond exposures significantly more than low bidding banks in those countries, opposite to what *H1* and *H2* assume. This could be driven by the interest rate incentive embedded in the TLTROs, which made the return on non-financial corporate lending more attractive. This might have motivated banks to shed sovereign assets and adjust their portfolios towards private sector lending. This effect is not found for the total sovereign bond portfolio (*GOVB*), probably because the banks in the stressed countries preferred to hold on to their relatively safe foreign sovereign bonds (included in *GOVB*).

We note that the impact of the TLTROs is driven by banks that are also high borrowers in the VLTROs, given that out of the 57 that are high borrowers in the TLTRO, 47 banks are also classified as high VLTRO-borrower (see section 3.2). This is particularly the case in stressed countries, where all high TLTRO-borrowers were also classified as high VLTRO-borrowers. This means that in stressed countries there is no difference in the impact of TLTROs on all banks, compared to the impact on high VLTRO-borrowers only.

VII. Robustness tests

In this section, we perform a number of robustness tests. First, we test the sensitivity of the outcomes for another threshold for defining high versus low borrowing banks. Second, we add a control variable for the APP. Third, we estimate all equations using aggregate data over two periods, i.e. before and after the treatment, as recommended by Bertrand, Duflo, and Mullainathan (2004) to mitigate serial correlation concerns. Fourth, we test for potential self-selection bias by propensity score matching. Fifth, we perform dynamic dif-in-dif regressions to test for endogeneity. Finally, we do placebo tests.

Threshold for high versus low borrowing

In the first robustness test, we change the *threshold* for identifying high borrowing banks. The threshold is changed into central bank borrowing over main assets in excess of the 75th percentile of the whole sample of banks, averaged over time (instead of the median, which is the threshold in the baseline model). This threshold implies that only banks in the top quantile of the distribution are identified as high borrowers. The estimation outcomes of this model set-up show only some differences in the significance levels of particular variables, compared to the baseline model. For instance, in the full country sample, the β coefficient of *GOV* becomes significant for VLTROs at the 10% confidence level, while β is insignificant when the median is used as threshold (compare Appendix B, Table B1 with Table 4). Hence, the results for the whole sample are only somewhat sensitive to changing the threshold for identifying the high borrowing banks.

Asset purchases

To control for the potential effect of the Asset Purchase Programme (APP) on the balance sheets of banks, an additional control variable is added to Equation (1). This impact variable is a dummy which takes a value of 1 when a bank has an above median increase in liquidity owing to the APP and zero otherwise (it concerns the overall liquidity position as indicated by a bank in the ECB bank lending survey). The impact variable is interacted with a time dummy, which takes a value of 1 from January 2015 onwards and is zero otherwise. As a robustness test, we check whether the APP affects the outcomes of the TLTROs, since only during these operations the APP was active. Since the APP impact variable is only available for around half of the sample of banks (banks that are included in the bank lending survey), Equation (1) is re-estimated for this limited sample, excluding and including the APP variable for the TLTROs. The outcomes in Appendix B, Table B2 show that the inclusion of the APP variable does not qualitatively affect the outcomes. The results for the whole sample remain insignificant, with and without the control for APP. For stressed countries, there is

evidence that the TLTRO led to a significant deleveraging of sovereign exposures, once the impact of the APP is controlled for. The APP variable is negatively and mostly significantly related to changes in sovereign exposures, as could be expected.

Estimations using the average outcomes

As recommended by Bertrand, Duflo, and Mullainathan (2004), another way to ensure that serial correlation in the errors is not biasing the results, is to ignore the time series information when computing standard errors by averaging the data before and after the policy in question. The results of the estimations are shown in Tables B3 and B4 for the full sample and the stressed sample respectively. For the full sample, the results remain broadly unchanged for the VLTROs and the results for TLTROs show that the operations were related to a significant reduction in sovereign bond holdings. For the stressed country group, high borrowers in the VLTROs continue to have significantly higher exposure to governments, while following the TLTRO they significantly reduce their exposure to sovereigns.

Propensity score matching

Like all micro-econometric studies of treatment effects, our analysis potentially suffers from selection bias. Such a bias may arise in our study as the distinction between high and low borrowing banks does not result from randomized trials but from (non-randomized) choices by the banks. High and low borrowers may differ also in the absence of, and for reasons other than, central bank borrowing. This selection bias is commonly addressed by propensity score matching (PSM). PSM is used to create a treatment and control group that are matched in every way except for the intervention. We use this method to define a control group of untreated banks which matches the properties of the group of treated banks.

PSM defines the average treatment effect on the treated group (ATT) as,

$$ATT = E\left[Y(1) - Y(0)|W = 1\right] \quad (2)$$

with W being the probability of being in the treatment group, $Y(1)$ the outcome of treatment and $Y(0)$ the outcome in the absence of treatment. To exclude that selection bias might be driving the treatment effect, ATT is identified only if the outcomes of banks in the treatment group ($W = 1$) and the control group ($W = 0$) would not differ in the absence of treatment ($Y(0)$).

$$\begin{aligned} &ATT \text{ identified only if } E\left(Y(0)\,|W = 1\right) \\ &\quad - E(Y(0)\,|W = 0) \\ &\quad = 0 \end{aligned} \quad (3)$$

If the outcome of Equation (3) would not be equal to 0 there is a potential selection bias. The literature has defined two identifying assumptions to solve the selection problem: Unconfoundedness and the Overlap or Common support condition (Caliendo and Kopeinig 2008). Unconfoundedness means that the assignment to the treatment or control group (W) is independent of the outcomes,

$$\begin{aligned} Unconfoundedness: \; &Pr\left[W|X, Y(1), Y(0)\right] \\ &= Pr\left(W|X\right) \end{aligned} \quad (4)$$

The overlap or common support condition means that similar covariates (X) drive both groups (W_i):

$$\begin{aligned} &Common\ support\ condition: p_i \\ &= Pr\left(W_i|X_i\right),\ 0 < p_i < 1 \end{aligned} \quad (5)$$

with Pr the likelihood of being treated and p_i the probability of being in the treatment group. Condition $p_i > 0$ implies that for treated banks there should be comparison banks in the control group with similar properties. It ensures that the combination of characteristics (X) of banks in the treatment group can also be observed in the control group.

We apply PSM by using the single nearest-neighbour matching method, which is most commonly employed. We use the covariates (X) which are included as control variables in the model. The propensity score model should satisfy the common support condition or balancing property, meaning that treated and controls are comparable in terms of observable covariates. This can be assessed by a mean difference test for the equality of means of the covariates (i.e. the null hypothesis that the means are equal should be accepted). The overall matching performance can be assessed by the (standardized) absolute mean bias. This exercise is conducted for each treatment variable (the

VLTRO and TLTRO dummy) and the main dependent variable (*GOV*). Tables B7 and B8 present the summary statistics of the matching criteria.

The propensity score weights are used to re-estimate the difference-in-differences model specified in Equation (1). We follow Stuart et al. (2015) who estimate a weighted regression model where observations are weighted by the weighing factors obtained from the propensity score model to ensure similarity on a number of observed characteristics.

The outcomes of the weighted regression model are then compared to the outcomes of the original, unweighted regression results (see Appendix B, Tables B5 and B6). This comparison reveals that both the significance level and the signs of the coefficients obtained from the original unweighted estimations are in almost all cases similar to those obtained by the weighted regressions. There are only three relevant differences. In the full sample with TLTROs, the coefficients of *GOVB* and *GOVDB* are significant in the weighted regression (also with a positive sign like in the unweighted regression) and in the stressed countries sample with TLTROs the coefficient of *GOVB* is significant in the weighted regression (also with a negative sign like in the unweighted regression).

Dynamic difference-in-differences

The benchmark model in Equation (1) assumes that banks' balance sheet ratios respond to VLTROs and TLTROs. However, if changes in government exposures would lead the central bank's refinancing operations rather than vice versa, the estimation outcomes would obscure this reverse causality. To explore these dynamics we perform dynamic difference-in-differences regressions with leads and lags of the treatment indicator, as in Autor (2003). More in particular, Equation (1) has been re-estimated with 3 and 6 months lags and leads of the identifying dummy variable $Liquidity\ operation_i{}^{*}Post_t$. This is done for the stressed country sample, given that most significant results are found in that subsample. The outcomes, illustrated graphically in Appendix B, Figures B1 and B2, show that the coefficients of the leads are insignificant (we only find a borderline significant outcome at a lead of 6 months with regard to the TLTROs) and have wider confidence bands than the β coefficient of the contemporaneous (actually the one month lagged) and 3 and 6 months lagged treatment indicator. This suggests that there is no strong evidence of an anticipatory response of VLTROs and TLTROs to changes in banks' exposures to governments.

Placebo tests

We carried out placebo tests using the policy date starting December 2010 (one year before the first liquidity operation) and find no significant differences in stressed countries for changes in government bond holdings between the high borrowing banks and the low borrowing banks using this date, suggesting that the liquidity operations were in fact the driving force between the differences.[5]

VIII. Conclusion

In this paper, we examine the differential developments of the exposures to governments of 117 euro area banks at the time of two types of long-term refinancing operations by the Eurosystem: VLTROs and TLTROs, respectively. We test the hypothesis that emerges from the literature that central bank liquidity incentivizes banks to increase sovereign exposures, while addressing potential selection bias by using propensity score matching techniques. The outcomes of difference-in-differences panel regressions and a battery of tests indicate that banks' government exposures developed differently at the time of the two types of refinancing operations. As in previous studies, we find evidence that central bank borrowing operations are accompanied by carry trades. Banks borrowing more than the sample median held more government bonds. We find this for VLTROs, but not for TLTROs. The latter were associated with a decline of government bond holdings by high borrowing banks, which differed significantly from low borrowing banks.

In sum, while these policies were instrumental in mitigating the effects of financial market stress on

[5]Results are not reported but are available upon request from the authors.

the banking system, our findings provide mixed support to the general (theoretical) prediction in the literature that central bank funding can have an impact on banks' balance sheets that may not be aligned to the initial goals of the operations. We find that banks borrowing in unconditional refinancing operations did more carry trades. In contrast, for conditional refinancing operations, i.e. TLTROs, we do not find this. In fact we show that, if anything, banks decreased their exposure to sovereigns, which implies that the TLTROs successfully shifted the relative return away from purchasing sovereign bonds, by incentivizing lending. The policy implication of our results is that it may be more effective to make long-term central bank refinancing conditional on banks' behaviour.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix A. Definition of bank balance sheet ratios

Carry trades

GOV Government exposures ratio ([domestic and other euro area government bond holdings + loans to governments]/main assets)

GOVB Government bond ratio ([domestic and other euro area government bond holdings]/main assets)

GOVDB Domestic government bond ratio ([domestic government bond holdings]/main assets)

Maturity transformation

MM Mismatch ratio ([[loans to households and nonfinancial corporations with maturity over 1 year] – [deposits with maturity over 3 months + securities issued with maturity over 1 year]]/main assets)

LTD Loan-to-deposit ratio ([loans to non-financial corporations and households]/[deposits of non-financial corporations and households])

Liquidity management

LA Liquid asset ratio ([cash + shares in money market funds + holdings of government bonds + holdings of financial and non-financial private sector debt securities]/main assets)

WS Wholesale funding ratio ([deposits of monetary financial institutions and other financial institutions + deposits of non-financial corporations + other wholesale

deposits + debt securities issued + repo funding]/main assets)

Leveraging

CAP Capital ratio (capital and reserves, monetary definition/main assets, unweighted for risk)

Table B1. Estimation outcomes (with 25th percentile as high borrowers, full sample).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
β	0.0092	0.0180*	0.0163
	(0.008)	(0.010)	(0.010)
Bank level controls	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	508	508	508
R2	0.549	0.523	0.523
Panel B. TLTRO	(1)	(2)	(3)
	GOV	GOVB	GOVDB
B	−0.0089	0.0091	0.0007
	(0.014)	(0.013)	(0.010)
Bank level controls	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
N	508	508	508
R2	0.550	0.519	0.517

***, **, * indicate that the parallel trend assumption is rejected on a 1%, 5%, 10% significance level. Bank levels controls include LTD, MM, LA, WS, ROA, SIZE, CDS.

Table B2. Estimation outcomes for TLTROs with APP control variable.

Panel A. full sample	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (excl APP variable)	−0.00491	0.0101	0.00389
	(0.0153)	(0.0173)	(0.0169)
β (incl APP variable)	0.0145	0.0212	0.0187
	(0.0162)	(0.0184)	(0.0165)
APP variable	−0.0147*	−0.00841	−0.0112**
	(0.00693)	(0.00591)	(0.00444)
N	350	350	350
Panel B. stressed countries	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (excl APP variable)	0.000829	−0.0273	−0.0381
	(0.0393)	(0.0334)	(0.0351)
β (incl APP variable)	−0.141***	−0.139***	−0.0804*
	(0.0346)	(0.0387)	(0.0375)
APP variable	−0.0270**	−0.0150**	−0.0180***
	(0.0113)	(0.00515)	(0.00436)
N	194	194	194

Baseline model (partial-correlation coefficient β of model excluding, versus including APP control variable (APP impact dummy x APP time dummy
Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Coefficients of bank levels controls, bank fixed effects, country time controls not reported.

Appendix B. Robustness tests

Table B3. Estimation outcomes based on average data before and after operations (full sample).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β	−0.000756	0.000610	−0.000382
	(0.00689)	(0.00641)	(0.00558)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes
N	65	65	65
R2	0.732	0.750	0.751
Panel B. TLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β	−0.0103	−0.0115*	−0.0115*
	(0.00617)	(0.00646)	(0.00595)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes
N	67	67	67
R2	0.527	0.528	0.558

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. Coefficients of bank levels controls, bank fixed effects, country time controls not reported.

Table B4. Estimation outcomes based on average data before and after operations (stressed countries).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β	0.0177*	0.0101	0.0140
	(0.00918)	(0.00710)	(0.00795)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes
N	28	28	28
R2	0.984	0.991	0.988
Panel B. TLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β	−0.00553***	−0.00484	−0.00511
	(0.00118)	(0.00741)	(0.00862)
Bank fixed effects	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes
N	29	29	29
R2	0.998	0.943	0.927

*** p < 0.01, ** p < 0.05, * p < 0.1. Coefficients of bank levels controls, bank fixed effects, country time controls not reported.

Table B5. Estimation outcomes based on propensity score matching (full sample).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (unweighted)	0.0007	−0.0110	−0.0085
β (weighted, after PSM)	0.0054	−0.0101	−0.0073
Panel B. TLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (unweighted)	0.0114	0.0223	0.0098
β (weighted, after PSM)	0.0135	0.0324***	0.0175*

Baseline model (partial-correlation coefficient β of unweighted, versus propensity score matching weighted difference-in-differences regression)

Table B6. Estimation outcomes based on propensity score matching (stressed countries).

Panel A. VLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (unweighted)	0.0596***	0.0331***	0.0222*
β (weighted, after PSM)	0.0592***	0.0324***	0.0250*
Panel B. TLTRO	(1)	(2)	(3)
	GOV	*GOVB*	*GOVDB*
β (unweighted)	−0.0523***	−0.0255	−0.0295**
β (weighted, after PSM)	−0.0538***	−0.0222**	−0.0301**

Baseline model (partial-correlation coefficient β of unweighted, versus propensity score matching weighted difference-in-differences regression)

*** p < 0.01, ** p < 0.05, * p < 0.1. Coefficients of bank levels controls, bank fixed effects, country time controls not reported. Weighted regression based on weights obtained from propensity score matching (PSM). The covariates for the weighted regressions are the control variables included in the model.

Table B7. Summary statistics Propensity score matching (comparison between treatment and control group (VLTRO, full sample)).

Full sample				Matched sample		
	Mean		% Bias	Mean		% Bias
Covariates	Treated	Controls		Treated	Controls	
LTD	11.9	4.7	15.1	7.6	2.3	11.5
MM	0.28	0.31	−8.0	0.28	0.34	−16.8
LA	0.25	0.23	15.3	0.26	0.26	−3.3
WS	0.72	0.72	−0.9	0.72	0.69	16.9
CAP	0.10	0.09	10.9	0.10	0.11	−6.1
ROA	−0.39	0.16	−20.0	−0.13	−0.15	0.8
Size	0.02	0.02	4.6	0.02	0.02	−5.4
CDS	399	289	26.1	377	401	−5.6

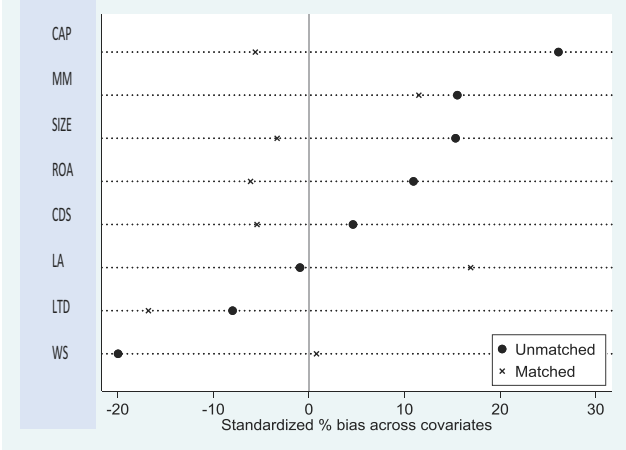
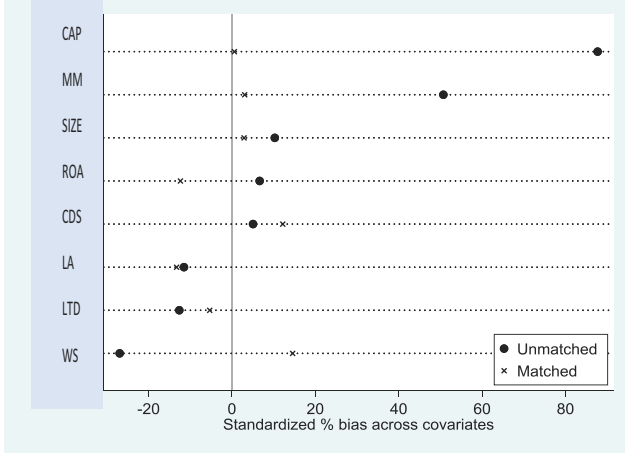


Table B8. Summary statistics Propensity score matching (comparison between treatment and control group (TLTRO, full sample)).

	Full sample			Matched sample		
	Mean		% Bias	Mean		% Bias
Covariates	Treated	Controls		Treated	Controls	
LTD	3.7	8.5	−12.6	3.9	5.9	−5.4
MM	0.43	0.23	50.7	0.41	0.4	3
LA	0.23	0.25	−11.5	0.23	0.25	−13.3
WS	0.69	0.73	−26.9	0.69	0.67	14.5
CAP	0.13	0.08	87.7	0.12	0.12	0.6
ROA	0.09	−0.05	6.6	0.08	0.03	−12.4
Size	0.02	0.02	10.3	0.02	0.02	2.9
CDS	337	316	5.1	312	259	12.2
	Full sample		**Matched sample**			
Absolute mean bias	26.4		8			



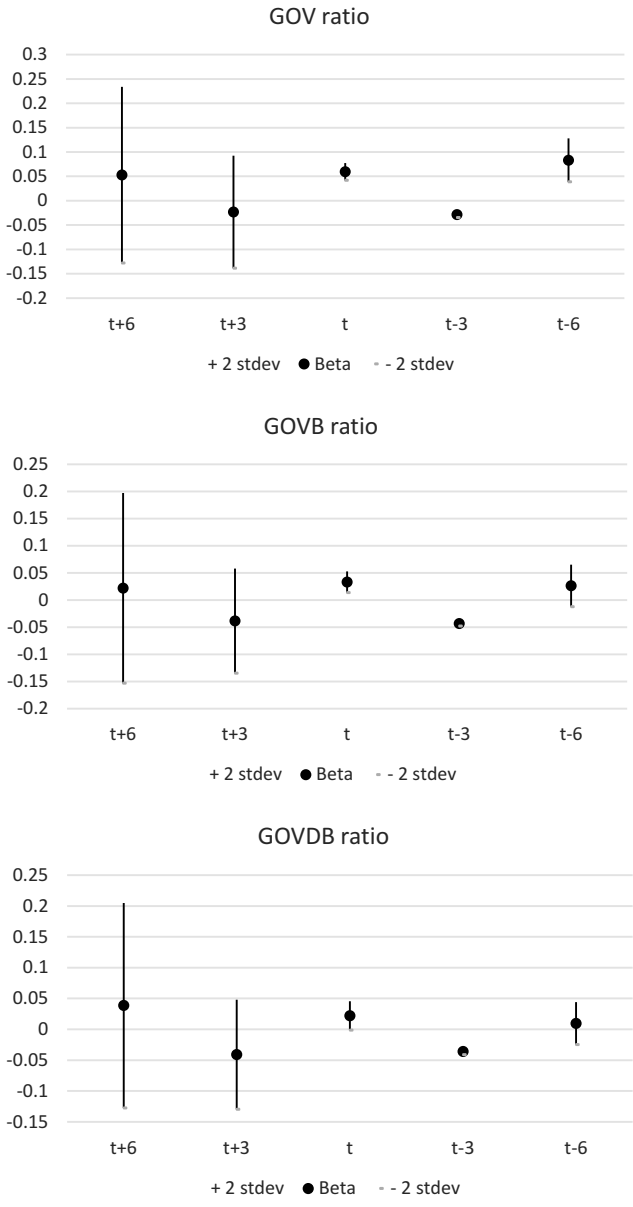

GOV ratio
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev
GOVB ratio
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev
GOVDB ratio
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev

Figure B1.

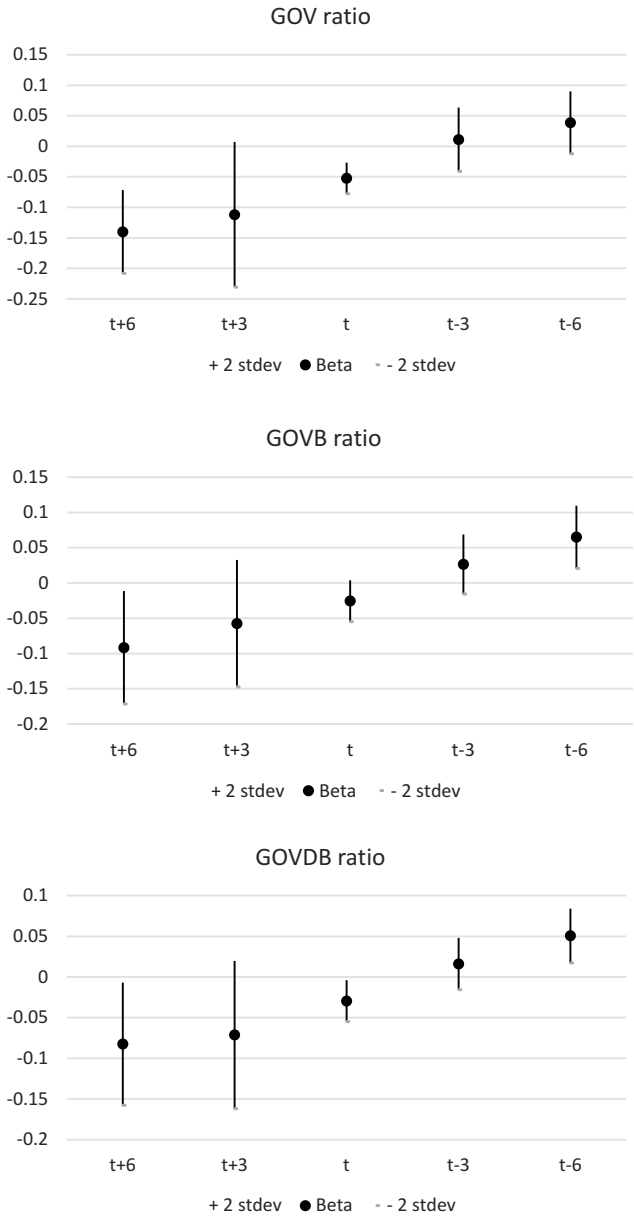

GOV ratio
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev
GOVB ratio
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev
GOVDB ratio
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
t+6
t+3
t
t-3
t-6
+ 2 stdev
Beta
- 2 stdev

Figure B2.