EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

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The impact of central bank liquidity support on banks' balance sheets

No 2326 / November 2019

Abstract

We empirically analyse the relationship between longer term central bank liquidity support and banks' balance sheet ratios, 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' funding policies and asset allocations. The results show that unconditional and conditional refinancing operations are associated with different developments on banks' balance sheets. Unconditional longer-term refinancing operations went together with higher maturity transformation by banks in stressed countries, and also more carry trades, 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
JEL classifications: E51, G21, G32

Non-technical summary

The aim of this paper is to empirically investigate whether the structure of banks' balance sheets that were differentially dependent on the liquidity support by the Eurosystem developed differently. While the Eurosystem liquidity support to banks was aimed at preventing disorderly deleveraging and in supporting lending to the real economy, it can be associated with other unintended effects on banks' balance sheets, such as reducing the pressure on banks to restructure their balance sheets and become self-financing again. We focus specifically on two of the longer term programmes: (i) 36 month refinancing operations (VLTROs) and (ii) targeted long-term refinancing operations (TLTROs) with a maturity of 4 years which were conditional on banks' lending activity. By distinguishing between the effects of these two types of refinancing operations on bank behaviour our paper adds value to the literature in that it highlights the different developments that are associated with conditional and unconditional operations.

Our main findings show that banks' balance sheets appeared to develop differently with conditional and unconditional longer-term refinancing operations. Specifically, we find evidence that unconditional longer term central bank borrowing (VLTROs) went together with carry trades in the form of an increase in government bonds holdings, while the opposite was the case for banks that borrowed in the TLTROs, which were designed specifically to support credit provision to the non-financial private sector. Moreover, there is some evidence that banks that used VLTROs developed higher maturity mismatches and lower self-insurance for liquidity risk in stressed countries, while on the other hand there is some evidence that banks that borrowed heavily in the TLTROs overall increased their self-insurance for liquidity risk.

One of the concerns in this literature is the self-selection of banks into the liquidity operations and the two-way causality between borrowing from the central bank on the one hand and bank balance sheet developments on the other. Given the difficulty in fully controlling for these factors, we speak of correlations and associations between take-up and banks' balance sheet developments. However, we use a battery of different methods to try and take account of some of these concerns and taken together they can provide a picture of the more robust balance sheet associations. We use difference-in-differences panel regressions for a large sample of banks in the euro area, where we regress key indicators of balance sheet adjustments on the use of the two longer-term refinancing operations. The difference-in-differences approach is aimed at finding out whether central bank borrowing is a distinguishing driver of balance sheet adjustments, by controlling for other confounding factors such as bank and country-specific characteristics and cyclical developments. Endogeneity is reduced 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, by including control variables, such as the business cycle that may also impact balance sheets. Potential selection bias is accounted for by propensity score matching techniques.

Overall, the findings provide mixed support for some of the (theoretical) assumptions in the literature that central bank funding can have a material impact on banks' balance sheet strategies. The findings do underscore the benefits of having conditionality attached to long-term refinancing operations.

1. 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). The aim of this paper is to empirically investigate whether the structure of the balance sheets at banks that were heavily dependent on the liquidity support by the Eurosystem developed differently to banks with low central bank dependence, controlling for the confounding factors over the period.

We test the association between bank balance sheets and liquidity support, by specifically focusing on two of the longer term programmes: (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 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 key indicators of balance sheet adjustments 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 balance sheet adjustments, by controlling for other confounding factors such as bank and country-specific characteristics and cyclical developments. Endogeneity is reduced 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. These tests indicate that the methodologies employed did not necessarily yield consistent or convincing causal evidence. While mean difference tests give mixed results as to the difference-in-differences assumption of compatibility of 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 balance sheet changes. As a robustness test, potential selection bias is accounted for by propensity score matching techniques.

We run several regressions where the dependent variable is a particular form of balance sheet adjustment (excluding the position vis-a-vis the central bank), which is based on predictions from the theoretical literature on the influence of central bank financing on bank strategies. The regression outcomes indicate that central bank borrowing can be associated with changes of banks' balance sheets, which differ between the two types of refinancing operations. There is some evidence that banks that used VLTROs in stressed countries showed higher maturity mismatches and lower self-insurance for liquidity risk, while on the other hand there is some evidence that banks that borrowed heavily in the TLTROs increased their self-insurance for liquidity risk. Given the different shocks that banks were exposed to over this period, drawing causality must be done with caution; notwithstanding this, we use a number of methods and can discern some clear trends. We find that unconditional longer term central bank borrowing (VLTROs) went together with increased exposure to sovereign bonds. Banks that borrowed in excess of the sample median in the VLTROs were more likely to increase holdings of government bonds, but the opposite was found for the TLTROs, which were designed specifically to support credit provision to the non-financial private sector. Overall, the findings provide mixed support for a some of the (theoretical) assumptions in the literature on the impact of central bank funding on banks' balance sheet strategies. The findings mainly underscore the benefits of having conditionality attached to long-term refinancing operations.

The rest of this paper is organised as follows. Section 2 provides an overview of the literature dealing with the link between bank behaviour and central bank funding and formulates the four hypotheses 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 the four hypotheses on bank reactions. The regression model is specified in Section 5 and Section 6 presents the estimation results. Section 7 provides robustness checks. Section 8 concludes.

2. Literature review and hypotheses

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

2.1 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 goods prices, 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 et al. (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. (2013) find that the 3 year LTROs have had a beneficial impact on credit supply and money market conditions. Using data for Portugal, Alves et al. (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. (2015) 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 (2016) 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 et al. (2016) find that interest rates on loans to 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 other balance sheet effects that may be associated with central bank borrowing.

The literature points out that lender of last resort financing by the central bank can give various incentives to bank behaviour. According to Farhi and Tirole (2009) and Mink (2011), central bank support stimulates banks to increase *maturity transformation*, i.e. to use more short-term and less long-term debt to finance their long-term assets. Banks would be tempted to do so to increase profits, since short-term debt usually has a lower interest rate than long-term debt. When long-term funding is provided by the central bank, it is likely that banks use this to substitute wholesale funding (Andrade et al., 2015).

Freixas et al. (2000) relates the moral hazard created by central bank liquidity to potentially laxer *liquidity management*. In the model of Repullo (2005), such behaviour is further specified by the assumption that with central bank funding a bank chooses the same level of risk, but holds a smaller liquidity buffer than

in the absence of a lender of last resort.[1] Furthermore, liquidity insurance by the central bank could reduce the need to seek liquidity insurance in the interbank market, which may affect the incentive of banks to be active in that market (Goodhart, 2008).

The prospect of receiving central bank support at a relatively low interest rate may also reduce pressure on banks to *deleverage*. In the theoretical model of Farhi and Tirole (2009), subsidizing liquidity by the central bank allows banks to increase their scale, rendering bailouts more likely. Reichlin (2014) also claims that central bank funding discourages banks to deleverage and to improve their capital ratio, in particular if longer-term funding is provided, like the ECB's long-term refinancing operations. However, one of the purposes of central bank liquidity is to prevent disorderly deleveraging and forced asset fire sales, which may impact credit provision (Darracq-Paries and De Santis, 2015).

Other empirical studies find that central bank funding encouraged risk shifting and *carry trades* through government bond purchases by - weakly capitalised - banks (Acharya and Steffen, 2012; Drechsler et al., 2016). A related strategy is collateral trading, whereby central bank funding incentivises 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 et al. (2016) find evidence for this behaviour by Portuguese banks in response to the VLTROs, and Altavilla et al. (2017) show similar behaviour for the euro area. Carpinelli and Crosignani (2016) similarly 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).

2.2 Hypotheses

Based on the literature, we formulate four 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: Maturity transformation: high borrowing banks engage more in maturity transformation than low borrowing banks (Farhi and Tirole, 2009).

We measure maturity transformation by two indicators: (1) the change in the loan-to-deposit ratio (*LTD*, loans over deposits) and by (2) the change in the mismatch ratio *MM* (long-term loans minus long-term funding over main assets; see Appendix A for the definition of the ratios). The LTD ratio reflects the funding gap of a bank, or the dependence on non-deposit funding. The MM ratio measures the dependence on short-term funding. *H1*

[1] If the central bank intervenes through asset purchases this would not necessarily be the case; purchases of less liquid bonds offers banks the opportunity to build-up liquidity buffers (EBA, 2014).

posits that these ratios should increase more (or decrease less) for high borrowing banks compared to low borrowing banks, given that central bank funding (long-term refinancing in particular) allows banks to cover their funding gap and limit the roll-over risk of short-term funding dependency. The LTD-ratio can also - passively - change due to inflows and outflows of deposits, that will not reflect active strategies by a bank. This underscores the importance of including control variables that deal with those kinds of exogenous influences (as we do in the regression analysis in Section 5) and of exercising caution in interpreting movements in these variables.

H2: Liquidity management: high borrowing banks less actively engage in self-insurance for liquidity risk than low borrowing banks (Repullo, 2005).

We measure liquidity management by two indicators: (1) changes in the liquid asset ratio (holdings of liquid assets over main asset ratio, *LA*) and (2) the wholesale funding ratio (wholesale funding over main assets, *WS*). Liquid assets mainly consist of bond holdings, which can be used as collateral in central bank refinancing operations. It excludes central bank reserves, since we measure the liquidity buffers that banks hold independently from central bank facilities. Wholesale funding is an indicator of self-insurance in the money market, as well as an indicator of access to the bond market. It measures to what extent banks are able to fund themselves independently of the central bank. *H2* assumes that both *LA* and *WS* of high borrowing banks decline more (or increase less) compared to the ratios of low borrowing banks. This is based on the theory that central bank funding provides liquidity insurance, so that banks have less incentives to self-insure through holdings of liquid assets or funding in wholesale markets. The latter might be substituted by central bank funding.

H3: Leverage: high borrowing banks show less deleveraging than low borrowing banks (Kaufman, 1991).

We measure leverage by the leverage ratio (*LEV*), defined as (unweighted) capital over main assets.[2] *H3* assumes that the leverage ratio increases less for high borrowing banks compared to low borrowing banks, assuming that the availability of central bank funding reduces the need for asset sales and therefore banks' propensity to deleverage (Reichlin, 2014).

H4: Carry trades: high borrowing banks show higher exposures to government debt than low borrowing banks (Acharya and Steffen, 2012; Drechsler et al., 2016).

We measure carry trade behaviour of banks by the exposures to governments over main assets ratio (*GOV*). *H4* 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.

[2] We do not use the 'Tier 1' capital ratio, since it is not available for all banks in the sample.

3. Data

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

3.1. 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 (IBSI) for individual monetary financial institutions (MFIs) over the period August 2007 to October 2017. 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 winsorised by limiting extreme outliers (at the top and bottom 1% of the distribution). The final dataset contains 172 banks in 14 euro area countries. Our variables of interest that capture different balance sheet strategies (as outlined in Section 2) are described in Appendix A. In the baseline model we include the monthly balance sheet variables in terms of year-on-year growth rates.

3.2 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. The Eurosystem allotted two 3 years operations (VLTROs) in December 2011 and February 2012.[3] 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 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.

[insert Figure 1]

Of the 172 banks in the sample, 82 banks are defined as high borrowers in the VLTRO and 75 are high borrowers in the TLTRO. There are 74 banks that are classified as high in neither operation and 59 that are

3 Most of the borrowings from the previously introduced 12 month operation shifted to the 36 month operation.

classified as high borrowers in both, leaving 23 that are only high borrowers in the VLTRO and 16 that are classified as high borrowers only in the TLTRO.

3.3 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.[4] 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.

[insert Table 1]

4. Graphical evidence

In this section we provide some first graphical evidence of the responses of balance sheet ratios to 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).

[insert Figures 2-3]

4.1. Maturity transformation

Figure 2 and 3, panels 1 and 2, provide some tentative evidence that the operations are associated with banks' maturity transformation. The average LTD-ratio (panel 1) of high borrowing banks showed a mostly stronger growth than the ratio of low borrowing banks during the periods of the refinancing operations (VLTROs as well as TLTROs), while before the operations high borrowing banks showed a relatively lower growth. This could suggest that central bank funding was an incentive for banks to increase their funding gap or that deposit outflows were greater for these banks. The increased gap between lending and deposits did not seem to go in tandem with a higher maturity mismatch at the time of the VLTROs; the mismatch ratio (panel 2) of the high

4 Stressed countries are defined as Spain, Ireland, Italy, Greece, Portugal and Slovenia. Other countries included are: Austria, Belgium, Germany, Finland, France, Luxembourg, Malta and the Netherlands.

borrowing banks showed a much slower growth than the mismatch ratio of low borrowing banks, as it did before the VLTROs. Only the TLTROs showed a markedly higher increase of the mismatch ratio of high borrowing banks compared to low borrowing banks. Figure 3, panel 2 indicates that an increase in the mismatch ratio occurred at the start of the TLTROs, providing tentative evidence in favour of *H1*.

4.2 Liquidity management

It is not obvious that the liquidity operations incentivized high borrowing banks to reduce liquid assets and wholesale funding more than low borrowing banks (Figures 2 and 3, panels 3 and 4). The growth of the high borrowers' LA ratio remained above the low borrowers' (panel 3), which would not support *H2*. Since the trend was evident also before the operations, and confounding factors should be controlled for as we do in Sections 5 and 6, implications for *H2* are ambiguous. With regard to the wholesale funding ratio (panel 4), the trend for the VLTROs would provide some tentative support for *H2*, as the ratio declined more for high borrowers. TLTROs did not have this effect; the *WS* ratio of high borrowing banks increased compared to *WS* of low borrowing banks during the targeted operations, at least at the beginning.

4.3. Deleveraging

Figures 2 and 3, panel 5, show that the VLTROs were associated with an increase of the leverage ratio (*LEV*) of high borrowing banks compared to low borrowing banks, which seems to be a break from the previous common trend in *LEV*. This therefore would not lend support to *H3* and implies that central bank funding was not perceived as a substitute for bank equity, or went together with a slower deleveraging by high borrowing banks. There is no clear difference between the change in *LEV* for high versus low borrowers during the TLTROs. The relative decline in *LEV* of high borrowers in the first stage of these refinancing operations reversed in the later stages.

4.4. Carry trades

Figures 2 and 3, panel 6, indicate that VLTROs were associated with carry trades; government bond holdings of high borrowing banks increased more than the holdings of low borrowing banks since the introduction of the VLTROs. For the TLTROs there is no strong initial evidence for a change in behaviour across the two groups with respect to carry trades.

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.

5. 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*,

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

where Y_{it} is a particular balance sheet ratio 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 balance sheet adjustment. *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 central bank borrowing. The dummy in each case is time-invariant, also to avoid endogeneity. 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[5]. 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. As our key regressor of interest, *Liquidity operation*$_i$ is not randomly assigned across banks and is driven by factors that could also drive the outcome variables, these variables are essential in removing any correlation between *Liquidity operation*$_i$ and the residuals which would bias the results. Therefore we include a comprehensive set of regressors that would potentially drive take-up in the liquidity operations and the outcome variables. In X_{it} we include time varying measures that capture bank solvency or credit risk (measured by CDS spread), bank size (main assets as share of the total banking sector), and bank profitability (return on assets).

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

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

changes in macroeconomic conditions at the country level that could impact banks behaviour and their balance sheets.[6] 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.

[insert Table 2]

6. 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, Panel C of Table 2 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*), between wholesale funding ratio (*WS*) and the leverage ratio (*LEV*) for high and low borrowers before the VLTRO. However, there is a difference between the mismatch ratios (*MM*), liquid asset ratio (*LA*) and marginally the loan-to-deposit ratio (*LTD*) for low and high borrowers before the VLTRO. For the stressed country sample, there are differences between the means of high and low borrowing banks for all variables with the exception of LTD ratio and WS. Given that the variables are included in terms of annual growth rates, mean difference testsare 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. The results indicate that all outcome variables have parallel trends before treatment.

6 We also estimated regressions with macroeconomic variables instead of country time dummies, but this alternative did not change our results substantially.

[insert Table 3]

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.

[insert Tables 4, 5 and 6]

6.1. Maturity transformation

The estimates indicate that the banks that heavily borrowed in VLTROs showed only some evidence of higher maturity transformation compared to low borrowing banks in stressed countries (Tables 4 and 5, columns 1 and 2). The partial-correlation coefficient β between central bank borrowing and the maturity transformation indicator *MM* is positive and significant in Table 5, however LTD is never significant (indicating only limited support for *H1*).[7] With respect to the TLTROs, there were no significant differences in maturity transformation between high and low borrowers.

6.2 Liquidity management

Across the whole sample, there is no significant evidence that banks that borrowed more heavily in the refinancing operations reduced their liquidity insurance. However, for banks in stressed countries we do find some significant differential developments in the *WS* ratio for banks that borrowed highly in the VLTROs (Table 5, column 4). We do not find such effects for the TLTROs. In fact, those operations were even associated with an increasing liquidity risk insurance by high borrowing banks (β is significant and positive for *WS* in the full sample).

6.3. Deleveraging

There is no evidence that the banks that heavily borrowed in central bank liquidity operations deleveraged at a slower pace. The results show that *H3* should be rejected, as central bank borrowing does not seem to be related to the pace of deleveraging by high borrowing banks.

6.4. Carry trades

For the VLTROs the estimation results suggest that the hypothesis (*H4*) that central bank funding was an incentive for carry trades may hold. The β coefficient of variable *GOV* is significant and positive with regard to the VLTROs, both in the full sample and in the stressed country sample (columns 6 in Tables 4-5). In contrast to that, the TLTROs had a significantly negative coefficient on *GOV* in both samples. As the TLTRO

[7] Since changes in the maturity function of banks may evolve slowly over time, we also estimated the model by including the 12 or 24 months ahead year-on-year changes of *LTD* and *MM* instead of a 1 month ahead change, but these were in almost all cases not statistically significant.

made the return on lending more attractive, banks may have shed sovereign assets and adjusted their portfolios towards lending.

The VLTROs and TLTROs overlap between 2014m9 and 2015m1. To avoid possible overlaps, we re-estimate the model for TLTROs using a sub-sample starting in 2016m1. The outcomes show that for the full sample the value of the negative coefficient of *GOV* remains similar and becomes even more significant in the subsample starting from 2016m1.[8] For the stressed country sample the coefficient of *GOV* remains negative as well, but is not significant anymore in the subsample starting in 2016m1.

7. Robustness tests

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

7.1 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 *MM* becomes significant for VLTROs and the level of significance of the β coefficient of *GOV* changes, while remaining significant (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.

7.2 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

[8] The outcomes are not shown, but are available on request from the authors.

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, since the signs and the significance of the coefficients are similar in the regressions excluding and including the APP variable. With regard to the APP variable, in both the full sample and the stressed country sample its coefficient is significantly positive in the model with *MM* as dependent variable (column 2 in Appendix B, Table B4). This suggests that the APP correlates positively with the extent of maturity transformation by banks, while the significantly negative coefficient of *WS* in the stressed country sample indicates that the APP is associated with a somewhat lower reliance on wholesale funding. The APP variable is not significant in the model with *GOV* as dependent variable, perhaps because banks can experience an increase in liquidity associated with APP also from higher deposits. While a bank's exposure to the APP does not significantly distinguish any differences in total exposure to the government sector, the negative coefficient for the TLTROs remains significant.

7.3 Estimations using the average outcomes

As recommended by Bertrand et al. (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 TLTROs, compared to the baseline estimations. For the stressed country group, high borrowers in the VLTROs continue to have higher maturity mismatches, but the other variables are no longer significant. The results for TLTROs in stressed countries show that high borrowers continue to have significantly lower *GOV* over the period of the TLTRO and also now show significantly higher wholesale funding access.

7.4 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,

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

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 ($Y(0)$).

$$\text{ATT identified only if } E(Y(0) \mid W = 1) - E(Y(0) \mid W = 0) = 0 \quad (3)$$

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, 2005). Unconfoundedness means that the assignment to the treatment or control group (W) is independent of the outcomes,

$$\text{Unconfoundedness: } Pr[W \mid X, Y(1), Y(0)] = Pr(W \mid X) \quad (4)$$

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

$$\text{Common support condition: } p_i = Pr(W_i \mid X_i), \; 0 < p_i < 1 \quad (5)$$

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-neighbor matching method, which is most commonly employed. The choice of the covariates (X) which determine the control group in the propensity score model is based on criteria in the literature (e.g. Caliendo and Kopeinig, 2005). First, variables are included that are largely unaffected by the participation in Eurosystem refinancing operations (or the anticipation of it). To this end, the preferred variables should be fixed over time or reflect structural characteristics of banks which are persistent through time. Second, 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 *t*-test on 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 absolute mean bias, which should – by rule of thumb - be smaller than 5%. We select covariates by treatment variable (the VLTRO and TLTRO dummy) which meet the matching criteria. The matching is based on structural, slow moving

variables, such as the cost-income ratio, net interest income, return on assets and size.[9] Tables B.7 and B.8 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. This indicates that the selection bias in the original model is limited. There are only two relevant differences. In the full sample with TLTROs the coefficient of *WS* is not significant in the weighted regression. Next, propensity score matching provides evidence of maturity transformation associated with the VLTROs, as the coefficient is significant in the weighted regression using the LTD ratio as dependent variable (Table B6, Panel A).

7.5 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 balance sheet ratios 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, 6 and 9 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 (except for variable *GOV*) and have wider confidence bands than the β coefficient of the contemporaneous (actually the one month lagged) and 3, 6 and 9 months lagged treatment indicator. This suggests that there is no strong evidence of an anticipatory response of VLTROs and TLTROs to changes in banks' balance sheet ratios.

7.6 *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 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.[10] For the maturity mismatch ratio and the wholesale funding

[9] Selected covariates for the weighted regression for VLTROs: cost-to-income ratio, provisioning costs, size and return on equity; for TLTROs: cost-to-income ratio, fee income, net-interest income, provisioning costs, size and return on assets.
[10] Results are not reported but are available upon request from the authors.

ratio we find significant effects already before the introduction of the operations, confirming that our findings for government bonds are the most robust.

8. Conclusion

In this paper we examine the differential developments of the balance sheets of 172 euro area banks at the time of two types of long-term refinancing operations by the Eurosystem: VLTROs and TLTROs, respectively. We test several hypotheses on banks' strategic responses to central bank liquidity support that emerge from the literature, while addressing potential selection bias by using propensity score matching techniques. The outcomes of difference-in-differences panel regressions indicate that banks' balance sheets developed differently at the time of the two types of refinancing operations. After performing a battery of tests, our most robust findings can be summarised in Table B9. With regard to the solvency position of borrowing banks, we do not find a relationship between refinancing operations and the pace of deleveraging by high borrowing banks. 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 the banking system, our findings provide only mixed support to certain (theoretical) predictions in the literature that central bank funding can have material 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 incentivising 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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Appendix A. Definition of bank balance sheet ratios

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

LEV	Leverage ratio (capital and reserves, monetary definition / main assets, unweighted for risk)

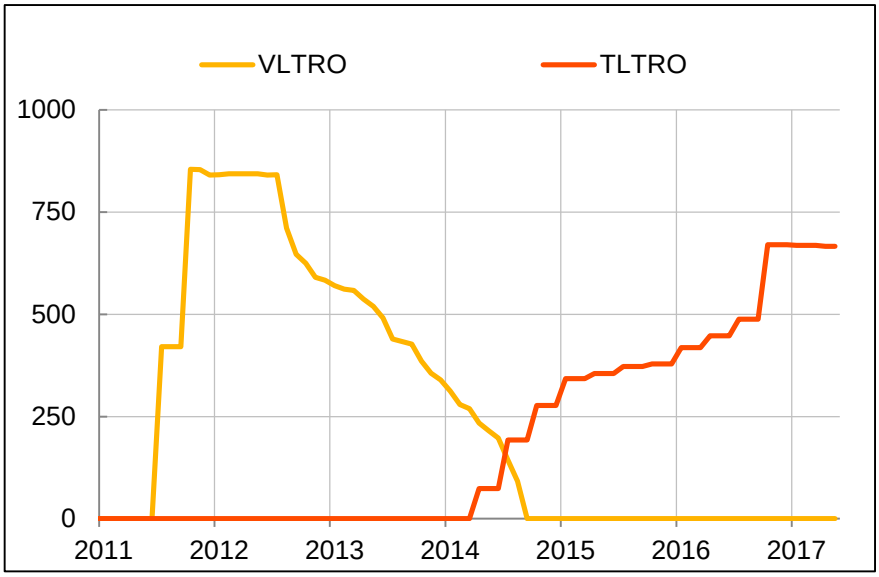
Carry trades

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

FIGURES

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.

Figure 2. Effect of VLTROs on balance sheet indicators

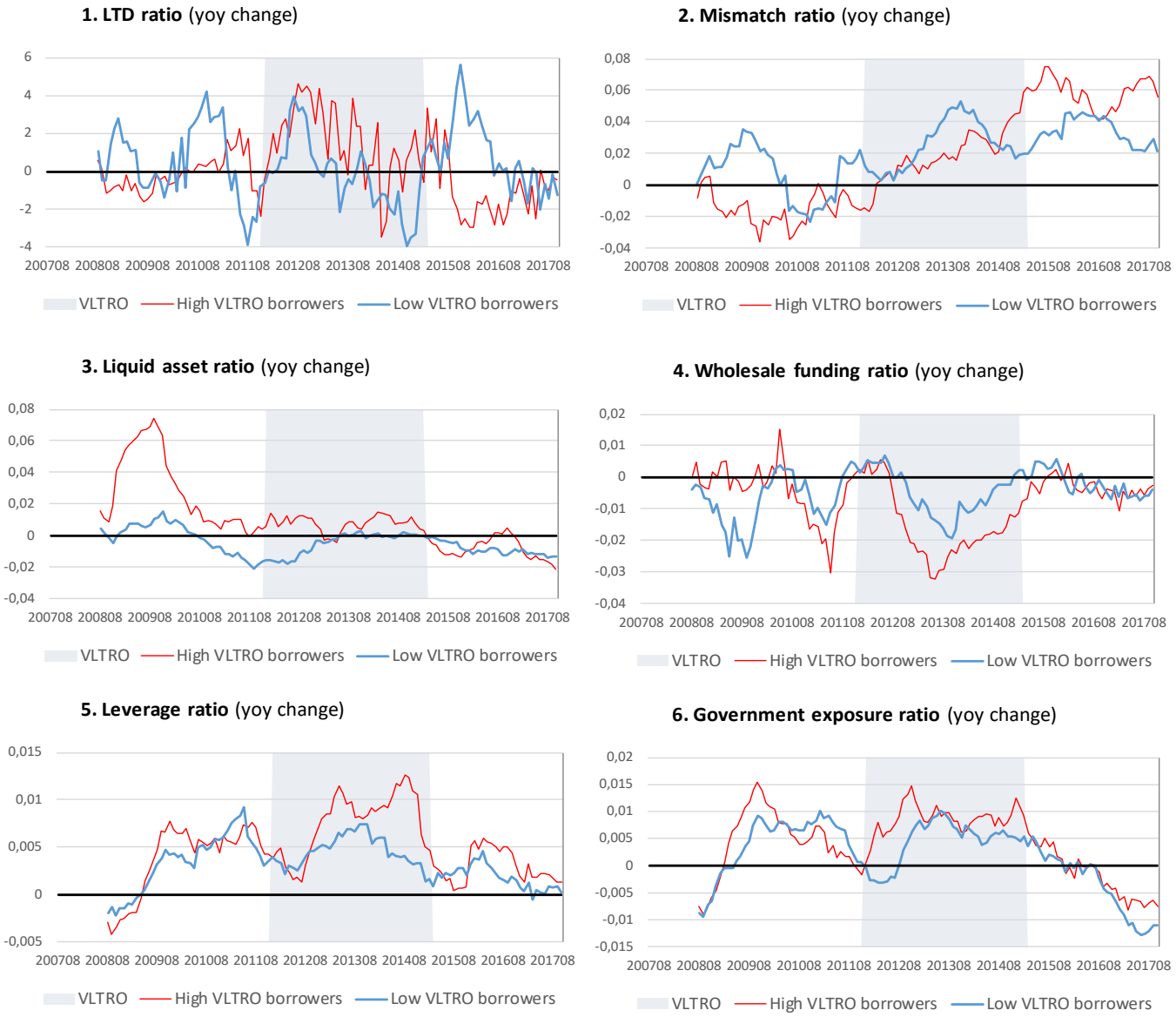
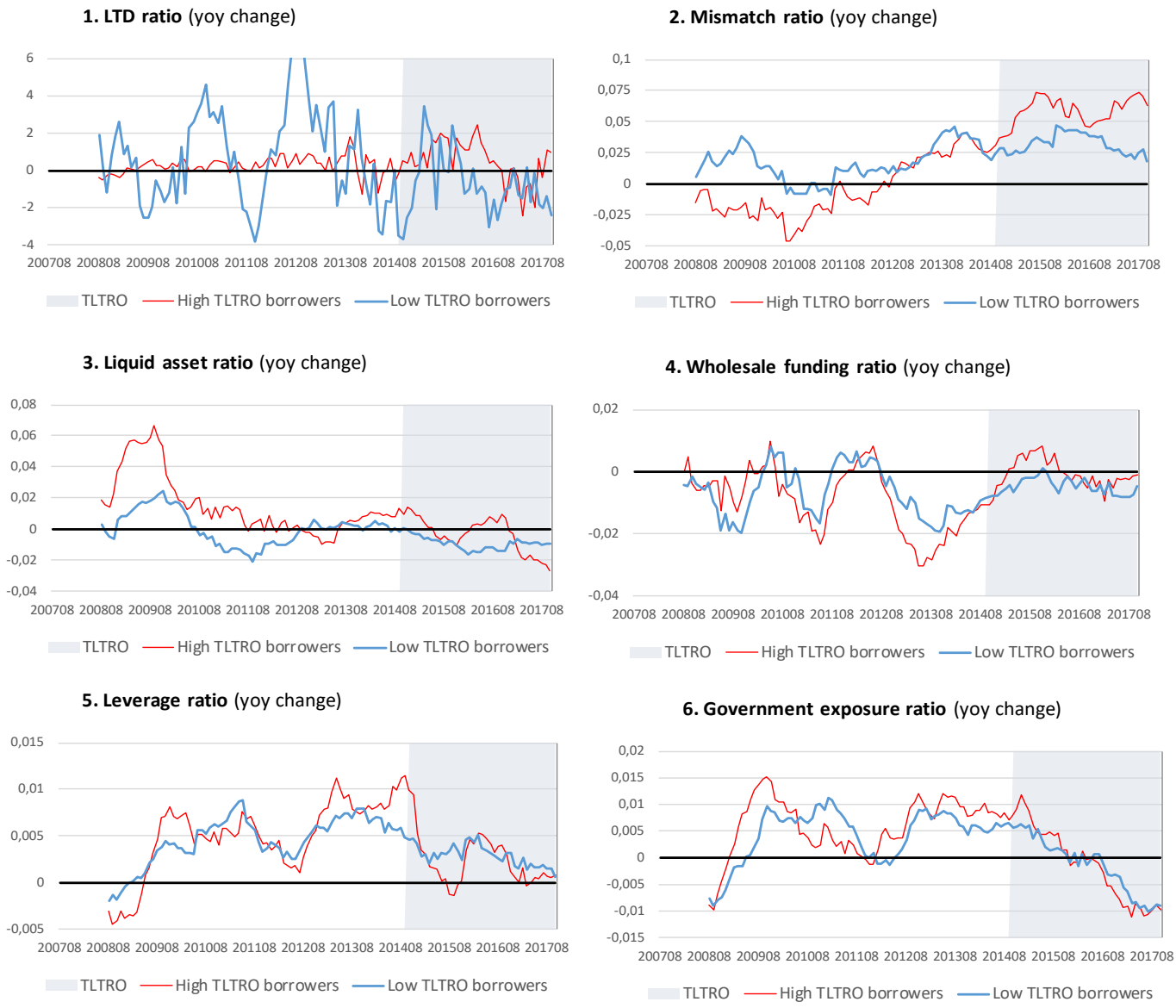


Figure 3. Effect of TLTROs on balance sheet indicators



TABLES

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	0.74	0.69
	Mean	0.69	0.41
	St. dev	1.25	0.64
Stressed	p25	0.00	0.00
	Median	1.15	0.69
	p75	2.85	1.39
	Mean	1.63	0.77
	St. dev	1.69	0.80
Non stressed	p25	0.00	0.00
	Median	0.00	0.00
	p75	0.23	0.40
	Mean	0.23	0.24
	St. dev	0.53	0.46
Panel B. Characteristics according to borrowing			
		VLTRO	TLTRO
CDS	High borrower	229.59	225.74
	Low borrower	132.86	143.84
CET 1 ratio	High borrower	11.43	11.24
	Low borrower	12.46	12.80
ROE	High borrower	0.88	0.88
	Low borrower	3.07	3.07

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

Table 2. Summary statistics model variables before VLTRO and TLTRO

Panel A – Before VLTRO

	LTD	MM	LA	WS	LEV	GOV	ROA	Size	CDS
Min	-80.138	-0.295	-0.153	-0.152	-0.036	-0.074	-6.800	0.000	3.657
Median	-0.014	0.002	0.000	-0.003	0.002	0.001	0.349	0.002	118.295
Mean	0.160	-0.003	0.012	-0.005	0.004	0.004	0.344	0.006	173.512
Max	101.512	0.278	0.232	0.108	0.065	0.093	4.302	0.060	2394.910
Standard dev.	11.966	0.090	0.060	0.040	0.014	0.025	0.693	0.009	197.006

Panel B – Before TLTRO

	LTD	MM	LA	WS	LEV	GOV	ROA	Size	CDS
Min	-80.138	-0.295	-0.153	-0.152	-0.036	-0.074	-50.290	0.000	3.657
Median	-0.021	0.013	0.000	-0.005	0.003	0.002	0.282	0.003	137.110
Mean	0.536	0.008	0.007	-0.008	0.005	0.005	0.094	0.006	201.865
Max	101.512	0.278	0.232	0.108	0.065	0.093	21.585	0.060	2394.910
Standard dev.	14.681	0.088	0.056	0.041	0.014	0.025	2.208	0.009	227.664

Panel C. Mean tests before VLTRO

	LTD	*MM*	*LA*	*WS*	*LEV*	*GOV*
			All			
Mean low borrowers	0.427	0.008	-0.001	-0.005	0.003	0.004
Mean high borrowers	-0.167	-0.015	0.028	-0.005	0.004	0.004
P value from difference test	0.059	0.000	0.000	0.758	0.22	0.475
			Stressed			
Mean low borrowers	0.091	-0.008	0.000	-0.013	0.011	0.002
Mean high borrowers	0.072	-0.025	0.037	-0.007	0.005	0.008
P value from difference test	0.973	0.001	0.000	0.436	0.000	0.000

Table 3. Test for parallel trend assumption (baseline model)

Full sample	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	MM	LA	WS	LEV	GOV
β	0.0337	0.000938	-0.00115	-0.00145	0.0000445	-0.000551
	(0.0382)	(0.00231)	(0.00120)	(0.000871)	(0.000161)	(0.000348)
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	391	373	321	160	464	457
R2	0.119	0.282	0.321	0.413	0.379	0.300
Stressed countries	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	MM	LA	WS	LEV	GOV
β	0.0743	0.00173	-0.00230	0.00261	0.0000234	-0.000911
	(0.0470)	(0.00370)	(0.00200)	(0.00792)	(0.000255)	(0.000572)
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	207	225	173	56	225	225
R2	0.306	0.287	0.326	0.593	0.402	0.305

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.

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

Panel A. VLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) LEV	(6) GOV
β	3.988	0.0389	-0.00716	-0.0135	0.00222	0.0118***
	(2.706)	(0.0281)	(0.0187)	(0.00823)	(0.00245)	(0.00347)
Bank level controls:						
ROA	-0.00170	-0.000584	-0.000419	0.00114	-0.00126**	0.000925*
	(0.0956)	(0.00203)	(0.00233)	(0.00102)	(0.000554)	(0.000503)
Size	122.4	-0.668	1.605	1.128	-0.387	0.699
	(116.2)	(2.054)	(1.689)	(1.073)	(0.308)	(0.457)
CDS	-0.00201	-0.0000033	-0.0000222	0.0000167	-0.00000828	0.00000309
	(0.00281)	(0.0000331)	(0.0000285)	(0.0000162)	(0.00000610)	(0.0000107)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.228	0.382	0.385	0.378	0.425	0.324

Panel B. TLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) LEV	(6) GOV
β	-1.977	-0.00848	0.00258	0.0195*	-0.000218	-0.00770*
	(2.559)	(0.0271)	(0.0118)	(0.0110)	(0.00394)	(0.00336)
Bank level controls:						
ROA	0.0283	-0.000469	-0.000447	0.000829	-0.00125**	0.00104**
	(0.105)	(0.00215)	(0.00231)	(0.000970)	(0.000559)	(0.000494)
Size	232.8	0.496	1.348	0.102	-0.360	1.125**
	(184.7)	(2.486)	(1.933)	(1.158)	(0.333)	(0.518)
CDS	-0.00202	-0.0000048	-0.0000220	0.0000174	-0.00000840	0.00000220
	(0.00280)	(0.0000350)	(0.0000286)	(0.0000161)	(0.00000617)	(0.0000101)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.226	0.376	0.384	0.383	0.424	0.318

Note: standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Bank levels controls include size, profitability and CDS spread.

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

Panel A. VLTRO	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	MM	LA	WS	LEV	GOV
β	0.802	0.0817*	-0.0434	-0.0385*	0.00525	0.0157***
	(0.556)	(0.0417)	(0.0319)	(0.0198)	(0.00490)	(0.00526)
Bank level controls:						
ROA	-0.0885	-0.000553	-0.00135	0.00179*	-0.00118*	0.00126**
	(0.0806)	(0.00206)	(0.00245)	(0.000997)	(0.000609)	(0.000543)
Size	269.6	1.835	-1.609	1.380	-0.719	1.108
	(195.8)	(4.966)	(3.193)	(3.915)	(1.121)	(1.014)
CDS	-0.000301	-0.0000033	-0.0000377	0.0000195	-0.0000100	0.00000594
	(0.000781)	(0.0000339)	(0.0000287)	(0.0000187)	(0.00000765)	(0.0000112)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.228	0.382	0.385	0.378	0.425	0.324
Panel B. TLTRO	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	MM	LA	WS	LEV	GOV
β	-0.837	-0.0160	0.00906	0.0495	0.00130	-0.0156***
	(1.882)	(0.0497)	(0.0213)	(0.0314)	(0.00931)	(0.00537)
Bank level controls:						
ROA	-0.0854	-0.000553	-0.00131	0.00139	-0.00120*	0.00138**
	(0.0834)	(0.00229)	(0.00242)	(0.000842)	(0.000624)	(0.000547)
Size	310.9	5.247	-3.343	0.330	-0.567	2.129**
	(193.8)	(4.541)	(3.427)	(3.584)	(0.994)	(0.977)
CDS	-0.000391	-0.0000129	-0.0000338	0.0000234	-0.0000105	0.00000323
	(0.000851)	(0.0000396)	(0.0000303)	(0.0000198)	(0.00000796)	(0.0000106)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.226	0.376	0.384	0.383	0.424	0.318

Note: standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Bank levels controls include size, profitability and CDS spread.

Appendix B. Robustness tests

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

Panel A. VLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) LEV	(6) GOV
β	1.458	0.0670*	-0.0268	-0.0224	0.00487	0.00960*
	(1.618)	(0.0337)	(0.0276)	(0.0136)	(0.00295)	(0.00525)
	1.458	0.0670*	-0.0268	-0.0224	0.00487	0.00960*
Bank level controls:						
ROA	0.00788	-0.000649	-0.000501	0.00106	-0.00126**	0.000932*
	(0.0970)	(0.00194)	(0.00231)	(0.00101)	(0.000553)	(0.000495)
Size	126.3	-0.279	1.562	1.375	-0.390	0.718
	(114.2)	(2.122)	(1.722)	(1.157)	(0.319)	(0.452)
CDS	-0.00193	0.00000482	-0.0000243	0.0000174	-0.00000813	0.00000303
	(0.00284)	(0.0000303)	(0.0000280)	(0.0000160)	(0.00000604)	(0.0000105)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.228	0.382	0.385	0.378	0.425	0.324
Panel B. TLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) LEV	(6) GOV
β	-1.441	-0.0171	0.00637	0.0236	0.00171	-0.00880**
	(1.162)	(0.0316)	(0.0136)	(0.0151)	(0.00494)	(0.00370)
Bank level controls:						
ROA	0.0342	-0.000255	-0.000533	0.000682	-0.00128**	0.00108**
	(0.104)	(0.00227)	(0.00227)	(0.000931)	(0.000569)	(0.000502)
Size	181.2	0.846	1.178	0.441	-0.423	1.024*
	(117.1)	(2.437)	(1.956)	(1.293)	(0.317)	(0.549)
CDS	-0.00196	-0.0000048	-0.0000218	0.0000160	-0.00000839	0.00000250
	(0.00277)	(0.0000342)	(0.0000285)	(0.0000156)	(0.00000615)	(0.0000102)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
N	1546	1329	1176	1251	1670	1663
R2	0.226	0.376	0.384	0.383	0.424	0.318

Note: standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Bank levels controls include size, profitability and CDS spread.

Table B2. Estimation outcomes for TLTROs with APP control variable

Baseline model (partial-correlation coefficient β of model excluding, versus including APP control variable (APP impact dummy x APP time dummy)

Panel B. full sample	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	*MM*	*LA*	*WS*	*CAP*	*GOV*
β (excl APP variable)	0.0638	-0.00255	0.0155	0.0240***	-0.000254	-0.0124**
	(0.182)	(0.0254)	(0.0243)	(0.00825)	(0.00467)	(0.00521)
β (incl APP variable)	0.0497	-0.00387	0.0165	0.0240***	-0.000265	-0.0124**
	(0.219)	(0.0223)	(0.0214)	(0.00804)	(0.00469)	(0.00519)
APP variable	0.0942	0.0364**	-0.0243	-0.00501	0.000424	0.00105
	(0.305)	(0.0147)	(0.0180)	(0.00643)	(0.00375)	(0.00396)
N	867	771	662	697	940	940
Panel B. stressed countries	(1)	(2)	(3)	(4)	(5)	(6)
	LTD	*MM*	*LA*	*WS*	*CAP*	*GOV*
β (excl APP variable)	0.0167	0.00540	0.0623**	0.0481***	-0.00295	-0.0232***
	(0.104)	(0.0452)	(0.0237)	(0.00516)	(0.00963)	(0.00734)
β (incl APP variable)	0.0143	0.0123	0.0535**	0.0423***	-0.00223	-0.0235***
	(0.102)	(0.0400)	(0.0193)	(0.00567)	(0.00914)	(0.00759)
APP variable	0.0545	0.0477**	-0.0327	-0.0163*	0.00498	-0.00173
	(0.0869)	(0.0180)	(0.0238)	(0.00841)	(0.00663)	(0.00625)
N	397	438	329	273	438	438

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

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

Panel A. VLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) CAP	(6) GOV
β	-3.324	0.0134	-0.0168	0.00213	0.0000557	0.0105**
	(4.391)	(0.0305)	(0.0146)	(0.00521)	(0.00204)	(0.00426)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
ROA	0.729	-0.0123	0.00610	0.0122	-0.000769	-0.00805**
	(0.792)	(0.0144)	(0.0103)	(0.00916)	(0.00141)	(0.00286)
Size	153.1	2.267	-5.192	0.335	0.417	-0.835
	(126.2)	(6.038)	(5.578)	(1.323)	(0.320)	(1.107)
CDS	0.00431	-0.000161***	-0.000000910	0.0000184	-0.0000252***	-0.0000175
	(0.00865)	(0.0000311)	(0.0000363)	(0.0000411)	(0.00000376)	(0.0000293)
N	178	129	115	169	185	185
R2	0.273	0.519	0.517	0.466	0.524	0.334
Panel A. TLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) CAP	(6) GOV
β	1.565	-0.00318	0.00947	0.0151**	-0.00346	-0.00592*
	(2.031)	(0.0194)	(0.00952)	(0.00736)	(0.00312)	(0.00505)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
ROA	0.357	-0.00590***	-0.000148	0.0104***	-0.00365*	-0.00143
	(0.619)	(0.00164)	(0.00333)	(0.00240)	(0.00174)	(0.00136)
Size	36.60	-1.862	7.624	-0.357	-0.451	2.020**
	(319.1)	(4.905)	(6.629)	(1.575)	(0.673)	(0.823)
CDS	-0.00530	0.0000345	-0.0000177	-0.0000415	-0.00000893	-0.0000162
	(0.0104)	(0.000108)	(0.0000638)	(0.0000335)	(0.0000109)	(0.0000265)
N	195	143	136	194	205	205
R2	0.0395	0.310	0.265	0.384	0.535	0.313

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) LTD	(2) MM	(3) LA	(4) WS	(5) CAP	(6) GOV
β	0.392	0.0754*	-0.0658	0.0158	0.00266	0.00844
	(0.261)	(0.0458)	(0.0140)	(0.00663)	(0.00498)	(0.0105)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
ROA	0.236	-0.00364	-0.00487	0.0171	-0.00128	-0.00450
	(0.296)	(0.0116)	(0.00802)	(0.0145)	(0.00156)	(0.00379)
Size	25.74	0.643	-7.693	-5.298	0.354	2.629
	(13.37)	(10.78)	(5.912)	(2.574)	(0.851)	(2.416)
CDS	-0.00192**	-0.000116**	-0.0000585	0.0000760*	-0.0000256***	-0.0000472*
	(0.000692)	(0.0000410)	(0.0000453)	(0.0000299)	(0.00000567)	(0.0000205)
N	58	63	49	47	63	63
R2	0.322	0.670	0.649	0.740	0.627	0.542
Panel A. TLTRO	(1) LTD	(2) MM	(3) LA	(4) WS	(5) CAP	(6) GOV
β	-0.619	-0.0142	0.0107	0.0534***	-0.00477	-0.0108*
	(1.060)	(0.0345)	(0.00927)	(0.00862)	(0.00771)	(0.00459)
Bank fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country time controls	Yes	Yes	Yes	Yes	Yes	Yes
Bank level controls	Yes	Yes	Yes	Yes	Yes	Yes
ROA	-0.401	-0.00466	0.000601	0.00998***	-0.00495***	-0.00135
	(0.384)	(0.00243)	(0.00240)	(0.000949)	(0.000894)	(0.00167)
Size	912.3	-26.70	23.03	11.10**	2.390	2.175
	(880.3)	(23.48)	(15.36)	(3.932)	(4.097)	(5.584)
CDS	0.00281	-0.0000407	-0.0000654	-0.0000436	-0.00000153	0.0000251
	(0.00291)	(0.000136)	(0.0000457)	(0.0000431)	(0.0000224)	(0.0000270)
N	61	69	62	58	69	69
R2	0.211	0.318	0.278	0.650	0.628	0.386

Note: *** 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)

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

Panel A. VLTRO	(1) *LTD*	(2) *MM*	(3) *LA*	(4) *WS*	(5) *LEV*	(6) *GOV*
β (unweighted)	3.988	0.0389	-0.00716	-0.0135	0.00222	0.0118***
β (weighted, after PSM)	1.025	0.0729	-0.0132	-0.0187	0.00536	0.0125***
Panel B. TLTRO	(1) *LTD*	(2) *MM*	(3) *LA*	(4) *WS*	(5) *LEV*	(6) *GOV*
β (unweighted)	-1.977	-0.00848	0.00258	0.0195*	-0.000218	-0.00770*
β (weighted, after PSM)	0.982	0.00618	-0.0135	-0.00231	0.00542	-0.00919**

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

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

Panel A. VLTRO	(1) *LTD*	(2) *MM*	(3) *LA*	(4) *WS*	(5) *LEV*	(6) *GOV*
β (unweighted)	0.802	0.0817*	-0.0434	-0.0385*	0.00525	0.0157**
β (weighted, after PSM)	1.077*	0.0834*	-0.0313	-0.0422*	0.00186	0.0150***
Panel B. TLTRO	(1) *LTD*	(2) *MM*	(3) *LA*	(4) *WS*	(5) *LEV*	(6) *GOV*
β (unweighted)	0.819	0.0134	0.0208	-0.0121	0.0149	-0.0190***
β (weighted, after PSM)	-3.176	0.0106	0.0177	0.00883	0.0147	-0.0191***

Note: *** 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). Selected covariates for the weighted regression for VLTROs: cost-to-income ratio, provisioning costs, size and return on equity; for TLTROs: cost-to-income ratio, fee income, net-interest income, provisioning costs, size and return on assets.

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

Panel A. *LTD*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	62.4	62.8	-0.33	62.4	62.4	0.99
provisioning costs	485.1	321.1	3.77***	489.4	598.0	-1.49
size	0.007	0.006	1.25	0.007	0.008	-1.11
return on equity	-4.59	3.33	-5.13***	-5.73	-2.71	-1.07
	Full sample			Propensity score (matched) sample		
Absolute mean bias	11.1			6.5		

Panel B. *MM*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	61.5	62.5	-0.74	61.5	58.5	2.11**
provisioning costs	434.7	315.4	2.62***	434.5	487.6	-0.69
size	0.006	0.006	-1.39	0.006	0.004	2.55**
return on equity	-6.1	3.0	-5.36***	-7.3	-2.0	-1.67*
	Full sample			Propensity score (matched) sample		
Absolute mean bias	11.3			11.0		

Panel C. *LA*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	62.0	62.1	-0.06	62.0	59.8	1.21
provisioning costs	443.1	334.5	2.11**	442.9	489.5	-0.56
size	0.006	0.007	-1.67*	0.006	0.005	2.74***
return on equity	-7.0	3.1	-5.10***	-8.5	-3.4	-1.35
	Full sample			Propensity score (matched) sample		
Absolute mean bias	10.8			9.9		

Panel D. *WS*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	62.2	62.8	-0.42	62.2	63.1	-0.51
provisioning costs	531.9	283.8	5.37**	513.0	508.3	-0.07
size	0.008	0.007	2.26**	0.008	0.008	-0.81
return on equity	-2.8	3.7	-3.62***	-4.2	-5.0	-0.82
	Full sample			Propensity score (matched) sample		
Absolute mean bias	14.4			3.0		

Panel E. LEV	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	61.9	62.5	-0.46	61.9	62.8	-0.52
provisioning costs	477.0	338.2	3.16***	477.0	538.4	-0.94
size	0.007	0.006	0.99	0.007	0.007	-0.33
return on equity	-4.6	3.4	-5.24***	-5.6	-4.5	-0.40
	Full sample			Propensity score (matched) sample		
Absolute mean bias	10.2			3.7		

Panel F. *GOV*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	61.9	62.5	-0.46	61.9	63.8	1.04
provisioning costs	477.0	333.6	3.29***	477.0	528.1	-0.79
size	0.007	0.006	0.97	0.007	0.007	-0.50
return on equity	-4.6	3.3	-5.24***	-5.6	-4.9	-0.25
	Full sample			Propensity score (matched) sample		
Absolute mean bias	11.1			6.5		

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

Panel A. *LTD*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	63.2	63.1	0.11	63.3	62.0	1.07
net-interest income	1323.9	1303.3	0.12	1122	1255.3	-0.76
size	0.008	0.006	5.42***	0.007	0.007	-0.53
return on assets	0.29	0.06	2.02**	0.28	0.28	0.99
provisioning costs	291.5	403.3	-2.22**	271.8	308.4	-0.90
fee income	820.9	759.4	0.57	712.1	674.5	0.32
	Full sample			Propensity score (matched) sample		
Absolute mean bias	9.4			3.5		

Panel B. *MM*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	63.4	62.7	0.56	63.5	60.1	2.83***
net-interest income	971.4	1136	-1.04	814.8	807.9	0.06
size	0.007	0.005	4.52***	0.006	0.006	0.02
return on assets	0.3	0.05	1.79*	0.3	0.3	-0.55
provisioning costs	247.4	388.4	-2.70**	235.9	242.0	-0.16
fee income	577.2	629.6	-0.53	514.8	410.9	1.20
	Full sample			Propensity score (matched) sample		
Absolute mean bias	10.9			4.3		

Panel C. *LA*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	62.8	62.5	0.22	62.9	63.4	-0.35
net-interest income	1054.8	1230.2	-0.95	893.7	737.3	1.20
size	0.007	0.006	3.53***	0.007	0.006	1.41
return on assets	0.29	0.02	1.85*	0.27	0.40	-1.26
provisioning costs	249.5	417.7	-2.79***	247.5	193.6	1.38
fee income	599.8	676.5	-0.66	555.4	345.7	1.99**
	Full sample			Propensity score (matched) sample		
Absolute mean bias	10.9			7.1		

Panel D. *WS*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	62.9	63.1	-0.19	62.9	61.6	1.01
net-interest income	1553	1388.3	0.83	1306.7	1315.9	-0.04
size	0.009	0.006	5.63***	0.008	0.008	-0.25
return on assets	0.28	0.14	1.16	0.27	0.17	0.66
provisioning costs	320.4	379.8	-1.09	297.0	319.2	-0.45
fee income	940.6	811.0	0.99	810.5	835.4	-0.16
	Full sample			Propensity score (matched) sample		
Absolute mean bias	9.9			3.0		

Panel E. LEV	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	63.2	62.9	0.32	63.3	63.7	-0.22
net-interest income	1323.9	1377.3	-0.31	1140.5	1051.9	0.55
size	0.008	0.006	4.99***	0.007	0.007	0.87
return on assets	0.29	0.06	2.02**	0.28	0.28	0.99
provisioning costs	291.5	423.2	-2.55**	276.4	240.0	0.96
fee income	820.9	833.3	-0.11	733.4	557.9	1.55
	Full sample			Propensity score (matched) sample		
Absolute mean bias	9.1			4.0		

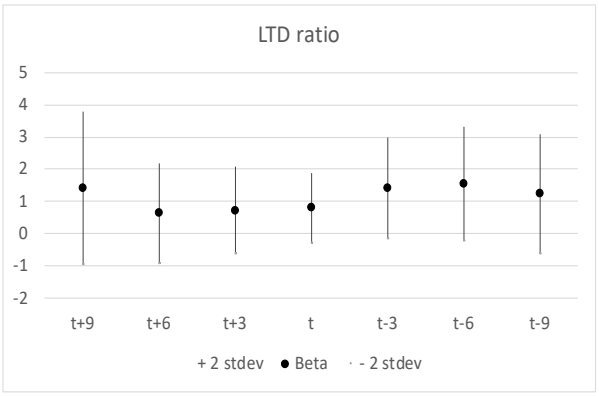
Panel F. *GOV*	Full sample			Propensity score (matched) sample		
Covariates	Mean Treated	Control	difference in mean t value	Mean Treated	Control	difference in mean t value
cost-to-income ratio	63.2	62.8	0.32	63.3	63.5	-0.13
net-interest income	1323.9	1359.2	-0.21	1140.5	966.2	1.15
size	0.008	0.006	4.97***	0.007	0.006	1.20
return on assets	0.29	0.09	1.81*	0.28	0.28	-0.00
provisioning costs	291.5	417.4	-2.46**	276.4	226.7	1.36
fee income	820.9	814.4	0.06	733.4	466.4	2.63***
	Full sample			Propensity score (matched) sample		
Absolute mean bias	8.9			5.5		

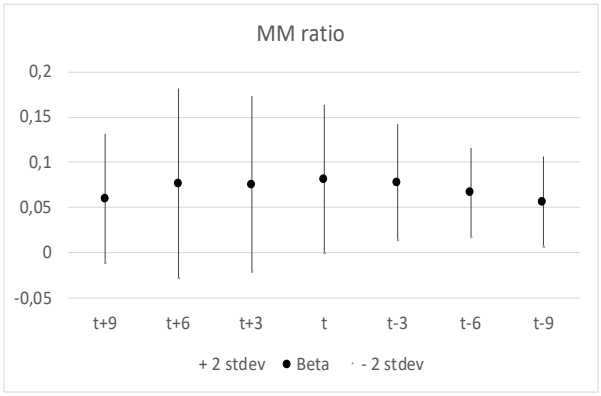
Table B9. Summary of findings

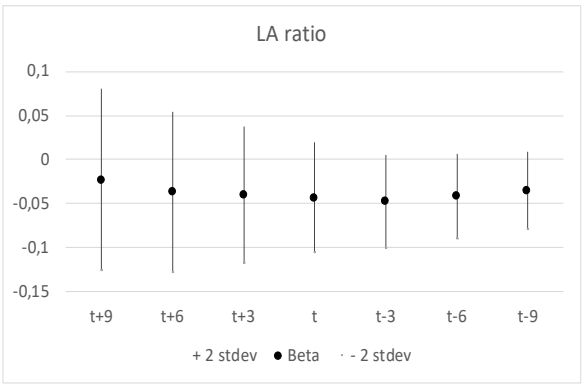
			Predicted	VLTROs	TLTROs
H1	More maturity transformation	LTD	+	0	0
		MM	+	+	0
H2	Lower liquidity self-insurance	LA	-	0	0
		WS	-	0	0
H3	Less deleveraging	LEV	-	0	0
H4	Carry trades	GOV	+	+	-

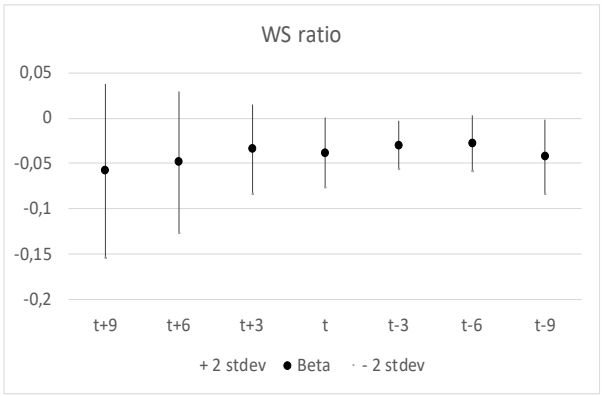
Explanatory note: "Predicted" gives the signs of the relations between the dependent variable and central bank refinancing as predicted by the hypotheses; "+", "-" and "0" denote a significant positive, negative sign, or insignificant sign respectively.

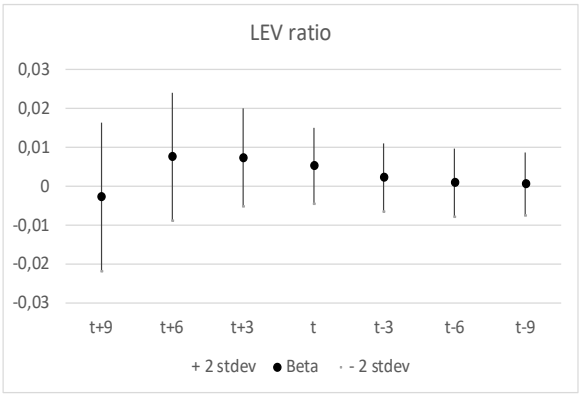
Figure B1. Outcomes of dynamic difference-in-differences for VLTROs (stressed countries)











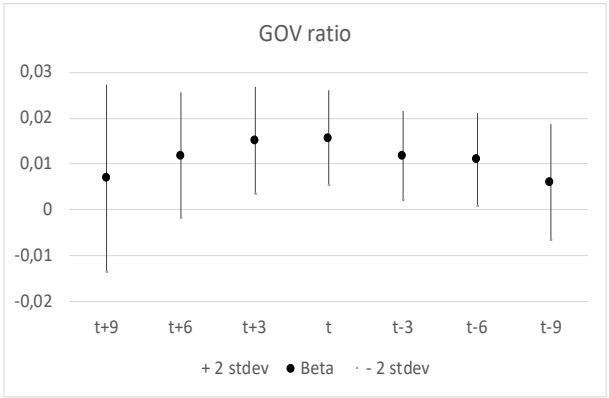
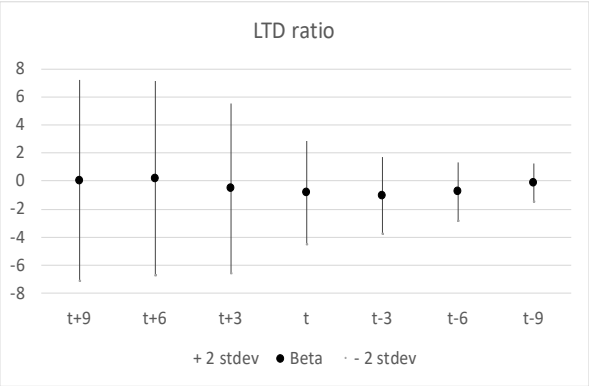
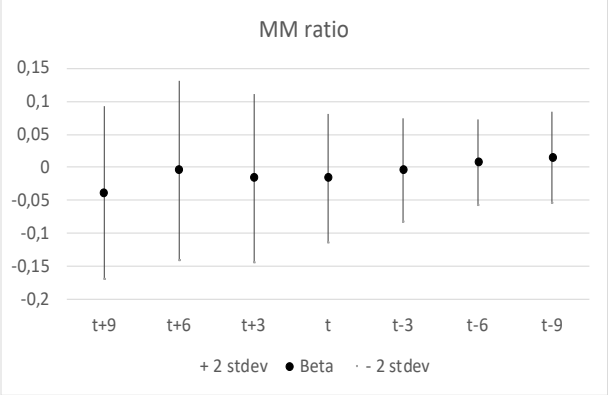
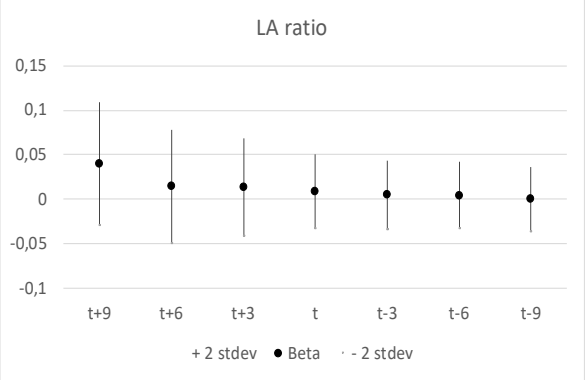
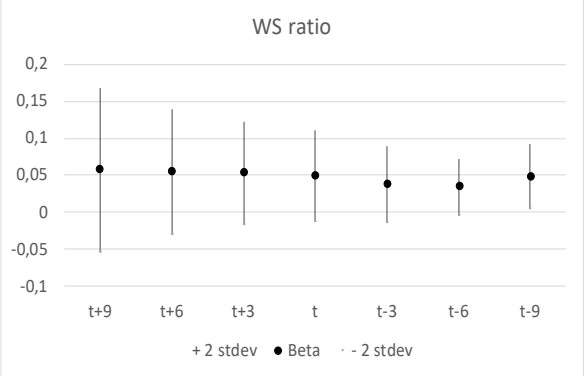


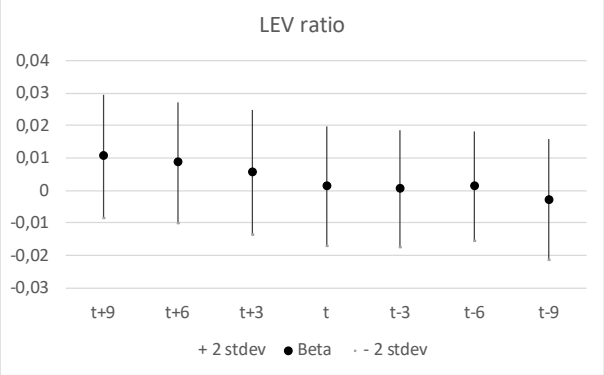
Figure B2. Outcomes of dynamic difference-in-differences for TLTROs (stressed countries)

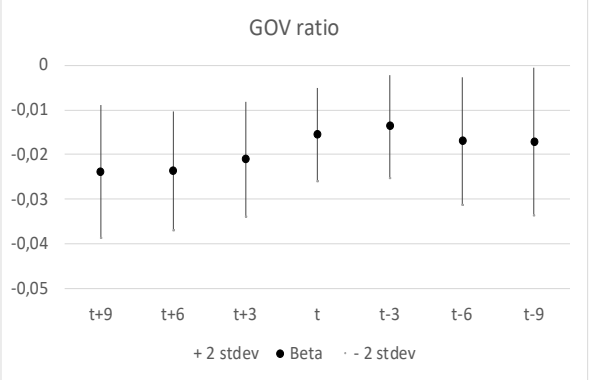












Acknowledgements

We thank Carlo Altavilla, Christiaan Pattipeilohy, Andrea Tiseno and participants at the INFINITI conference (Valencia, 2017), the IPAG conference (Paris, 2018), the DNB research seminar (Amsterdam, 2018) and the MPC workshop on banking analysis (Paris, 2019) for their comments on a previous version of the paper and Neeltje van Horen for helpful advice. Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank, the Central Bank of Ireland or the European Central Bank.

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PDF ISBN 978-92-899-3895-2 ISSN 1725-2806 doi:10.2866/15373 QB-AR-19-107-EN-N