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Quantitative Easing and the Hot Potato Effect: Evidence from Euro Area Banks

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Abstract

We use a bank-level data set to examine the behaviour of central bank reserves in the euro area banking system over the course of the ECB QE programme. Previous research on QE has generally paid little attention to the role of reserve dynamics within the banking system and some have assumed that the system passively absorbs additional reserves generated by asset purchases. However, with a negative deposit rate in place throughout the sample we study, euro area banks have had a disincentive to hold excess reserves and thus could wish to treat them as a "hot potato" that is preferably passed on to other banks. We find evidence for this hot potato effect, reporting substantial month-to-month churn in bank reserves as well as evidence that banks are responding to high reserve balances by pushing them off their balance sheets. Unlike in the traditional money multiplier model, where excess reserves are used in loan creation, banks appear to be primarily managing reserves through debt security purchases. As such, this hot potato effect seems likely to have had an effect on European bond yields that is distinct from the portfolio rebalancing effect emphasised in the QE literature thus far.

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Non-Technical Summary

Unconventional monetary policies enacted since the outbreak of the financial crisis, have led to an unprecedented expansion in the size of central bank balance sheets. When central banks carry out quantitative easing (QE) programmes, the purchase of financial assets (typically debt securities) drives the expansion of the asset side of the balance sheet. However, this is mirrored on the liability side by an expansion in reserve accounts, as it is through credits to these accounts that central banks pay for purchased assets.

Much of the empirical literature examining the effects and transmission channels of quantitative easing programmes has focused on the impact of purchases on the available supply of specific assets to the private sector (the portfolio rebalancing channel). The literature has also examined the role of announcements regarding future bond purchases and their affect on market participant expectations (the signalling channel). The role of reserve creation in the transmission of QE programmes has received little attention, with many studies either implicitly or explicitly assuming that banks passively allow reserve balances to build-up over time.

Our paper examines the behaviour of reserves held by euro area banks during the ECB's Asset Purchase Programme (APP), using a monthly bank-level data set. In particular, we assess whether the banking system has passively absorbed these reserves (as the collapse in the money multiplier during the APP might suggest) or whether there is evidence of banks trying to push reserves off of their balance sheets. The latter is referred to as the "hot potato" effect: As Eurosystem reserves can only be held by euro area banks, if one bank successfully reduces its reserve balance then these reserves will simply land on the balance sheet of another, who in turn will push them onto the balance sheet of yet another bank. The euro area is a particularly interesting case for examining such an issue as, due to the Eurosystem's negative deposit facility rate, banks have been paying to hold reserves throughout the relevant period.

We find substantial evidence that banks are in fact actively managing their reserve holdings and are seeking to reduce them at the individual bank-level on a month-to-month basis, thus creating a high level of "churn" in reserves across the euro area banking system. We then ask *how* they are doing so, as this will determine transmission to the real economy. For example, if banks use reserves to make loans to households or firms, then the "hot potato" effect will have a direct impact on the real economy. If banks are purchasing debt securities, the impact on the real economy will be more indirect but could occur via lower bond yields. By examining the balance sheet adjustments made by banks that have successfully resisted the aggregate upward trend in reserve holdings, we find strong evidence that banks are managing reserves by adding to their debt security holdings and paying down a broad range of funding sources.

As such, it is likely that the response of banks to reserves created through the APP has had an effect in driving down European bond yields and we believe this effect is conceptually different from the portfolio rebalancing effect which has dominated the literature on QE. Our analysis is also interesting to consider in the context of the traditional money multiplier model. While we find that banks are actively working to reduce their reserve balances, they do not seem to be doing so via loan creation as this model would suggest.

The Fed puts those reserves in the system. The banks can pass them around from each other, but the total is just given. They can't do anything about that. It's like a hot potato.

Ben Bernanke, May 22, 2013 at the Joint Economic Congressional Committee.[1]

1 Introduction

In this paper, we use a bank-level data set to examine the behaviour of central bank reserves in the euro area banking system during the ECB's Asset Purchase Programme (APP), which has effectively been the euro area's version of Quantitative Easing (QE).[2] The APP began in late 2014, with the relatively limited purchasing of covered bonds and asset backed securities. In March 2015 the programme expanded substantially to include the purchase of public sector securities at an average rate of €60 billion per month.[3] We analyse how the banking system has reacted to absorbing the large volume of excess reserves created by these purchases, focusing on dynamic adjustments of bank balance sheets.

Reserves are accounts that commercial banks hold with central banks and it is via credits to these accounts that central banks have paid for the assets purchased during QE programmes. When asset purchases are carried out between two commercial banks, the purchasing bank transfers the required amount from its reserve account to that of the seller. While this transaction affects the reserve balance of each individual bank, it leaves the total stock of reserves unchanged. When a central bank purchases assets, however, it is able to credit the seller's reserve account with the push of a button because central banks are free to create reserves from nowhere. Via this mechanism, the QE programmes of the past decade have created enormous increases in the supply of central bank reserves.

A student of textbook macroeconomics might imagine that these increases in reserves have been the main mechanism through which QE programmes are supposed to influence the economy. Macro 101 students learn the money multiplier model in which an increase in the supply of reserves is multiplied into a larger increase in the total money supply (and an increased supply of bank credit) via the actions of the banking system. In this model, reserves earn no interest and are considered an inferior asset to loans, which do earn interest. As a result, banks only hold the amount of reserves needed to satisfy reserve requirements. By making loans, which are then spent and re-deposited in the system, the banking system as a whole translates an initial increase in reserves into a much larger increase in the broader money supply and also in the supply of credit.

From the perspective of our analysis, it is worth noting that in the traditional money multiplier model, reserves act like the "hot potato" described in the quote above from former Fed Chairman Ben Bernanke: Nobody in the banking system wants to be holding a large amount of excess reserves, so while the total supply of reserves doesn't change, the reserves end up being passed around the system. In the money multiplier model, this is done via making new loans, which are spent in the real economy and re-deposited in the banking system. A hot potato effect could still exist, however, even if banks do not use the excess reserves to make loans, with individual banks instead reducing their reserve balances through purchase of securities. In such a scenario, the hot potato effect may increase demand for securities but will not necessarily produce a large increase in the supply of credit or broader money.

The textbook money multiplier model was what many of the early critics of QE programmes had in

[1] Available here.

[2] Throughout the paper QE as carried out by the Eurosystem is referred to as the APP. When carried out by other institutions or discussed in abstract it is referred to as QE.

[3] The volume and nature of securities purchased has since changed a number of times. For further detail see Annex B.

mind when they predicted that large expansions in the supply of base money would trigger significant inflation. For example, a letter signed by a number of academic and financial market economists in 2010 warned Ben Bernanke that "*The planned asset purchases risk currency debasement and inflation.*"[4]

These critics, however, were somewhat behind mainstream thinking in monetary policy circles by the time QE programmes were adopted. After their experiences with monetarist policies in the 1980s, central banks such as the Fed and the Bank of England no longer believed that the money multiplier was a stable ratio, creating a predictable link between the monetary base and broader measures of the money supply. The money multiplier's implicit model of the banking sector was also understood to be highly simplistic. In particular, the model's assumption that banks would automatically use injections of reserves to make bank loans was thought by central bank officials to be misleading in a weak economy where banks were concerned about default risk from creditors and faced regulatory-capital-related restrictions on the size of their balance sheets. In addition, with modern central banks generally paying interest on reserves (the Fed, for example, began paying interest on reserves in 2008), the money multiplier model's assumption that reserves were a highly inferior asset was no longer necessarily correct. According to this view, the banking sector was likely to largely absorb the additional reserves in a passive manner, without actively trying to reallocate the additional reserves via balance sheet adjustments.

The outcome of the QE programmes adopted by the Fed and the Bank of England from 2009 onward appear to have largely validated this "modern" view on the money multiplier. Enormous increases in the supply of bank reserves were not matched by increases in the broader money supply, implying a collapse in the money multiplier. There was also little evidence that QE purchases translated into a large increases in the supply of credit.

For these reasons, the academic research on the impact of QE has tended to ignore the role played by large increases in the supply of reserves. Instead, as summarised by Christensen and Krogstrup (2016b), the literature has focused on two main channels through which QE could influence the economy by affecting long-term interest rates. The first channel is a portfolio rebalancing effect driven by reduced availability of assets purchased by the central bank. This increases their price and reduces their yields via a lowering of term premia. The second channel is a signalling channel: If the portfolio balance channel is effective, then communication about the quantities of future bond purchases can provide a signal about when the central bank intends to normalise monetary policy and increase interest rates. Studies such as Gagnon et al. (2011), D'Amico and King (2013), Joyce et al. (2011) and Christensen and Rudebusch (2012) found that QE purchases had statistically significant but economically modest effects in reducing long-term interest rates, with the effects being a mix of these two channels. A typical conclusion was that the QE programmes depressed long-term bond yields by about 100 basis points.

There are two exceptions in the empirical literature which have focused on the role played by reserves. Ennis and Wolman (2015) focuses on the the evolution of the cross-sectional distribution of reserves across US banks during the QE programme. Christensen and Krogstrup (2016b) examine reserve-induced portfolio rebalancing by examining an increase in reserves at Swiss banks that was not matched by a corresponding reduction in bond supply. The authors find an effect of higher expected reserves in reducing long-term bond yields.

Our paper examines the behaviour of reserves held by euro area banks during the ECB's APP. We use a monthly bank-level data set to examine the dynamics of reserve balances and to assess whether the banking system has passively absorbed these reserves (as the collapse in the money multiplier in QE episodes might suggest) or whether there is evidence of a hot potato effect in which banks are attempting to offload reserves. We find substantial evidence that banks are in fact actively managing their reserve holdings and are seeking to reduce them at the individual bank-level on a month-to-

[4] Open letter available here.

month basis, thus creating a high level of "churn" in reserves across the euro area banking system. We then ask how banks are carrying this out. Specifically, are they managing reserves through loan creation or by purchasing debt securities? By examining the adjustments made by banks that have successfully resisted the aggregate upward trend in reserve holdings, we find that banks are managing reserves by adding to their debt security holdings and by paying down a broad range of funding sources.

As such, it is likely that the response of banks to reserves created through the APP has had an effect in driving down European bond yields. We believe this effect is, at least conceptually, separate from the portfolio rebalancing channel which has dominated the literature on QE. As laid out above, the portfolio rebalancing channel results from the reduced availability of a set of assets. The mechanism we are examining, on the other hand, results from the expansion of reserves. Both channels have operated simultaneously during the APP but they could in theory operate independently. To illustrate with extreme examples, if a government decided to retire a large share of its outstanding debt this would reduce the available supply of government bonds to the private sector but would not affect the reserve base. Large scale purchases of non-financial assets (widgets) by a central bank would also result in expansion of its reserve base, without reducing the available stock of any outstanding financial asset.

The period we are looking at is of particular interest because there has been a financial incentive for banks not to accumulate reserves. Throughout the period we examine, from late 2014 to summer 2018, the ECB was charging banks for their excess reserves, with a negative interest rate that increased from 20 basis points in late 2014 to 40 basis points from March 2017 onward. At a Eurosystem level and as at end 2017, this negative remuneration represented 2 per cent of total bank assets but 29 per cent of total equity, which from a return on equity perspective is not insubstantial.[5] In this sense, even more than non-interest-bearing reserves of the textbook model, Eurosystem reserves were a true hot potato because the more of the reserves you held, the worse off a bank would be.

Like Ennis and Wolman (2015), we examine the cross-sectional distribution of reserves but our data set is a monthly one whereas the data set analysed by Ennis and Wolman is quarterly. This allows us to get a better sense of the higher-frequency dynamics of reserves in the Eurosystem and we focus on the extent to which it appears that banks with relatively high reserve holdings adjust their balance sheets to offload these reserves. We find that the allocation of reserves across the Eurosystem during the APP has been complex and dynamic. Our examination of these dynamics shows behaviour that is consistent with a hot potato effect. We also discuss whether this effect has played a role in reducing yields on European bonds over this period.

The paper is structured as follows. Section 2 contains a review of related literature. Section 3 introduces our bank-level data set. Section 4 describes the evolution of central bank reserves in the euro area in recent years. Descriptive statistics are considered in the context of the hot potato effect and how we would expect the distribution of reserves and euro area balance sheets to behave were it to operate. We also use simple regressions to examine the distribution of reserves across the banking system. Section 5 describes the month-to-month dynamics of bank reserves and provides evidence that the increase in reserves is not being passively absorbed by European banks. Finally, Section 6 provides evidence that, when shifting reserves off their balance sheets, banks are purchasing securities and paying down funding.

[5] These are calculated by applying the -40bps charge to total Eurosystem *excess* reserves and dividing be either total assets or total capital. Capital in this case reflects both capital and earning reserves.

2 Related Literature

As central banks around the world increasingly adopted unconventional monetary policies in response to the financial crisis, a literature examining their effectiveness and transmission channels has developed. The literature on QE has examined the policy's effect on a range of key economic variables such as long-term interest rates (see for example Gagnon et al. (2011), Christensen and Rudebusch (2012) and Eser and Schwaab (2016)), asset prices (Joyce et al. (2011)), bank lending (Rodnyanksky and Darmouni (2017)), macroeconomic aggregates such as GDP and inflation (Wieladek and Pascual (2016), Baumeister and Benati (2017) and Gambetti and Musso (2017)) and market participant expectations (Christensen and Rudebusch (2012), Ciccarelli et al. (2017) and Bauer and Rudebusch (2014)).

Much of this literature cites the portfolio rebalancing channel, whereby QE purchases reduce the available supply of specific assets to the private sector and therefore raises their price and those of their close substitutes (see Krishnamurthy and Vissing-Jorgensen (2011), Joyce et al. (2011) and Vayanos and Vila (2009)). Portfolio rebalancing itself has also been directly examined by Koijen et al. (2017) and ECB (2017b) who show that non-euro area counterparties were the main sellers of securities to the Eurosystem during APP. Koijen et al. (2017) propose that these counterparties rebalance their portfolio towards assets outside of the euro area due to their more elastic demand for euro area securities. Both pieces of analysis find that banks were the next largest selling sector. However, the role of reserve creation in the transmission of QE programmes or as a driver of portfolio rebalancing has received little attention.

Two papers that do explicitly focus on the impact of reserve creation as a transmission mechanism distinct from the portfolio rebalancing channel are Christensen and Krogstrup (2016a) and Christensen and Krogstrup (2016b). The authors refer to this additional mechanism as the *"reserve-induced portfolio channel"*. While the conventional portfolio channel examines rebalancing in response to lower availability of purchased assets, the authors argue that the expansion of reserves creates its own rebalancing effect. This is much closer to the mechanism originally outlined by Bernanke and Reinhart (2005) who describe QE as the central bank *"changing the size of its balance sheet, that is, by buying or selling securities to affect the overall supply of reserves and the money stock."* Bernanke and Reinhart argue that through a large increase in money supply the central bank could push investors to rebalance portfolios towards non-money assets, thus raising their prices.

Christensen and Krogstrup (2016a) provides a theoretical framework for the reserve-induced portfolio channel. Like the conventional portfolio rebalancing channel, this channel relies on the imperfect substitutability of assets. However, the authors highlight an additional friction specific to the reserve-induced channel: Reserves can only be held by banks. As a result, the purchase of assets from the non-bank sector will still result in the expansion of reserves held by banks.[6] The authors argue that banks will respond to this by rebalancing their portfolios away from reserves. In the context of our work, it should be noted that this framework focuses exclusively on the impact of initial asset purchases. However, unless the central bank reverses a QE policy, these reserves remain in the banking system after the bank which first receives them moves them off their balance sheet and thus the so-called "hot potato" effect may continue as successive banks repeat this process.[7]

Christensen and Krogstrup (2016b) empirically assess the reserve-induced channel by examining changes in long term Swiss government bond yields following announcements by the Swiss National Bank (SNB) regarding its own QE programme. This programme consisted of substantial reserve ex-

[6] Specifically, the central bank pays for the asset by crediting the reserve account of the bank with which the non-bank entity holds its cash deposits. The bank in turn credits the deposit account of the non-bank. This will increase both the reserves and deposits on the bank's balance sheet, without the bank making any active decision that this should happen.

[7] For discussion of the closed system of central bank reserves see Section 4.2.

pansion without the purchase of long term securities.[8] The authors find that this policy led to a tightening of long-term yields even though the supply of these assets and their closest substitutes remained unchanged.

Kandrac and Schlusche (2017) look at regulatory changes made by the Federal Deposit Insurance Corporation (FDIC) which increased the cost of holding reserves for some banks and as a result changed the distribution of reserves in the US financial system over the course of QE. Using treatment by this regulatory change as an instrument for increased reserve holdings, the authors examine the effect this has on bank loan growth and risk-taking within lending portfolios, where loans to specific sectors (e.g. commercial real estate) are considered high risk and non-performing loans (NPLs) are considered to be the result of riskier lending. The authors find that increased reserve holdings resulted in higher rates of loan growth, an increase in lending to riskier sectors and an increase in NPLs.

Demiralp et al. (2017) examine excess liquidity in a euro area context, with the ultimate aim of examining the effects of negative interest rates.[9] Holdings of excess liquidity are used as a measure of banks' exposure to negative interest rates and the authors examine the relationship between excess liquidity and a number of balance sheet variables over the full 2007 to 2016 period. The authors acknowledge the closed system within which reserves operate (for further detail see Section 4.2) but this does not feature in their specification or analysis of their results. As such, their specification does not take into account aggregate euro area excess liquidity dynamics when examining the role of bank-level excess liquidity. Due to the time period examined, the authors are also mixing periods when the quantity of excess liquidity was primarily supply driven (during the APP) and when it primarily demand driven (for further detail see Section 4.1). Thus, their analysis, as intended, is an examination of the effects of negative interest rates as opposed to excess liquidity.

A number of largely descriptive pieces have also been completed which examine the distribution of post-crisis excess liquidity across banks. Baldo et al. (2017) provides a thorough analysis of the topic for the euro area and in particular highlights the role of the euro area's financial structure and cross-country variation in sovereign bond yields in determining the distribution of liquidity across countries.[10] The authors also highlight the role of regulation in determining excess liquidity holdings. For example, where banks use excess liquidity to buy assets or make loans they may have to hold capital against these assets that would not be required for reserves. Excess liquidity is also treated more favourably than any other asset when assessing compliance with the liquidity coverage ratio (LCR).

Ennis and Wolman (2015) examine excess liquidity among US banks during the implementation of unconventional policies by the Federal Reserve. Ennis and Wolman (2015) focus on the distribution of excess liquidity across banks, finding that the largest banks held a disproportionately larger share of total reserves at the peak of the financial crisis. However, over later periods these reserves became more evenly distributed, with foreign banks in particular accumulating significant reserve holdings. During the later stages of their examined period, reserves were also largely held by well capitalised banks and as a result it should have been possible to transform these into loans without hitting regulatory capital limits.

In the context of this build-up in excess reserves in the US banking system, Keister and Andrews (2009) provides an excellent explanation the mechanics of the closed system in which central bank reserves are circulated. They demonstrate that, due to this closed system, aggregate reserve figures

[8]The programme examined consisted instead of the purchase of purchase of short term debt securities, repos and short term FX swaps.

[9]The term "excess liquidity" is commonly used to refer to central bank reserves which exceed reserve requirements at either an individual institution or a system-wide level. We use the terms "excess liquidity" and "excess reserves" interchangeably throughout our paper.

[10]For further discussion see Section 4.3.

do not tell us much about individual bank behaviour. In particular, they do not tell us if these reserves are simply sitting in banks' reserve accounts or if they are being actively used to create loans and therefore moving constantly from bank to bank. The authors also stress the role of reserve remuneration in incentivising the use of reserves for loan creation and tie this back to the traditional view of the money multiplier. For example, they state: *"Textbook accounts of the money multiplier assume that banks do not earn interest on their reserves. . . . If the central bank pays interest on reserves at its target interest rate, . . . then banks never face an opportunity cost of holding reserves and the money multiplier does not come into play."*

3 Data

Our work uses two related data sets collected by the ECB. Our main source of data is a confidential data set, providing granular bank-level balance sheet information for the euro area's largest banks, on a residency basis and at a monthly frequency (for a detailed discussion of approaches taken to constructing this data set see Bojaruniec and Morandi (2016)). While this data set has been available within the Eurosystem since 2012, a recent expansion substantially increased the number of variables available. Of particular interest for this paper is the newly available series reflecting bank-level reserve holdings with their national central bank (NCB).[11]

Focusing our analysis on institutions for which this variable is available provides us with an unbalanced panel of between 173 and 192 banks from January 2015 to May 2018. Prior to the start of 2015, approximately half this number of banks are available as the reserves series is only reported by a subset of countries. Over the 2015-2018 period, however, the sample covers all euro area countries except France. For these eighteen countries our sample covers 80 per cent of total bank assets and 66 per cent of total reserves (at end May 2018). In addition to banks' reserve holdings, the data set also provides detailed information on a large number of other balance sheet items. This allows for the construction of a broad range of balance sheet control and interaction variables. For further detail on our approach to data cleaning see Annex A.

A second and related data set is also drawn on. This is compiled using the same ECB framework and provides the same balance sheet variables but at a country and euro area aggregate level. This data set is used to examine bank-level variables in the context of the country in which they are operating (e.g. their size relative the entire national banking system), to examine country-level dynamics in total reserves (see Section 4.3) and to calculate system-wide variables which account for all banks in the system, not just those contained in our bank-level data set.[12]

[11]The data set categorises reserves as a loan with a central bank counter-party. The series includes both required and excess reserves.

[12]Again, the key variable of interest is loans from monetary financial institutions excluding the ESCB to both domestic and other euro area central banks. Comparison with published NCB balance sheet data shows that this variable reflects the *"Liabilities to euro area credit institutions related to monetary policy operations"* entry. This is made up of current accounts, the deposit facility, fixed term deposits, fine-tuning reverse operations and deposits related to margin calls. However, at a euro area level, over the course of 2015-2018, current accounts and the deposit facility made up just short of 100 per cent of the total entry.

4 Excess Liquidity in the Euro Area

4.1 ECB Policy and Euro Area Excess Liquidity

Unconventional monetary policies enacted by the ECB since the outbreak of the financial crisis, including both increased lending to euro area credit institutions and large scale asset purchases, have led to significant expansions in the size of its balance sheet. As can be seen in Figure 1, in the years 2008, 2011 and 2012 this was driven largely by an expansion in lending to credit institutions and from 2015 onward has been driven by increased holdings of euro area securities due to the APP. On the liability side, both pre- and post-APP periods featured expansions in Eurosystem deposit facilities and current accounts, as both loans and purchases are carried out by crediting banks' reserve balances.

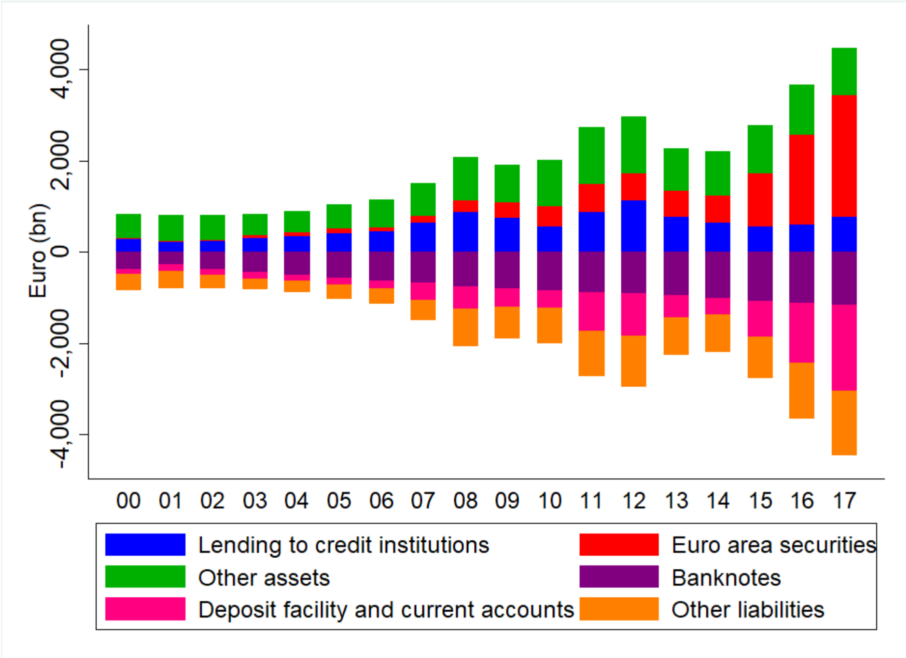
Figure 2 focuses on this aspect of the Eurosystem's liabilities and shows the expansion of total reserves held by euro area banks with the Eurosystem since 2007. Prior to the financial crisis the euro area banking system operated under a "reserve scarcity regime", whereby central bank reserve holdings rarely exceeded their required levels. As such, banks did not generally hold "excess liquidity". This was due to the Eurosystem's approach to liquidity provision whereby banks were required to bid competitively for a fixed supply of central bank liquidity and this liquidity was then distributed throughout the system via money markets.

However at the onset of the financial crisis, in response to the breakdown of interbank markets following the collapse of Lehman Brothers, the Eurosystem replaced this approach with a fixed rate full allotment (FRFA) policy under which liquidity was supplied elastically through fixed rate tenders, allowing all counterparties to borrow as much as they wanted subject to the provision of eligible collateral. FRFA was followed in 2011 by a series of longer-term refinancing operations (LTROs), aiming to support the provision of credit to the real economy. Both the perceived risk by investors of providing liquidity to many euro area financial institutions and the risk aversion of those institutions themselves, led to increased take-up of central bank liquidity and the build-up of liquidity buffers by banks. As funding conditions in the euro area gradually recovered, banks' demand for Eurosystem funding decreased and in 2013 many took part in voluntary early repayment of LTROs, leading to a fall in overall excess liquidity (ECB (2017a)).

Further LTROs were announced in June 2014 and March 2016, but Figure 1 shows that from 2015 onward the ECB balance sheet expansion is driven primarily by increased security holdings as a result of the APP. Annex B provides an overview of the ECB's use of this tool over time, in terms of both type and volume of assets purchased. While a number of smaller programmes were conducted between 2010 and 2012, this policy tool began to be used more intensively in late 2014 with the introduction of the third Covered Bond Purchase Programme (CBPP3) and, at a much larger scale again, in March 2015 with the introduction of the Public Sector Purchase Programme (PSPP). On the liability side of the balance sheet, these programmes have driven the final expansion in excess liquidity evident in Figure 2.

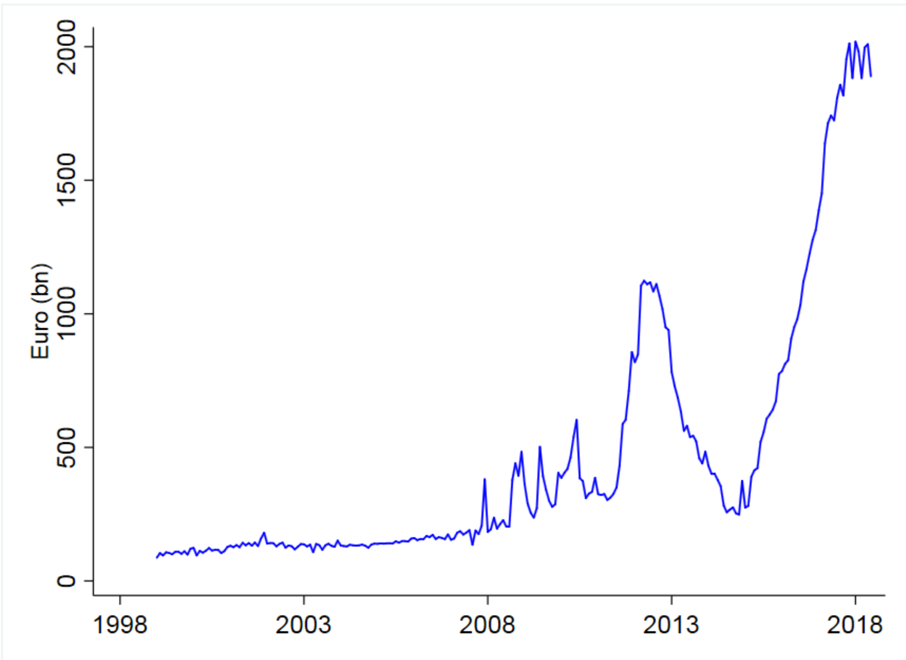
However, a fundamental difference between excess liquidity created over the two periods should be noted. While first expansion of excess liquidity was driven primarily by the Eurosystem responding to bank demand, liquidity created through the APP is supply driven and has been a mechanical result of Eurosystem purchases ECB (2017a). Of course both mechanisms are at work during the APP. For example, growth can be seen to slow at the end of the series: This can be attributed to a halving of the monthly purchase volume under PSPP to €30bn per month, combined with early repayments of TLTRO-I. However, as previously noted Figure 1 shows that from 2015 onward the APP is the most important driver of Eurosystem balance sheet, and as a result excess liquidity growth.

Figure 1: Consolidated Eurosystem balance sheet



Note: Positive figures show asset holdings and negative figures show liabilities. Source: ECB.

Figure 2: Total Eurosystem reserves over time



The expansion in reserves over the course of the APP should also be considered in the context of the aggregate balance sheet of euro area banks. Figure 3 uses simple t-accounts to provide a snapshot of the aggregate euro area balance sheet at end 2014, when purchases had just begun, and end 2017. Absolute changes over this period are also shown. First, it should be highlighted that even at end 2017 total reserves constitute a very small share of total assets. Second, the expansion in reserves clearly has not resulted in a large scale expansion in loans as would be suggested by a pure application of the money multiplier model. While we have noted that banks could also be pushing reserves off of their balance sheets by purchasing debt securities, aggregate holdings will be subject to the total stock of debt securities available and the existence of other buyers, most notably the Eurosystem. Figure 4 shows the role of the Eurosystem, banks and other actors in the total outstanding market for long-term government debt securities.[13] While the outstanding stock of long term government debt securities has increased steadily over the full period shown, both the share and outstanding stock held by banks has decreased over the 2015-2017 period. This reflects the findings in ECB (2017b) that euro area banks have been the second largest seller of government securities to the Eurosystem during the APP.

Figure 3: Aggregate adjustments in euro area bank balance sheets (EURtr)

End 2014

Assets		Liabilities	
Reserves	0.37	Total deposits	19.41
Loans	19.48	*o/w from eurosystem*	*0.72*
o/w to real economy	*9.11*	*o/w from real economy*	*8.44*
EA gov bonds	1.85	Debt securities issued	4.33
Other bonds	3.62	Other non-capital funding	5.02
Other assets	5.83	Capital	2.40
Total assets	**31.16**	**Total liabilities**	**31.16**

End 2017

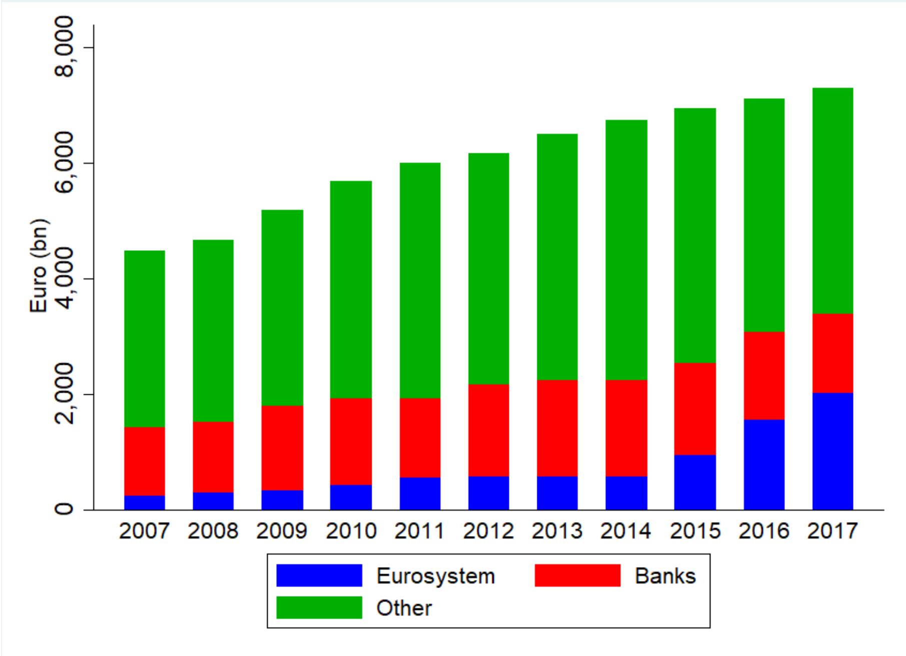
Assets		Liabilities	
Reserves	1.88	Total deposits	20.27
Loans	19.32	*o/w from eurosystem*	*0.84*
o/w to real economy	*9.50*	*o/w from real economy*	*9.47*
EA gov bonds	1.49	Debt securities issued	3.68
Other bonds	3.06	Other non-capital funding	3.87
Other assets	4.63	Capital	2.57
Total assets	**30.38**	**Total liabilities**	**30.38**

2014-2017 change

Assets		Liabilities	
Reserves	1.51	Total deposits	0.86
Loans	-0.16	*o/w from eurosystem*	*0.12*
o/w to real economy	*0.39*	*o/w from real economy*	*1.03*
EA gov bonds	-0.37	Debt securities issued	*-0.65*
Other bonds	-0.56	Other non-capital funding	-1.15
Other assets	-1.21	Capital	0.16
Total assets	**-0.78**	**Total liabilities**	**-0.78**

[13] Total outstanding stock figures are taken from Eurostat. Securities with a maturity over 1 year are defined as long-term.

Figure 4: Developments in sectoral holdings of long term euro area government bonds



Due to the wide range of factors influencing both the real economy lending and debt security purchases of euro area banks, we do not expect reserve management to be the main driver of either. However, a net reduction in allocation to either real economy loans or debt securities over the period (at an aggregate level) does not necessarily mean that banks have not been using these as a means of reserve management. Further, our bank-level analysis will allow us to examine this issue from a cross-sectional perspective and to compare outcomes for banks within the system which have differing reserve dynamics.

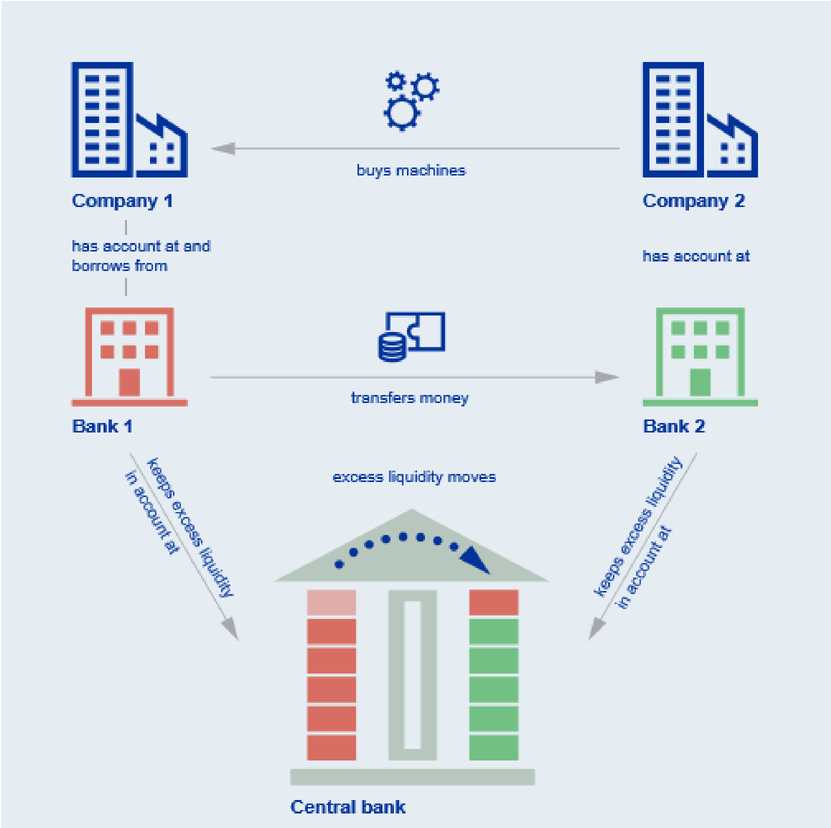
4.2 The Closed System and Movement Within It

It is important to emphasise a defining characteristic of central bank reserves: They can only be held by banks. Moreover, reserves held with the Eurosystem can only be held by euro area banks.[14] This creates a closed system within which efforts by one bank to reduce its excess reserves through lending or the purchase of securities will result in increased reserve holdings by another institution. Figure 5 provides an illustration of this process whereby

1. Bank 1 has excess liquidity which it uses to make a loan to Company 1
2. In doing so, it first credits Company 1's deposit account by the loan amount (but there is no change to its liquidity position)
3. Company 1 then uses this loan to buy machines from Company 2, which keeps a deposit account with Bank 2
4. Bank 1 transfers the money to Bank 2 by crediting Bank 2's central bank reserve account

[14] In the context of the APP this means that all purchases made by central banks, regardless of the location or entity type of the ultimate seller, are settled through euro area banks. For example, if the Eurosystem purchases assets from a non-bank entity these purchases are settled through the non-bank entity's bank. Specifically, the Eurosystem credits the bank's reserve account and in turn the bank credits the deposit account of the non-bank entity, resulting in an increase in the bank's overall excess liquidity position and its balance sheet as a whole. A similar mechanism is used for purchases from non-euro area counterparties.

Figure 5: The closed system of reserves



Source: ECB.

5. Bank 1 now holds a loan where it previously held reserves but those reserves are being held by Bank 2

6. At an aggregate level, despite the use of reserves in loan creation, excess liquidity is unchanged.[15]

There are instances in which the banking sector can choose to run down its stock of bank reserves. For example, some banks that borrowed money via the ECB's LTROs chose to repay the money earlier than the full term of the loans, thus retiring reserves that were issued when the loans were made. During the APP, however, asset purchases by the ECB was the dominant force driving up aggregate reserves. Of course, aggregate measures of excess liquidity (such as Figure 2) will only tell part of the story as they cannot capture the extent to which this liquidity is moving around the system as a result of bank activity. This movement within the system, or the "hot potato" effect, is a key determinant of the ultimate effect of monetary operations on both the real economy and the financial system. If banks simply allow reserves to build-up in their central bank accounts, the "reserve channel" discussed in Bernanke and Reinhart (2005), Christensen and Krogstrup (2016b) and Christensen and Krogstrup (2016a) will not operate.[16]

One exception to the "closed system" is that banks can reduce the total amount of reserves held with the Eurosystem if they decide instead to hold cash. A bank's request for deliveries of cash are honoured by reducing the amount held in its reserve account. In theory, one might have expected European banks to be interested in holding large amounts of cash because cash, by definition, carries a zero interest rate whereas bank reserves now carry a negative interest rate. However, it appears

[15] Keister and Andrews (2009) provides a thorough discussion of this characteristic of reserves and a number of further illustrated examples of how reserves may move between institutions following their initial introduction into the system.

[16] For a related discussion of the APP in the context of monetary aggregates and multipliers see ECB (2017a).

that, in practice, a negative interest rate has not been sufficient to discourage banks from holding cash in warehouses instead of holding reserves with the central bank. As Figure 1 above shows, there has been little change in amount of banknotes issued since the beginning of the negative deposit rate policy.

4.3 Country-Level Patterns

While the (dis)incentive to hold reserves created by the negative interest rate applied to deposits is uniform across euro area countries, Figure 6 shows quite clearly that the build-up in reserves since the financial crisis has not occurred uniformly across countries. Although the use of ECB policies discussed above can be seen in most cases (with Greece as the most notable exception) both dynamics and magnitude vary substantially across countries. For example while both Italy and Finland experience a clear expansion in reserves over the APP period, in Italy this peaks below four per cent of total bank assets while in Finland it peaks close to twenty five. For the same period, reserves in Ireland do not reach three per cent of total bank assets.

Figure 7 compares changes in reserve holdings by banks over the course of the Public Sector Purchase Programme (PSPP) to Eurosystem purchases of government bonds for each euro area country. The PSPP programme limits national central banks (NCBs) in the euro area to purchasing their own country's sovereign bonds. As a result total purchases of a given country's government bonds should reflect the scale of purchasing activity being carried out by the relevant NCB.[17] It is clear that the ECB's purchases are driving the accumulation of reserves in the euro area as a whole (again, with the exception of Greece) but there are large discrepancies across countries between APP purchases by the national central bank and the build-up of reserves by banks in those countries. In countries such as the Netherlands, reserve holdings far exceed the volume of purchases by the NCB, while in countries such as Spain the opposite is true. There are a number of ways we could approach explaining this behaviour. If we were to assume that all NCB purchases were from banks within their own jurisdiction, these charts would indicate that banks in certain jurisdictions (Spain) were pushing reserves created through the APP across borders and banks in receiving countries (the Netherlands) were unable or unwilling to do the same. However this would be a strong assumption. For example, ECB (2017b) suggests that the largest counter-party to APP transactions has in fact been non-resident entities.[18]

In this context, Baldo et al. (2017) highlight the role of the euro area financial structure, whereby the types of institutions which are likely to be recipients of liquidity inflows directly related to Eurosystem purchases are concentrated in specific countries (such as France, Germany, Belgium and Luxembourg). For example, these may include the banks accepting reserves on behalf of non-resident or non-bank entities selling securities to the Eurosystem. Thus, cross country differences in Figure 7 could reflect reserves initially being deposited in these countries and remaining there. Clearing and depository institutions involved in Eurosystem purchases are also concentrated in these countries. Other countries host a large number of institutions used as euro accounts for non-euro area parent banks (Finland, Germany and the Netherlands), arguably the same dynamics may be at play in these cases.

[17] Of course this will not include purchases under programmes outside of PSPP (e.g. covered and corporate bonds and asset backed securities). However as shown in Table B, PSPP is by far the largest of the programmes and as such this should be a useful proxy for APP intensity at a national level. We correct total purchases of a given country's sovereign bonds to allow for the 10 per cent of these purchases carried out directly by the ECB.

[18] Many APP transactions are carried out by institutions on behalf of the ultimate seller. ECB (2017b) assesses likely ultimate sellers by examining changes in holdings of euro area government bonds over the period.

Figure 6: Reserve developments across euro area countries

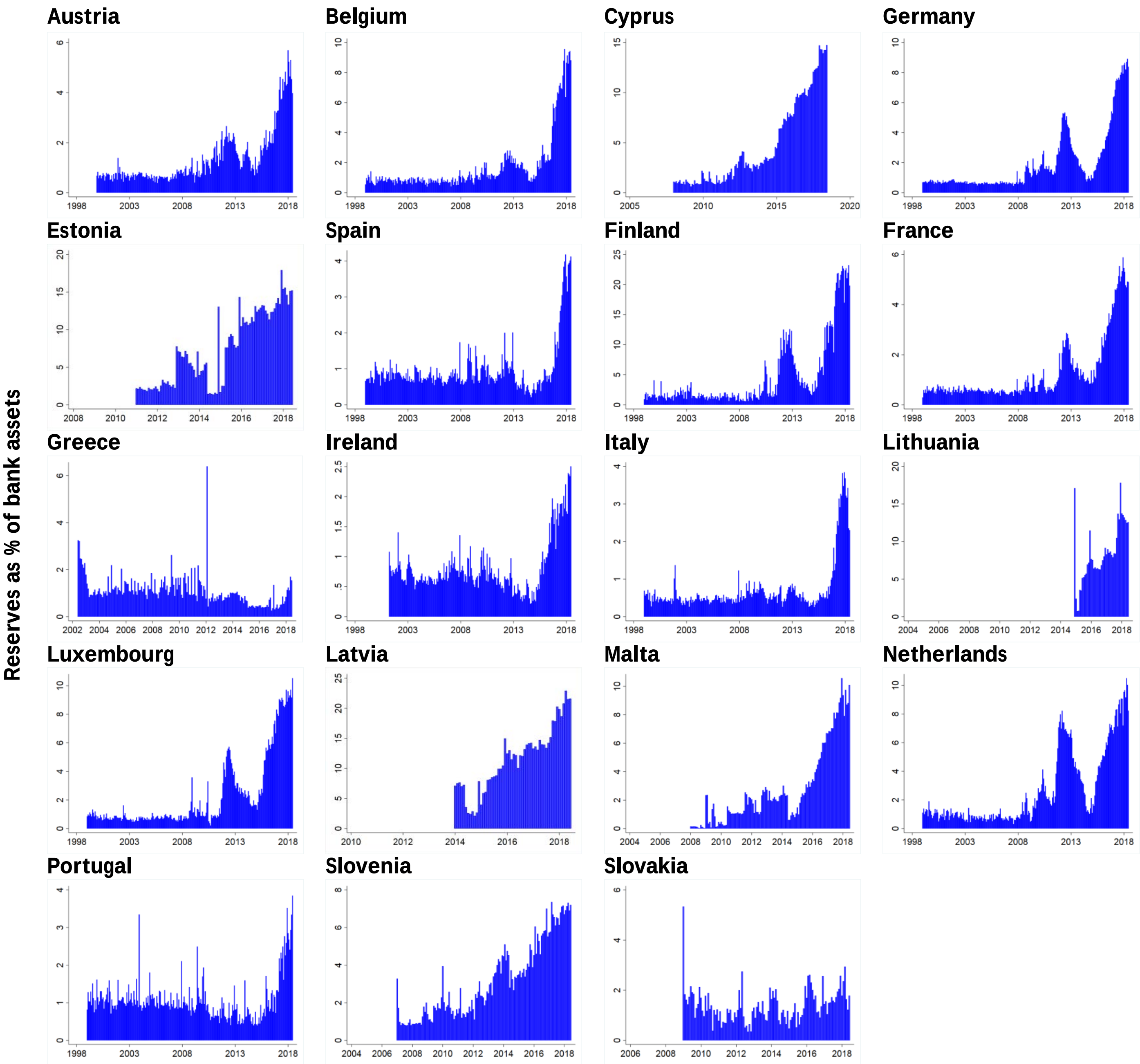
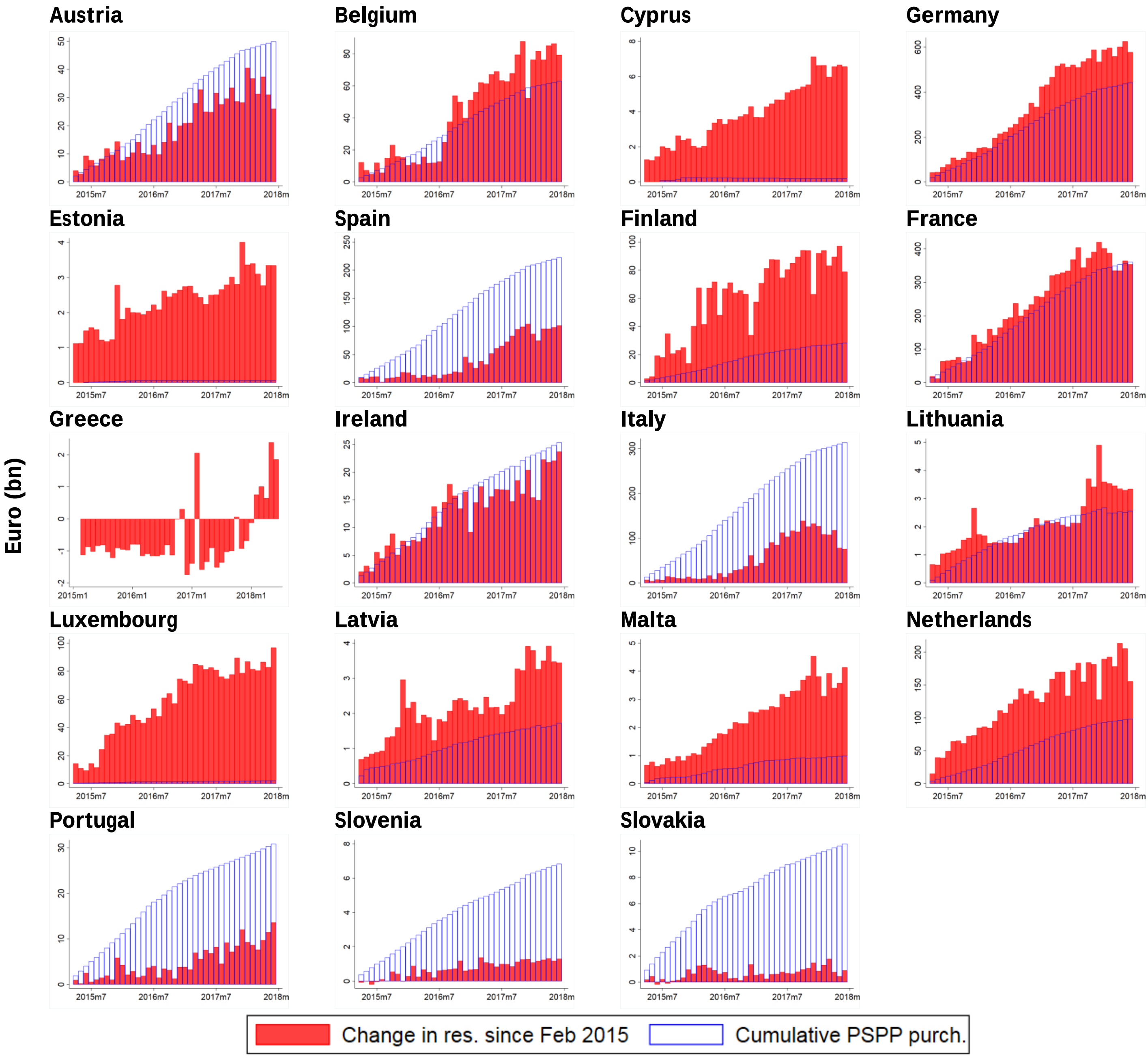
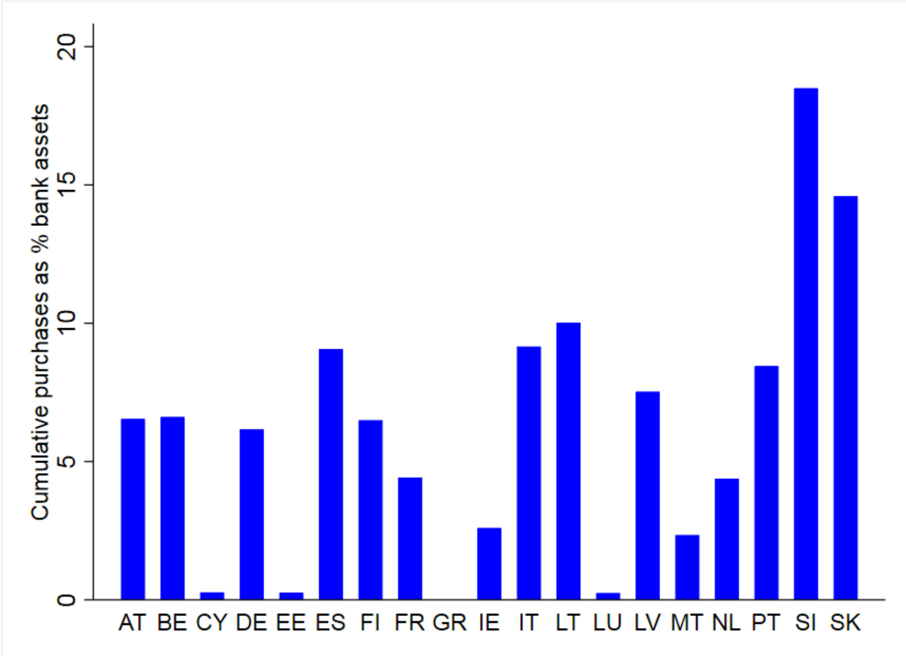


Figure 7: Changes in reserves over the course of PSPP vs. NCB purchase activity



Note: Total purchases of each country's sovereign bonds are corrected to allow for the 10 per cent of these purchases which are carried out directly by the ECB.

Figure 8: Intensity of APP in terms of bank assets varies across countries



Note: Total purchases reflect cumulative government bond purchases under PSPP as of 2017-09.

Finally, Figure 7 also highlights the difference in purchase volume across countries. This is particularly noticeable in countries such as Greece, Cyprus and Estonia where purchases appear to be negligible. When purchases are considered relative to the size of the national banking system in Figure 8 this heterogeneity becomes even more marked. Allocation of purchases across NCBs is determined by a number of factors. First and foremost, reference is made to the ECB capital key. As this is based on a country's GDP and population, banks in a country with a larger banking system relative to its real economy, such as Ireland, may be exposed, per unit of assets, to a lower intensity of purchase activity. The reverse will hold for countries such as Slovakia with a smaller banking system relative to its population and real economy. A number of other factors are also taken into account, including limits on the share of outstanding securities issued by a single issuer which can be owned by the Eurosystem and credit risk limits. These further increase the disparity in PSPP intensity across countries.[19]

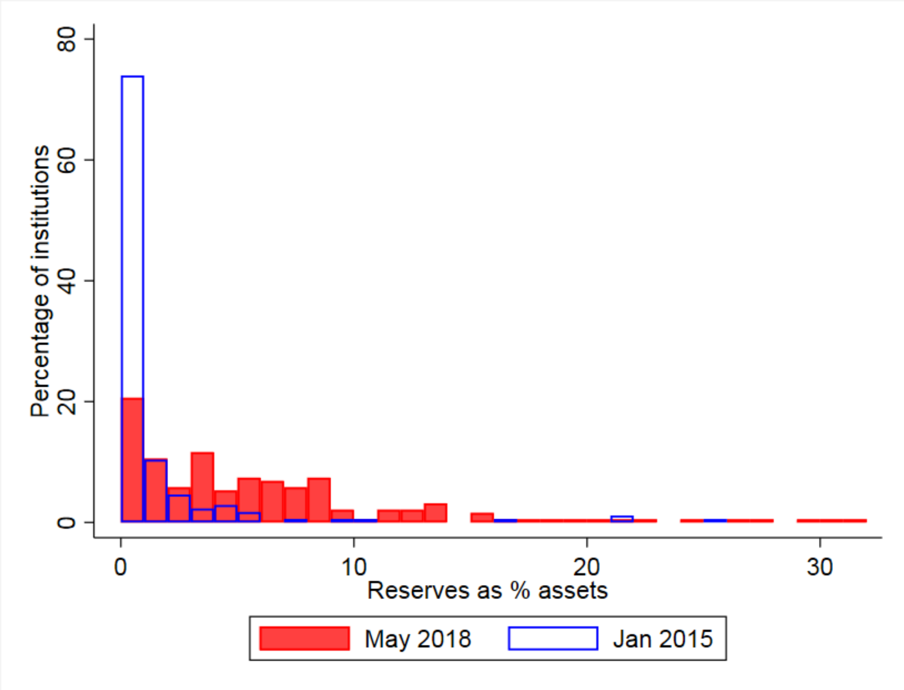
4.4 Bank-Level Reserve Holdings

Using more our bank-level data set, we are also able to examine reserve accumulation at the individual bank-level. Figure 9 shows the distribution of bank reserve holdings as a share of assets for January 2015 and May 2018.[20] The most striking feature of the chart is the reduction in the share of banks holding reserves less than or equal to one per cent of their total assets. This reduces from 74 per cent to 20 per cent and can be considered as a change in the share of institutions holding limited to no excess reserves. The magnitude of excess reserves institutions were holding by May 2018 varied quite widely, with 16 per cent of banks holding between one and three percent of assets as reserves (up from 15 per cent in the earlier period) and 17 per cent holding between four and five per cent (up from five per cent in the earlier period). The share of banks in the sample holding more than five per cent of their assets as reserves increases from 6 per cent in 2015 to 47 per cent in 2018.

[19] For more detail on the allocation of PSPP purchases see the ECB website here.

[20] Due to the substantial expansion in our sample of banks at the beginning of 2015 we use January 2015 as a proxy for pre-asset-purchase reserve holdings. While reserve holdings at this point will reflect three months of CBPP3 purchases and two months of ABSPP purchases, this is still limited compared to the volume of purchases occurring once PSPP begins.

Figure 9: Increased reserve holdings can also be seen at bank-level



Note: 3 outlier institutions are not shown for May 2018.

Figure 10 combines euro area aggregate and bank-level data to compare reserve holdings as a share of assets for individual banks in our sample with total Eurosystem reserves as a share of total Eurosystem bank assets.[21] As at a euro area and country-level, increased reserve holdings around 2012 and from 2015 onward are clearly shown. However, the more granular data highlights that each of these periods are also characterised by an increase in the variation in reserve holdings across institutions. The behaviour of the right tail of the distribution which can be seen in Figure 9 can also be seen over time, as some institutions reach holdings of up to and over ten per cent during the 2012 period and many exceed ten per cent from 2015 onward.

To provide greater insight into the determinants of reserve holdings at the institution level we run a number of simple regressions. The first set, shown below, examine the role of developments in the system average and the intensity of NCB purchase activity in each bank's country.

$$\frac{reserves_{it}}{assets_{it}} = \alpha + \beta system\, average_t + \epsilon \tag{1}$$

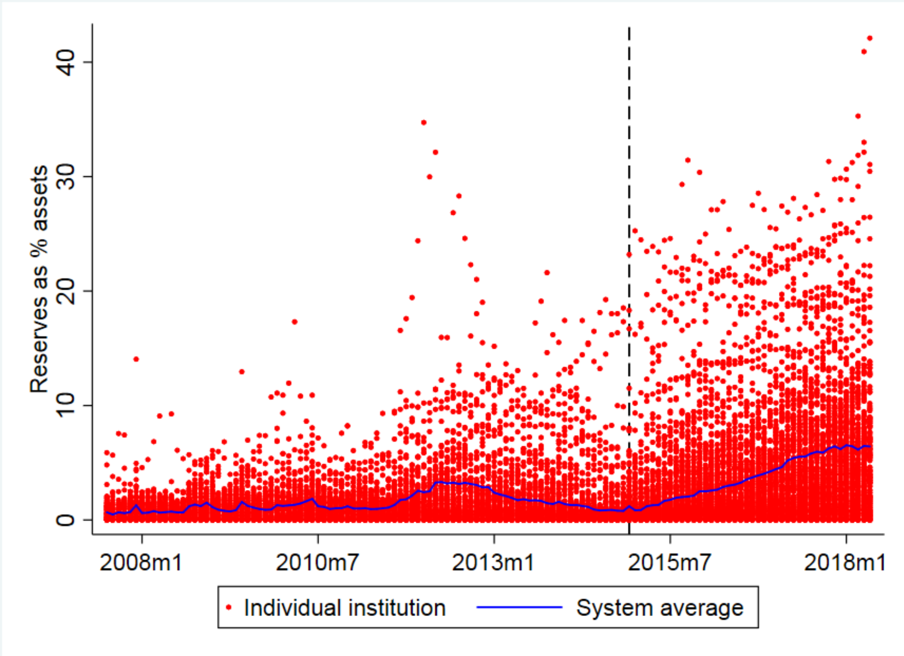
$$\frac{reserves_{it}}{assets_{it}} = \alpha + \beta cumulative\, PSPP_{jt} + \epsilon \tag{2}$$

where $cumulative\ PSPP$ is measured as

$$cumulative\, PSPP_{jt} = \frac{cumulative\, government\, bond\, purchases_{jt}}{total\, bank\, assets_{jt}}$$

[21] The black dashed line marks the substantial change in the sample of banks occurring at the beginning of 2015. This is discussed in further detail in Section 3.

Figure 10: Reserve holdings by individual institutions vs. the system average



Note: The vertical dashed line denotes a large increase in the sample size - at end 2014 the sample of banks increases from 111 to 173 and the sample of countries from 10 to 16. 7 outlier institutions have been dropped to enhance readability. System average reflects euro area aggregates throughout.

for country j at time t. $system\ average_t$ is

$$system\ average_t = \frac{total\ Eurosystem\ reserves_t}{total\ euro\ area\ assets_t}$$

and $reserves_{it}$ reflects reserve holdings by bank i at time t.[22] These regressions are run over the course of the ECB's Asset Purchase Programme, from end 2014 to the end of our sample in May 2018. As PSPP data is not available before the beginning of this programme, the second regression is run on our sample starting in March 2015. Errors are clustered at the bank-level.

Our results in Table 1, indicate that $PSPP\ intensity$ actually plays a limited role in explaining reserve build-up, most likely due to the purchase of these bonds from non-domestic entities. This rejects one possible explanation for the wide cross-sectional variation in reserve-to-assets ratios, i.e. that these reflect cross-country differences in the intensity of the APP and the banks in these countries passively absorbed whatever they were provided with in reserves via the APP. Our positive and highly statistically significant result for $system\ average$ is, of course, to be expected. Due to the closed system for central bank reserves, system level reserve growth must be reflected at the individual institution level. It contrasts with the insignificance of the PSPP variable in suggesting significant underlying dynamics across all banks in the euro area in reserve positions, with the total system supply of reserves being the key driver.

We then incorporate a number of bank balance sheet variables into Equation 1. The literature suggests a variety of factors which may drive the accumulation of reserves in a given institution. For example Ennis and Wolman (2015) and Choulet (2015) highlight high reserve holdings among foreign owned banks in the US during QE. Baldo et al. (2017) highlights the possible role of capital constraints, while Ennis and Wolman (2015) demonstrates that reserves in the US were dispropor-

[22] $cumulative\ PSPP$ is represented by blue bars in Figure 7

Table 1: Examining the relationship between bank-level reserve holdings, the system average and NCB activity

VARIABLES	(1) System	(2) PSPP
System avg.	0.807***	
	(0.0754)	
Cumulative NCB purch		-1.24e-06
		(3.38e-06)
Constant	1.220***	4.721***
	(0.310)	(0.533)
Observations	7,852	6,947
R-squared	0.048	0.001

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

tionately held by banks for which these were not binding. We enter these balance sheet variables into our regressions both on their own and as interactions with $system\ average$; variables entered alone should reflect general relationships between a given characteristic and reserve holdings over the whole estimation period. Interactions on the other hand should reflect how different types of banks respond to increasing reserves within the system.[23]

Results in Table 2 show that banks with a higher share of funding from real economy deposits have a tendency to hold more reserves, as do those whose parents are not from within the euro area. Interaction effects suggest that, as system wide reserves increased, banks with a higher share of assets as real economy loans and better capitalised banks accumulated fewer reserves. Larger banks (relative to other banks in the same country) have also accumulated more reserves as the system average has increased. Finally,R^2 values in Table 2 are approximately six times those in Table 1. This highlights the significant explanatory role of bank balance sheet characteristics, even though R^2 values are still relatively low.

Table 3 examines the role of a bank's location in explaining its reserve holdings. These results indicate that banks in international financial services centres (Luxembourg and Malta) tend to hold far more reserves than those in core countries (Austria, Belgium, Germany, Finland and the Netherlands). Banks in these countries have also accumulated more reserves as the reserves of the system as a whole has increased. As we would expect given Figure 7, periphery country (Cyprus, Spain, Ireland, Italy, Greece and Portugal) banks have accumulated less reserves as reserves in the system as a whole increased. However, R^2 values for these regressions are about a third of those seen in our bank characteristic regressions; this would suggest that banks' business models are a greater determinant of their reserve balances than their location.

Finally, in Table 4, we examine developments on the liability side of the balance sheet associated with changes in reserve holdings. Specifically, we want to examine the relationship between deposit flows and changes in reserve holdings. To do this we run simple bivariate regressions to examine the correlations between monthly changes in reserve holdings and monthly changes in the volume of funding from various types of deposits. Changes in reserves are correlated with changes in deposits from across the financial system, both banks and non-banks. There is a particularly high correlation with changes in deposits from non-euro area counterparties, likely reflecting deposits from non-resident sellers of bonds to the Eurosystem.

[23] Due to the panel structure of our data, standard errors are clustered at the bank-level throughout the paper. Regressions are run over the same end 2014 to May 2018 period.

Table 2: Examining the role of bank characteristics

VARIABLES	(1) Bank variables	(2) Bank interactions	(3) Both
System avg.	0.871***	1.791***	1.922***
	(0.0884)	(0.378)	(0.340)
Real ec. deposits * System avg.		0.0136*	0.00650
		(0.00728)	(0.00555)
Real ec. loans * System avg.		-0.0222***	-0.0219***
		(0.00592)	(0.00501)
Leverage * System avg.		-0.0444***	-0.0325**
		(0.0158)	(0.0137)
Size * System avg.		0.0223*	0.0219**
		(0.0117)	(0.00859)
EA parent * System avg.		0.119	-0.0411
		(0.172)	(0.142)
Non-EA parent * System avg.		2.283***	0.695
		(0.644)	(0.456)
Real ec. deposits	0.0603**		0.0341**
	(0.0299)		(0.0171)
Real ec. loans	-0.0851***		-0.000946
	(0.0247)		(0.0153)
Leverage	-0.180***		-0.0612
	(0.0631)		(0.0429)
Size	0.0873*		0.00384
	(0.0505)		(0.0363)
EA parent	0.661		0.775
	(0.725)		(0.510)
Non-EA parent	10.49***		7.734***
	(2.881)		(2.399)
Constant	4.280***	1.032***	0.400
	(1.347)	(0.293)	(0.907)
Observations	7,850	7,850	7,850
R-squared	0.307	0.311	0.329

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Real economy deposits are expressed as a share of non-capital liabilities, real economy loans and capital as a share of assets and size as a share of the bank's national banking system. Parent location dummies reflect outcomes relative to those of domestically owned institutions.

Table 3: Regional variation in reserve holdings

VARIABLES	(1) Region dummies	(2) Region interactions	(3) Both
System avg.	0.790***	0.726***	0.775***
	(0.0735)	(0.143)	(0.120)
Periphery	-1.364		-0.475
	(0.842)		(0.631)
International	4.052**		0.723
	(1.870)		(1.034)
New	3.979**		2.861**
	(1.662)		(1.177)
Periph.* System avg.		-0.332*	-0.232*
		(0.196)	(0.139)
Int. * System avg.		0.982**	0.831**
		(0.441)	(0.364)
New * System avg.		0.889**	0.290
		(0.384)	(0.247)
Constant	0.950*	1.240***	1.004**
	(0.573)	(0.310)	(0.461)
Observations	7,852	7,852	7,852
R-squared	0.123	0.124	0.129

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Core = AT, BE, DE, FI, NL. Periphery = CY, ES, IE, IT, GR, PT. International = LU, MT. New = EE, LV, LT, SI, SK. Regional results are relative to base "Core" dummy.

Table 4: Examining the role of deposit flows

VARIABLES	(1) Reserves	(2) Reserves	(3) Reserves	(4) Reserves	(5) Reserves
MFI deposits	0.273***				
	(0.0553)				
Non-euro area deposits		0.517***			
		(0.0365)			
OFI deposits			0.166**		
			(0.0651)		
Real economy deposits				0.392	
				(0.275)	
All deposits					0.338***
					(0.0233)
Constant	116.1***	95.09***	120.8***	136.8***	123.8***
	(21.36)	(15.64)	(21.32)	(27.09)	(20.46)
Observations	7,781	7,361	7,781	7,781	7,361
R-squared	0.038	0.299	0.012	0.004	0.280

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Dependent variable is the monthly change in reserves. Explanatory variables are monthly changes in each type of deposit funding. Other Financial Institutions (OFIs) include pension funds, investment funds and insurance companies. Real economy deposits are defined as deposits from households and NFCs. Non-EA deposits are from counterparties outside the euro area. MFI deposits are from monetary financial institutions.

5 Bank-Level Dynamics

While these regressions provide insight into reserve accumulation over the period, they do not tell us whether or not banks are actively managing reserves. For example, banks with particular business models may simply be receiving higher reserve inflows and, as such, have higher reserve accumulation over the period. On its own, looking at cross-sectional data from one point in time cannot tell us whether banks receiving higher reserve inflows are seeking to actively push some of these reserves off their balance sheets to other banks. To get a sense of this, we need to look at panel data, thus following individual banks' reserve holdings over time.

In this section, we use our bank-level panel data to provide two different ways of illustrating the extent to which banks in the euro area have been actively managing reserve holdings rather than just passively absorbing them. First, we provide a few graphical illustrations and a simple measure of the month-to-month "churn" in reserves. Second, we provide regression analysis illustrating the extent to which banks are adjusting their reserve holdings on a month-to-month basis.

5.1 Some Illustrations of "Churn" in Reserves

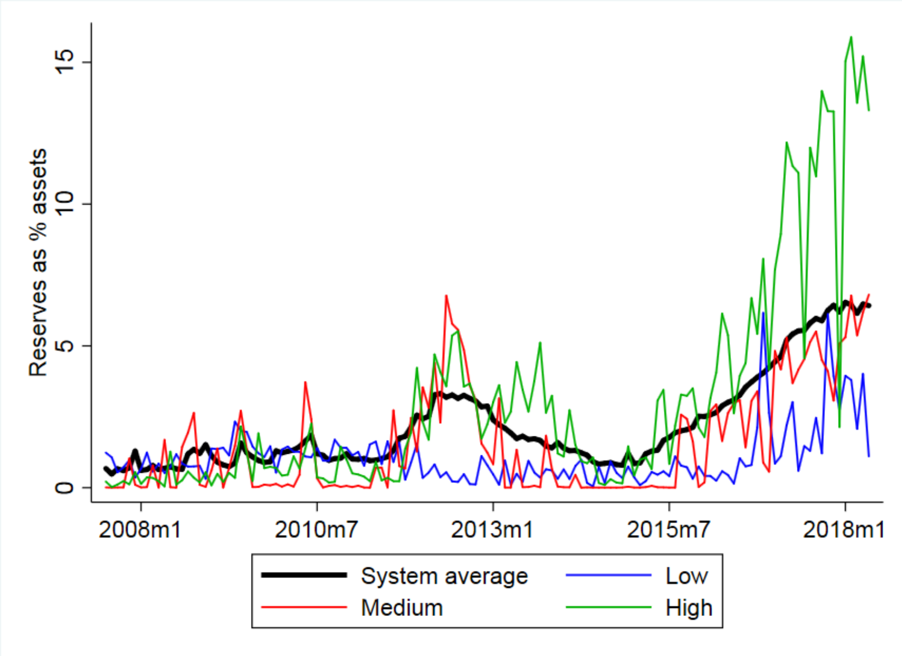
To give a first illustration of the kinds of dynamics determining reserve holdings at an institution-level, Figure 11 plots the build-up of reserve holdings for three individual institutions which are at (or close to) the 30th, 60th and 90th percentile values for reserve holdings as a share of assets in September 2017 (labelled Low, Medium and High, respectively). For the "Medium" and "High" percentile institutions in particular, their elevated reserve holdings at the end of the period are not the result of consistently high holdings for the full 10 years shown (i.e. structurally high reserve holdings as a result of their business model) but have a clear link to reserves in the system as a whole and so ECB policy.

For example, consider the green line, our "High reserve" bank. Prior to the global financial crisis, this bank tended to have slightly lower reserve-to-assets ratios than the system average. Its reserve-to-assets ratio jumps upwards during the period when the ECB began providing credit via LTROs but had eased back to pre-crisis levels by the late 2014. Since then, the bank's reserve-to-assets ratio has jerked upwards and downwards, including a big fall below the system average level in early summer 2017 before another big surge placed them at the 90th percentile in September 2017, with ratio of reserves to assets of about 13 percent. Similar patterns are evident for the other banks shown here. The "Low reserve" bank (denoted by the blue line) experienced a brief surge in its reserve-to-assets ratio in early 2017 (placing it just below the "High" bank) before ending up well below the system average. We view these figures as inconsistent with the idea that banks are passively absorbing the reserves created by the APP and as further evidence in favour of the hot potato effect.

Moving beyond illustrations based on individual banks, we also calculate a simple measure to illustrate the level of "churn" in reserves throughout the system. In an earlier working paper version of their article, Ennis and Wolman (2012), proposed a simple metric to examine the extent to which reserves are moving around the US banking system. Their metric compared the sum of the net quarterly change in reserve holdings across banks with the sum of the gross changes (i.e. the absolute values) of the quarterly changes in reserves across banks.

As an illustration of how to consider this measure, note that if banks were to passively absorb all reserves created by the APP in a given month, and the impact of the programme was spread relatively evenly around the banking system, then we would expect reserve holdings for all banks to increase, resulting in equal net and gross flows. However, if Bank 1 manages to actively push reserves off its balance sheet over the course of a period of time, this will result in a negative flow of reserves for Bank 1 and a larger positive flow for Bank 2, the ultimate recipient of these reserves. As a result, the

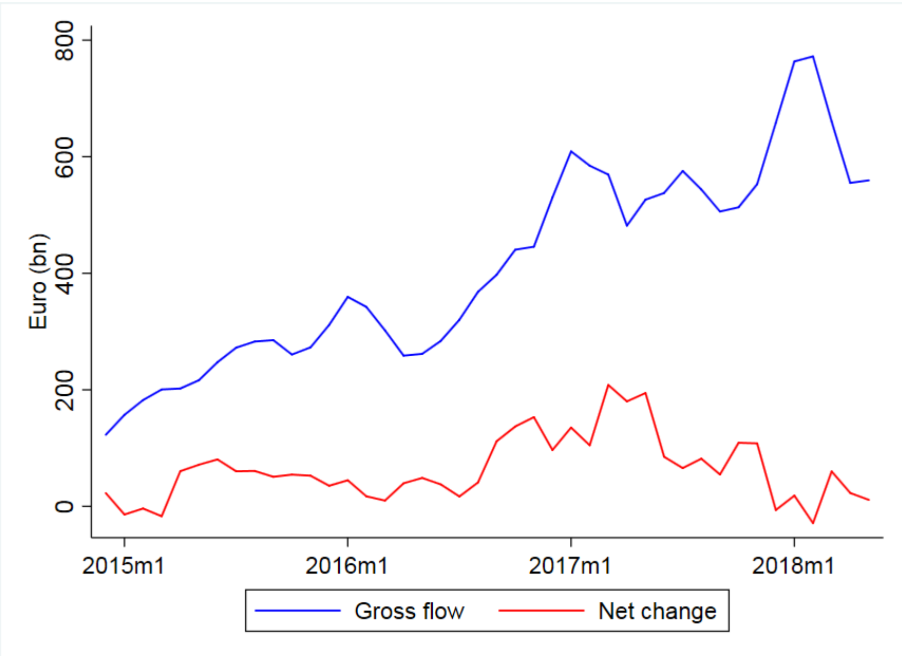
Figure 11: Examining reserve holdings for individual institutions



gross flow figure can be expected to exceed the net flow. For this reason, we view the ratio of total gross flows to total net flows to be an indication of the amount of churn in reserves as a result of active balance sheet management aimed at shifting reserves onto other banks.

Like Ennis and Wolman (2012), we can calculate these net and gross flow series but our data set is monthly rather than quarterly, which gives us a better chance at observing relatively high-frequency dynamics in reserve flows at individual banks. Figure 12 shows these two measurements for our full sample of banks over 2015 and 2018. On average over the period total gross flows are more than eight times total net flows, suggesting that reserves are being moved around the system in a very active manner and are not being hoarded or passively absorbed.

Figure 12: Measuring movement within the system - Net vs. gross flows



Note: Measures are smoothed using one quarter rolling sum.

5.2 Regression Analysis of Reserve Dynamics

We provide a more formal examination of this idea by looking at banks' responses to high reserve balances. In particular, we want to know if banks are responding to a high reserve balance in one period by decreasing their reserves (or allowing them to increase by less) in the next. Ideally, this type of exercise should be carried out using daily or even weekly data, as the difference between month-end reserve balances is unlikely to capture the full flow of reserves in and out of banks' accounts over the course of a month. As such using monthly data runs the risk of producing Type I errors, whereby banks are actively managing reserves but this is done efficiently and on a daily or weekly basis so it cannot be picked up with our data. Our highly statistically significant result suggests that this is not the case but it is still possible that our coefficient underestimates the full extent of reserve management by banks, by not capturing total intra-month flows. Nonetheless, it should also be kept in mind that most sources of balance sheet data are recorded on a quarterly or yearly frequency (including those used by Baldo et al. (2017) and Ennis and Wolman (2015)) and our monthly data is a substantial improvement on this.

Defining "high reserve balances" also presents something of a challenge due to the upward trend in reserve balances over the period. For example, Figure 9 would suggest that anything over one per cent of assets could be considered as "high" in January 2015, whereas in May 2018 the majority of the sample fell into the category. To allow for this we define "high reserve balances" relative to the system average for each period and enter this into our specification with the variable $distance_{it}$. This is calculated as

$$distance_{it} = log(\frac{reserves_{it}}{assets_{it}}) - log(\frac{total\, Eurosystem\, reserves_t}{total\, euro\, area\, bank\, assets_t})$$

This results in the error correction model (ECM) style framework shown in Equation 3.

$$\Delta reserves_{it} = \alpha + \theta_t + \beta distance_{i,t-1} + \gamma \Delta system\, average_{t-1} + \epsilon \qquad (3)$$

$\Delta reserves_{it}$ reflects the month-on-month change in the log of reserve holdings by bank i for time t, $\Delta\ system\ average_t$ is the month-on-month change in log of total Eurosystem reserves as a share of total Eurosystem bank assets, θ_t are a series of time fixed effects and α is an intercept (which is not bank or time specific). β is our main coefficient of interest throughout. If banks are passively absorbing reserves produced by the APP we would not expect this coefficient to be statistically significant. However, if banks are actively managing reserves we would expect a negative and statistically significant coefficient (Type I errors aside).

Column 1 of Table 5 shows results from this specification for all banks in the sample and a negative and highly statistically significant coefficient on $distance_{i,t-1}$ is reported. The R^2 value is quite small but we do not see this as a problem. Reserve holdings at the bank-level are a very noisy series and it would be difficult to explain them well with a parsimonious model. Instead, we are asking for whether there is a systematic relationship between changes in reserves and an institution's reserve holdings relative to the system as a whole.

The specification is repeated in Columns 3 and 4 using only observations above the system average and then only observations below the system average. When we restrict the sample to observations with above system average reserve holdings we find a much larger coefficient, indicating the response is stronger among these institutions. Our R^2 also becomes substantially larger and indicates that for these institutions our specification explains about half of all changes in reserve holdings. For observations with reserve holdings below the system average, the negative and statistically

Table 5: Baseline specification and influence of above and below system average samples

VARIABLES	(1) Baseline	(2) With Dummy	(3) Baseline Above Avg.	(4) Baseline Below Avg.
Above avg. dummy		0.974***		
		(0.0649)		
Distance (lagged)	-0.168***	-0.360***	-0.426***	-0.346***
	(0.0175)	(0.0301)	(0.0461)	(0.0347)
System avg. ch. (lagged)	-7.023***	-7.700***	-9.316***	-6.816***
	(1.135)	(1.024)	(1.121)	(1.485)
Constant	0.215***	-0.235***	0.766***	-0.205***
	(0.0575)	(0.0602)	(0.0626)	(0.0740)
Observations	7,441	7,441	2,487	4,954
R-squared	0.104	0.251	0.478	0.215

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

significant coefficient indicates that these institutions are being pulled back up towards the system average. This makes sense in the context of the closed system discussed in Section 4.2; if high reserve institutions are pushing reserves off of their balance sheets they must end up in another part of the system and our result indicates that they are subsequently held on low reserve institutions' balance sheets.[24]

Column 2 includes a dummy variable for observations with above average reserves, this allows for the intercept to differ between high and low reserve banks. Resulting coefficients and R^2 values for Column 2 are a weighted average of those for Columns 3 and 4. Differences in R^2 and $distance$ coefficient values for Columns 1 and 2, however, indicate there is a role played by differing intercepts between the above and below average sample (i.e. above average observations overall tend to have higher reserve inflows).

While the primary driver of aggregate reserves over the period examined has been Eurosystem asset purchases, as discussed in Section 4.1, LTRO operations were still in place. These will lead to an increase in reserves on draw down which may then be followed by falling reserve balances as banks use these funds. In particular, the main LTRO operations in place during the examined period included explicit incentives for banks to use these funds for loan creation. If these dynamics were driving our results we would in fact be measuring the effectiveness of these incentives as opposed to a hot potato effect. We assess this possibility by identifying changes in banks' deposits *from* the Eurosystem (as opposed to deposits *with* the Eurosystem) which resemble LTRO draw down. Specifically this is done by generating an $LTRO$ dummy variable which equals one where banks experience a large increase in Eurosystem deposits on a date associated with LTRO settlement.[25] The dummy then equals one for six months afterwards. Table 6 shows that the coefficient for $LTRO * Distance$ is statistically insignificant. So LTRO draw down is not associated with a stronger response to distance from the system average. While we do find that LTRO draw down is associated with lower reserve growth, the

[24]Observation numbers for Columns 3 and 4 also highlight that our sample is disproportionately made up of banks with reserve holdings below the system average. This may be a result of our sample not including French banks which, from Figures 7 and 6 we can assume have higher than average reserve holdings. It may also be due to many smaller institutions not included in our sample tending to have high reserve holdings.

[25]This is identified as a large increase in Eurosystem deposits as a share of total assets on a date corresponding with LTRO settlement. A large increase is defined as one greater than 1.13 per cent of total assets (this is the 75th percentile value of month-on-month increases over the full pooled sample where change in Eurosystem deposits is positive.) When these conditions are satisfied, $LTRO$ equals 1 for the subsequent 6 months. Settlement dates are sourced from the ECB website. Where LTRO settlement occurs on the last day of the month, LTRO may equals 1 for the following 7 months.

Table 6: Examining the role of LTRO

VARIABLES	(1) LTRO	(2) With region control
Distance (lagged)	-0.166***	-0.178***
	(0.0210)	(0.0227)
LTRO (lagged)	-0.117**	-0.0782
	(0.0477)	(0.0479)
International		0.127*
		(0.0671)
New		0.103
		(0.0639)
Periphery		-0.0916**
		(0.0413)
Distance* LTRO (both lagged)	-0.0230	-0.0202
	(0.0355)	(0.0364)
System avg. change (lagged)	-6.740***	-6.915***
	(1.145)	(1.138)
Constant	0.230***	0.227***
	(0.0574)	(0.0603)
Observations	7,441	7,441
R-squared	0.106	0.112

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

addition of region dummies indicates that this is driven by the geographic concentration of LTRO in Periphery countries.

Finally, to ensure that our results are not being driven by a specific type of institution or institutions in particular parts of the euro area, we include a range of macroeconomic and bank balance sheet control and interaction variables. By interacting macroeconomic and balance sheet characteristics with our $distance$ variable, we also loosen our assumption that all banks are "targeting" the system average level of reserves and allow for this "target" to vary across different types of banks. Most importantly, Tables 7 and 8 show that our β coefficient remains negative and statistically significant throughout. This indicates that the active reserve management we are examining is broad-based.

Coefficients for interaction variables are also of interest as they reflect characteristics which are associated with increased or decreased active reserve management by banks. At the macro level we examine the role of yields on ten year domestic government bonds, a series of region dummies and dummies for each deposit facility rate (DFR) over the relevant period.[26] All variables are lagged by one period to account for possible endogeneity. Government bond yields are entered as dummies for each quintile value to avoid loss of negative observations through the application of logs. We find that these macro variables generally have little effect on active management except that reserve management is found to be less intensive during periods with the most negative DFR, relative to those with the least. This contradicts the assumption that a lower interest rate would disincentivise passive reserve accumulation. However, when we include a continuous time variable and interact it with $distance$ the DFR interaction loses its significance. This suggests that our earlier result may reflect changing behaviour over time as opposed to a rate effect.

[26] Bond yield data is sourced from the ECB's Statistical Data Warehouse, where it is classified as "harmonised long-term interest rates for convergence assessment purposes". This broadly reflects secondary market yields of government bonds with maturities of or close to ten years. However in a number of cases proxies are used. For example, Cypriot primary market yields are reported. As there are no Estonian sovereign debt securities that comply with the definition of long-term interest rates for convergence purposes, a proxy is not provided. Regions are classified as follows: Core = AT, BE, DE, FI, NL; Periphery = CY, ES, IE, IT, GR, PT; International = LU, MT; New = EE, LV, LT, SI, SK.

Table 7: Examining the role of macroeconomic variables

VARIABLES	(1) Macro variables	(2) DFR and time
Distance (lagged)	-0.189***	-0.206***
	(0.0398)	(0.0274)
System avg. change (lagged)	-0.567	0.299
	(0.876)	(0.233)
10Y gov. yield:		
2nd quintile (lagged)	0.00233	
	(0.0280)	
3nd quintile (lagged)	-0.0165	
	(0.0392)	
4nd quintile (lagged)	-0.0553	
	(0.0609)	
5nd quintile (lagged)	-0.0583	
	(0.0724)	
2nd quintile Distance (both lagged)*	-0.0279	
	(0.0271)	
3nd quintile Distance (both lagged)*	0.00731	
	(0.0296)	
4nd quintile Distance (both lagged)*	-0.0257	
	(0.0426)	
5nd quintile Distance (both lagged)*	-0.00131	
	(0.0504)	
DFR = -30bps	0.329	0.0164
	(0.350)	(0.0344)
DFR = -40bps	0.159	-0.0198
	(0.381)	(0.0276)
DFR = -30bps* Distance (both lagged)	0.0439	0.0517*
	(0.0305)	(0.0309)
DFR = -40bps* Distance (both lagged)	0.0411**	0.0504
	(0.0203)	(0.0311)
Continuous time variable		0.000287
		(0.00135)
Time * Distance (lagged)		5.96e-05
		(0.00135)
Constant	-0.256	-0.0820*
	(0.389)	(0.0445)
Observations	7,265	7,077
R-squared	0.104	0.087

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Regional dummies show management intensity relative to Core countries. Deposit Facility Rate (DFR) dummies are relative to -20bps rate. Regions are classified as follows: Core = AT, BE, DE, FI, NL; Periphery = CY, ES, IE, IT, GR, PT; International = LU, MT; New = EE, LV, LT, SI, SK. Macro variables are also entered on their own but not shown above for the sake of readability. Time period dummies are also included in regressions and errors are clustered at the bank-level. All control and interaction variables are lagged by one period.

Table 8: Examining the role of bank characteristics

VARIABLES	(1) Bank variables
Distance (lagged)	-0.156**
	(0.0664)
System avg. change (lagged)	-6.995***
	(1.184)
Real Ec. deposits (lagged)	0.0304*
	(0.0178)
Real Ec. deposits* Distance (lagged)	0.0148
	(0.0118)
Real Ec. loans (lagged)	-0.0346*
	(0.0190)
Real Ec. loans* Distance (lagged)	-0.00210
	(0.00954)
Size (lagged)	0.0314**
	(0.0137)
Size* Distance (lagged)	0.0103
	(0.0102)
Leverage (lagged)	-0.0819
	(0.0593)
Leverage* Distance (lagged)	-0.0287
	(0.0308)
EA parent (non-domestic)	0.00583
	(0.0697)
Non-EA parent	0.212***
	(0.0575)
EA parent* Distance (lagged)	-0.0361
	(0.0423)
Non-EA parent* Distance (lagged)	0.123***
	(0.0348)
Constant	0.407***
	(0.130)
Observations	7,083
R-squared	0.125

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Parent location dummies show management intensity relative to domestically owned institutions. Bank variables are also entered on their own but not shown above for the sake of readability. Time period dummies are also included in regressions and errors are clustered at the bank-level. All control and interaction variables are lagged by one period.

At the bank-level, we examine the same bank characteristics as in Section 4.4. Again, logs are applied to all non-dummy variables and all variables are lagged by one period. Our results in Table 8 indicate that active management is also weaker among banks with non-euro area parents. Our findings regarding this type of bank, both here and in Section 4.4, may reflect the use of these institutions by their parents as a conduit to the Eurosystem (also noted in Baldo et al. (2017)). While Eurosystem reserves may not be an attractive asset from a returns perspective, non-euro area institutions may want to hold them to carry out euro area security transactions and to make use of euro area market infrastructure, where they are in some cases the required means of payment.[27] As these benefits may counteract some of the cost imposed by the negative deposit facility rate, it makes sense that we find these banks holding more reserves and making less effort to remove them from their balance sheets. Finally, these institutions are also typically quite small and in some cases may not have the required risk management systems in place to manage debt security or loan portfolios acquired through the use of reserves. [28] We find no evidence for other bank characteristics being associated with more or less active reserve management.

In some ways, these results are not particularly surprising. Banks that are above the mean level of reserve-to-assets ratios tend to revert back to the mean and this sees banks with relatively low levels of reserves-to-assets come back towards the mean. Such a result could even appear to be a mechanical result of the closed system of reserves. However, our result would not hold under all of the various hypotheses about the factors driving reserve holdings that we have discussed. For example, if banks were passively absorbing reserves received from APP sales then we would tend to see certain banks steadily building up relatively high reserve-to-asset ratios while others do not. Similarly, if cross-sectional differences in reserve holdings reflected consistent differences across countries in the intensity of APP programmes then we would see banks from certain countries steadily building up reserve balances while others did not. In either of these scenarios our the coefficient for $distance$ would not be statistically significant, as distance from the system average would not have an effect on reserves dynamics. As such, our results represent further evidence against the idea that banks passively absorb the reserves created via the APP.

6 How Are Banks Getting Rid of Reserves?

6.1 Are Banks Lending or Buying Debt Securities?

Having examined whether or not banks are actively managing their reserves, the natural next step is to examine how they are doing so and whether these actions are likely to have any direct impact on the real economy. Specifically, are banks that are shifting reserves off their balance sheets doing so via lending to the real economy or purchasing debt securities? If these banks are lending to the real economy, then the balance sheet adjustments will as a result have a direct effect on the real economy. If banks are purchasing debt securities, the impact on the real economy will be more indirect but could occur via lower bond yields. In either case, this represents a channel through which QE affects the real economy which differs from the portfolio rebalancing and signalling channels that are usually covered in the QE literature.

One potential regression specification to address this issue would be to regress variables related to changes in loans or security holdings on variables describing the monthly changes in reserves: Perhaps we could find a negative relationship between accumulation of reserves and holdings of securities or loans? Specifications of this sort were run by Kandrac and Schlusche (2017), who used instruments for the change in reserves variable. We do not see this kind of specification as ideal, however,

[27] For a detailed discussion of the roles of commercial and central bank money in payments systems see CPSS (2003)

[28] It should also be noted that these banks represent quite a small share of our sample.

Table 9: Average monthly changes in bond and loan holdings for banks with high and low reserve growth

	Low growth = 1	Low growth = 0
Log change real economy loans (month on month)	0.003	0.002
Log change debt security holdings (month on month)	0.003	-0.015

because it assumes a symmetry that may not hold. Banks that are reducing their reserves during the APP may be achieving this by accumulating securities or making loans. But it doesn't follow that banks that are accumulating reserves during these periods are necessarily taking these reserves as substitutes for securities or loans. The use of a variable such as percentage change in reserves (or change in reserves to asset ratios) in these regressions would fail to capture this potentially important asymmetry.

Instead, to get at this question, we investigate whether those banks that are more successful in resisting the system-wide trend of increasing reserves are achieving this by accumulating more securities or making more loans than other banks. It may seem as though this result would have to hold but it is not *a priori* necessarily the case. A bank that reduces its reserves does not have to reallocate its assets towards loans or securities because it could choose to pay off liabilities. So, ultimately, we want to carry out a cross-sectional examination of whether banks that are shifting reserves off their balance sheets are doing so by accumulating more securities and loans than other banks.[29]

To answer this question, we start by calculating month-on-month log changes in reserves as a share of assets at the bank and euro area level. We consider reserve growth below that of the system as a whole as an indication that a bank has (successfully) actively managed their reserves in a given month. To reflect this we calculate a $low\ growth$ variable as

$$low\ growth_{it} = \begin{cases} 1, & \text{if } \Delta \frac{reserves_{it}}{assets_{it}} < \Delta \frac{Eurosystem\ reserves_t}{Eurosystem\ bank\ assets_t} \\ 0, & \text{otherwise} \end{cases}$$

We then examine the relationship between $low\ growth$ and changes in other parts of the balance sheet. Table 9 compares average changes in our key dependent variables for periods where $low\ growth$ is equal to 1 and 0.

These dependent variables are calculated as

$$\Delta loans_{it} = log(real\ economy\ loans_{it}) - log(real\ economy\ loans_{it-1})$$

$$\Delta bonds_{it} = log(debt\ securities_{it}) - log(debt\ securities_{it-1})$$

This simple comparison indicates that both loan and debt securities grow by more when reserves are growing slowly. (In fact bond holdings on average contract when $low\ growth$ equals 0). A simple univariate regression of our dependent variables on $low\ growth$ for the same period, reported in Table 10, finds a highly statistically significant result for $\Delta bonds$ but no statistical significance for $\Delta loans$.

[29] In the context of our discussion in Section 4.1 the cross-sectional nature of the method should also be noted. As we are comparing outcomes across banks findings that, for example, banks are managing reserves through debt security purchases are still consistent with a net reduction in debt security holdings by the sector as a whole.

Table 10: Simple OLS regression of dependent variables on $low\ growth$ variable

VARIABLES	(1) Loans	(2) Bonds
Low growth = 1	0.00158	0.0181***
	(0.00163)	(0.00349)
Constant	0.00186	-0.0148***
	(0.00119)	(0.00255)
Observations	7,384	6,882
R-squared	0.000	0.004

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

However, it is possible that observations with low reserve growth are disproportionately made up of banks which, due to characteristics unrelated to their reserve management, had high loan, reserve or debt security growth over the period. This would bias our coefficient of interest. Figures 13a, 13b and 13c examine the share of observations with reserve growth below the system average ($low\ growth$ equal to one) and show that this is fairly balanced over time, across countries and for each institution. In particular, to examine whether or not our low growth sample is consistently made up of the same banks, we calculate the share of observations with low reserve growth for each institution. Figure 13c examines the distribution of this variable across banks and finds that 80 per cent have between 40 and 60 per cent of observations classified as low growth. No institution is consistently low growth and only 3 are consistently high growth throughout the period (less than 2 per cent of the sample). This suggests that a fixed effects model may be useful here as we have quite a bit of variation in $low\ growth$ at the bank-level and are concerned that bank characteristics may be driving our result. These business model characteristics are also unlikely to vary substantially over our estimation period.

Tables 11 and 12 show results for $\Delta loans$ and $\Delta bonds$ respectively, using a number of specifications and examining again late 2014 to May 2018 period. Across all specifications we continue to find highly statistically significant results for changes in debt security holdings but not for loans to the real economy.[30] This would suggest that banks are primarily managing reserves through the purchase of debt securities. Our R^2 values are all very small. As before, we do not see this as a problem given we are not aiming to fully explain the dynamics of our dependent variables but instead are examining the relationship between these variables and reserve management. We use Hausman tests to assess whether or not bank-level fixed effects should be used. Interestingly, there is no support for their inclusion in our specification.

A more nuanced result may be found by replacing $low\ growth$ with dummy variables for each quartile of reserve growth in a given period.[31] This allows us to see whether or not the banks who are being most aggressive in reducing reserve holdings have notably different behaviour in other parts of their balance sheets.[32] As can be seen from Table 13 this approach provides similar results for $\Delta loans$: There is no evidence that lower reserve growth is associated with higher monthly growth in loans. For $\Delta bonds$ again there is strong evidence that banks in the bottom two quartiles are accumulating more debt securities than those in the top quartile. Interestingly the coefficient for the second quartile is larger than that for the first. This suggests that institutions in the first quartile may also be

[30] As previously real economy loans are defined as households and non-financial corporations (NFCs).

[31] For example, the dummy for the first quartile will equal one for all institutions with reserve growth below the 25th percentile value for that specific period.

[32] In comparing these results to those using $low\ growth$ it should be noted that throughout the the APP the median reserve growth value for our sample roughly equals that of the system average discussed above.

Figure 13: Distribution of observations with reserve growth below that of system average (red lines highlight fifty per cent mark)

a: Over time

b: Across countries

c: By institution

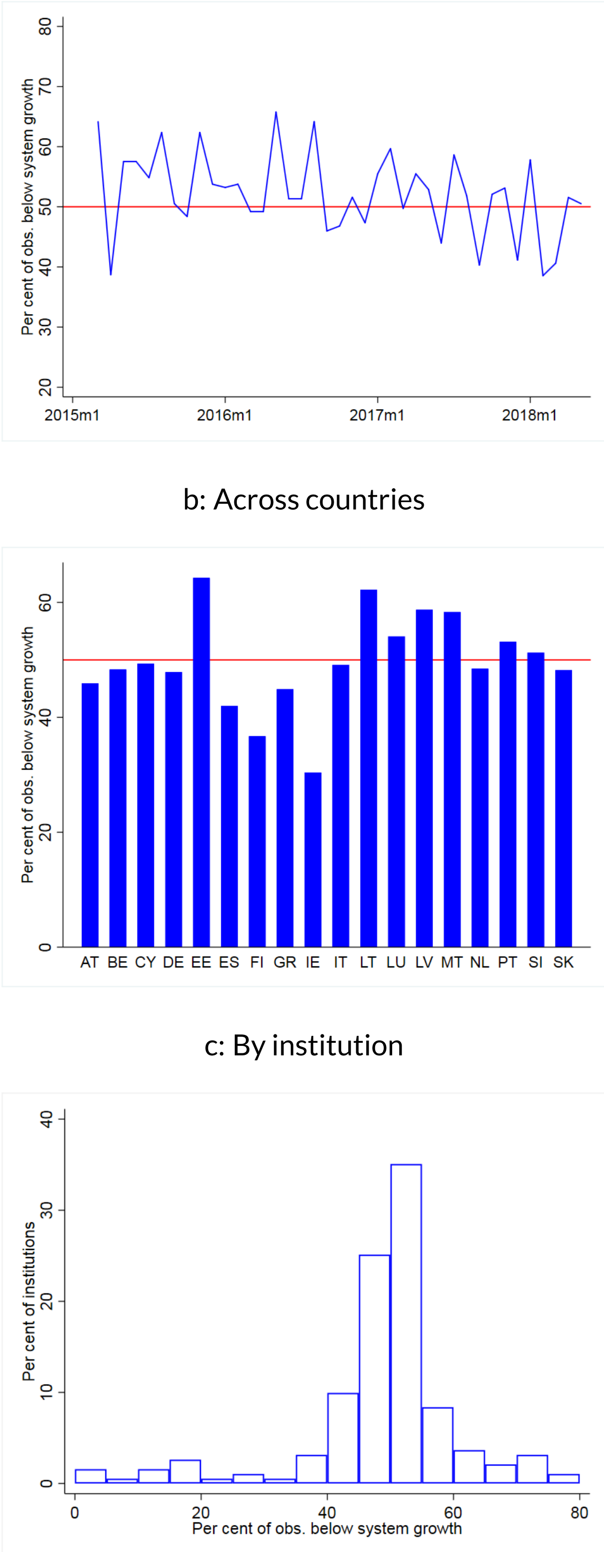


Table 11: Using loan growth as a dependent variable

VARIABLES	(1) No FE	(2) Bank FE	(3) Time FE
Low growth = 1	0.00158	0.00167	0.00196
	(0.00194)	(0.00199)	(0.00197)
Constant	0.00186	0.00181*	0.0145
	(0.00169)	(0.00107)	(0.0231)
Observations	7,384	7,384	7,384
R-squared	0.000	0.000	0.006
Number of banks		185	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 12: Using debt security holdings growth as a dependent variable

VARIABLES	(1) No FE	(2) Bank FE	(3) Time FE
Low growth = 1	0.0181***	0.0176***	0.0179***
	(0.00465)	(0.00442)	(0.00481)
Constant	-0.0148***	-0.0145***	-0.0290
	(0.00219)	(0.00237)	(0.0176)
Observations	6,882	6,882	6,882
R-squared	0.004	0.004	0.013
Number of banks		175	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

reducing their reserve balances through additional mechanisms, such as by paying off liabilities and reducing the overall size of their balance sheet.[33]

6.2 Are Banks Paying Back Funding?

Another approach banks with surplus reserves may take is to use this funding to pay off some of their existing liabilities. If a previous build-up in reserves stemmed from inflows that increase the bank's balance sheet more than it would have liked, it could react by substituting this funding for other pre-existing funding such as deposits or bond market funding.

In Table 14 we first replace our dependent variables with log changes in total assets. Results in the first column show that asset growth for banks in the first three quartiles is lower than for those in the highest quartile of reserve growth. We also find that the coefficient is largest for those in the first quartile (ie. those who are most aggressively managing their reserves). Columns 2 to 5 then repeat the exercise but this time examining monthly log changes in debt securities issued, real economy deposits, non-euro area deposits and MFI deposits as dependent variables. Our results indicate that, among banks with the lowest reserve growth, reserves are used to pay off all of these funding sources. For the next reserve growth quartile we find similar results, although the evidence for reductions in debt securities is weaker.

[33] By repeating the process with a range of other asset-side balance sheet items we find strong evidence for reserve management through loans to non-euro area counterparties and weak evidence (statistical significance of 10 per cent) that banks in the lowest reserve growth quartile are accumulating more cash holdings.

Table 13: Using a quartile based approach

VARIABLES	(1) Loans vs. 4th quartile	(2) Loans vs. 4th quartile (Bank FE)	(3) Bonds vs. 4th quartile	(4) Bonds vs. 4th quartile (Bank FE)
Growth quart. = 1	0.000247	0.000370	0.0121***	0.0113***
	(0.00231)	(0.00243)	(0.00420)	(0.00407)
Growth quart. = 2	-0.00102	-0.00114	0.0144***	0.0143**
	(0.00239)	(0.00227)	(0.00441)	(0.00555)
Growth quart. = 3	0.000243	-0.000496	0.0103*	0.0103*
	(0.00243)	(0.00238)	(0.00614)	(0.00577)
Constant	0.00282	0.00301*	-0.0143***	-0.0140***
	(0.00223)	(0.00154)	(0.00283)	(0.00308)
Observations	7,352	7,352	6,852	6,852
R-squared	0.000	0.000	0.001	0.001
Number of banks		185		175

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: Examining changes in funding volumes

VARIABLES	(1) Assets vs. 4th quartile	(2) Debt sec vs. 4th quartile	(3) Real Ec. deposits vs. 4th quartile	(4) Non-EA deposits vs. 4th quartile	(5) MFI deposits vs. 4th quartile
Growth quart. = 1	-0.0232***	-0.0127**	-0.0245***	-0.0557***	-0.0400***
	(0.00383)	(0.00495)	(0.00794)	(0.0107)	(0.0105)
Growth quart. = 2	-0.0144***	-0.0143*	-0.0141**	-0.0382***	-0.0320***
	(0.00260)	(0.00821)	(0.00709)	(0.00848)	(0.00889)
Growth quart. = 3	-0.00669***	-0.000595	-0.00698	-0.0150**	-0.0197*
	(0.00174)	(0.00686)	(0.00557)	(0.00739)	(0.0112)
Constant	0.0115***	-0.00313	0.000361	0.0238***	0.0170***
	(0.00199)	(0.00370)	(0.00470)	(0.00615)	(0.00618)
Observations	7,486	6,082	7,120	6,955	7,377
R-squared	0.031	0.001	0.002	0.012	0.003

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Given Hausman tests do not support the use of fixed effects, none are used here.

Table 15: Banks are mostly buying domestic government bonds when managing reserves

VARIABLES	(1) All government bonds vs. 4th quartile	(2) Domestic government bonds vs. 4th quartile	(3) Other euro area government bonds vs. 4th quartile	(4) Non-government bonds vs. 4th quartile
Growth quart. = 1	0.0200***	0.0217***	0.00713	0.00450
	(0.00565)	(0.00516)	(0.00869)	(0.00688)
Growth quart. = 2	0.0187***	0.0184***	0.00243	0.00979
	(0.00581)	(0.00555)	(0.0103)	(0.00891)
Growth quart. = 3	0.0178**	0.0119***	-0.00326	0.00581
	(0.00780)	(0.00450)	(0.0108)	(0.00696)
Constant	-0.0151***	-0.0171***	0.00611	-0.0148**
	(0.00418)	(0.00400)	(0.00671)	(0.00599)
Observations	5,447	6,665	5,305	5,425
R-squared	0.003	0.004	0.000	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: Given Hausman tests do not support the use of fixed effects, none are used here.

6.3 Further Questions

Our results raise a number of further questions which cannot be answered fully without a more granular balance sheet data set but are worth considering in brief here.

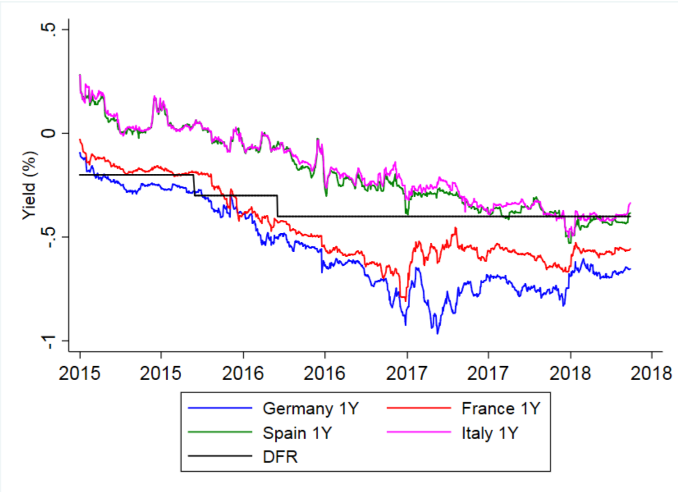
Substituting to Negative Yield Bonds?

Table 15 shows that banks appear to be buying almost exclusively domestic government bonds when managing reserves via debt security purchases. The logic of the hot potato effect suggests banks are likely seeking out assets that have a higher return than the negative yield on deposits. However, many of the shorter-term government bonds that would be the most natural substitutes for risk-free reserves have had yields below the ECB's deposit rate for most of our sample (see the left hand side of Figure 14) so these would seem like strange assets to use for this purpose.

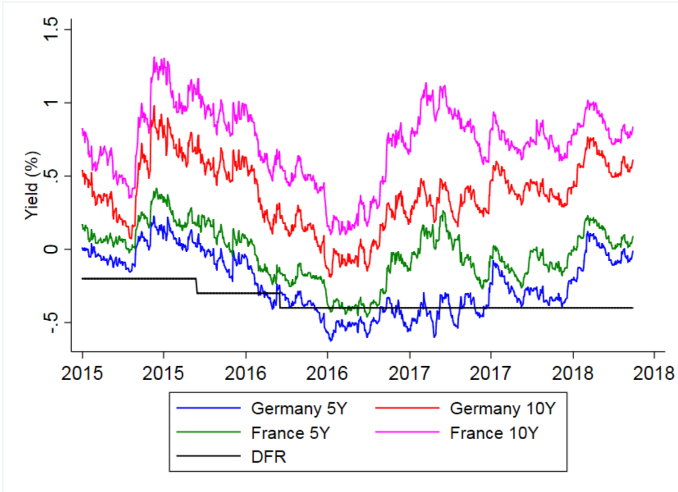
Our data set does not allow us to break down debt security holdings by maturity. Without being able to definitively say what maturity of security is being bought we can propose two possible answers. One possibility is that banks are using reserves to buy bonds which have a lower yield than the DFR but which they expect to increase in value (e.g. as the Eurosystem balance sheet continues to expand). This implies obvious risks as it leaves banks vulnerable to sudden market adjustments or changes in monetary policy. The other is that banks are buying longer maturity bonds which do yield more than the DFR. The right hand side of Figure 14 shows that longer term government bond yields have largely remained above the DFR throughout the period, although the maturity required for yields to exceed the DFR varies across countries. However, in selling reserves to buy these longer maturity bonds banks will be changing the risk profile of their assets, particularly from a duration perspective.

Figure 14: Yields on euro area government bonds

(a) Short maturity



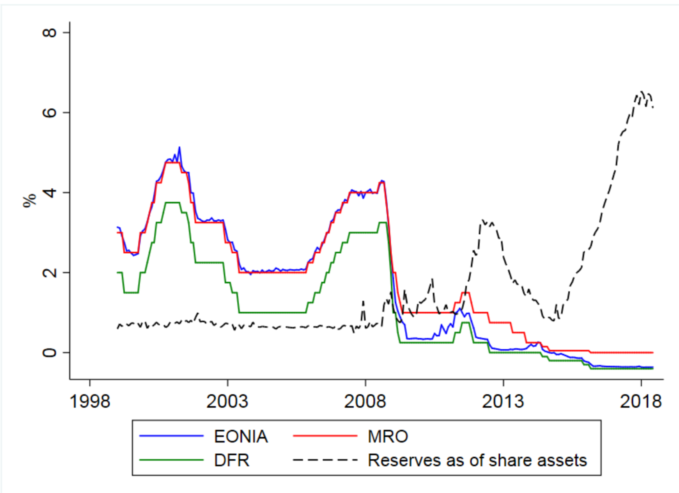
(b) Longer maturity



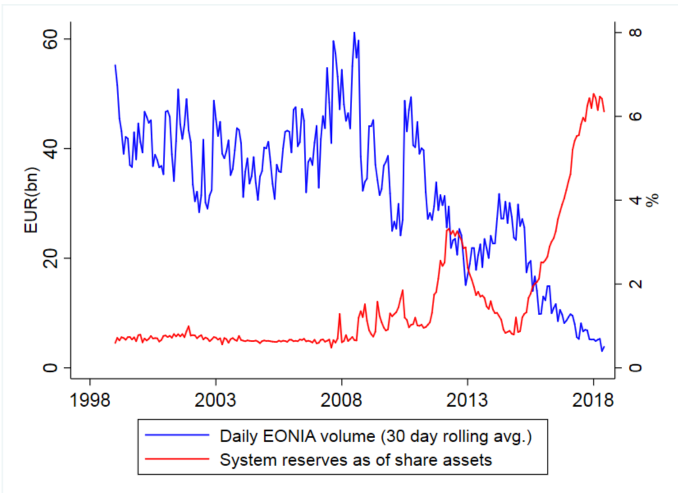
Source: Bloomberg

Figure 15: Unsecured money markets and excess reserves

(a) ECB official rates, EONIA and total reserves



(b) Volume of EONIA activity over time



Note: EONIA volume is 30 day rolling average of daily value

Implications for Money Markets?

For banks trying to push reserves off of their balance sheet, another possible avenue is via money markets, where reserves are traded among euro area banks. Unfortunately, our data set does not allow us to identify this type of activity on our banks' balance sheets.[34] Aggregate bank balance sheet and unsecured money market data show that liquidity created during the APP has had clear consequences for money market rates. As the supply of reserves in the banking system has expanded and demand from banks seeking to reach reserve requirements has decreased, EONIA has fallen from close to the MRO rate to just above the DFR (see Figure 15a).[35] This is a well-documented phenomenon, with ECB (2014) providing an examination for the LTRO period. Veyrune et al. (2018) also examine the sensitivity of the EONIA-DFR spread to excess liquidity, with a focus on the possible role of market segmentation.

However, this does not tell us anything about a hot potato effect as we would expect EONIA to drop towards the DFR even if banks were passively absorbing reserves. Figure 15b instead shows developments in the volume of EONIA trading. Here it can be seen that over the the APP, the volume of activity in euro area money markets has fallen consistently and to levels far below those seen during previous excess reserve periods. Given this very limited involvement in unsecured money markets by euro area banks, we can assume (but cannot show) that this is not being widely used as a mechanism for reserve management.

7 Conclusions

Despite the prominence given to the role of central bank reserves in macroeconomics textbooks, the issuance of trillions of dollars, pounds and then euros in reserves via QE programmes has played a minor role in the academic literature on the effect of these programmes. There are good reasons for this. Despite its persistence in textbooks, the traditional model in which reserves are "multiplied" to deliver larger increases in the broad money supply was long out of fashion in academic and policy circles prior to the implementation of QE programmes. And indeed, the money multiplier collapsed in both the US and UK after the introduction of QE, illustrating the weakness of this model. Some researchers also believed that the payment of interest on reserves invalidated the money multiplier model's assumption that reserves were an inferior asset (and thus a hot potato to be moved around the banking system). Together, these points suggested, at least, that the underlying dynamics of reserves across the banking system were not particularly important and, at most, that they were not interesting because banks were likely passively absorbing these additional reserves.

The recent QE programme implemented by the ECB provides an important testing ground for these ideas. Throughout the implementation of this programme, the ECB has had a negative deposit rate, thus forcing banks to pay for their excess reserve holdings. Even with normal monetary policy conditions, one could question the idea that the payment of interest on reserves eliminates the opportunity cost associated with reserves: Interest rates paid on reserves are usually the bottom rate in "corridor" systems rather than the target policy rate and even target policy rates are generally lower than the yields on most relevant investments that could be purchased by banks. However, the negative interest policy is not a normal monetary policy and this policy seems particularly likely to induce

[34] No maturity breakdown is available for loans to other MFIs and our monthly frequency is also likely insufficient to capture this type of activity.

[35] In a typical "reserve scarcity" environment, such as that prior to the financial crisis, the Eurosystem provides just enough liquidity for the system as a whole. This is then traded among banks seeking to ensure sufficient liquidity to meet payments obligations and reserve requirements. Such a set-up allows the ECB to steer very short term rates close to the minimum bid accepted for its marginal refinancing operations (MRO). This can be seen in the pre-crisis period shown in Figure 15a where EONIA quite closely tracks the MRO rate.

banks to seek to move reserves on.

Our findings generally endorse this intuition. We find that, since the introduction of the APP, there is substantial evidence that banks are actively managing their reserve holdings, seeking to reduce them on a month-to-month basis and that this has lead to a high level of “churn” in reserves across the system. Examining the adjustments made by banks that have successfully “leaned against the wind” of the aggregate upward trend in reserve holdings, we find strong evidence that banks are carrying out this adjustment by adding to their security holdings and paying down a broad range of funding sources.

In this sense, while we find the money multiplier model’s hot potato effect is alive and well, the actions of banks in moving on reserves are not consistent during this period with the model’s assumption that all excess reserves get turned into loans, get spent in the real economy and then create further increases in credit. Still, it is likely that the mechanism documented here has had an effect in driving down European bond yields and we believe this effect is conceptually different from the portfolio rebalancing effect which has dominated the literature on QE.

References

Baldo, L., B. Hallinger, C. Helmus, N. Herrala, D. Martins, F. Mohing, F. Petroulakis, Marc Resinek, O. Vergote, B. Usciati, and Y. Wang, "The distribution of excess liquidity in the euro area," Occasional Paper Series 200, European Central Bank November 2017.

Bauer, M. and G. Rudebusch, "The Signaling Channel for Federal Reserve Bond Purchases," *International Journal of Central Banking*, 2014, *10*.

Baumeister, C. and L. Benati, "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound," *International Journal of Central Banking*, 2017, *9*.

Bernanke, B. and V. Reinhart, "Conducting Monetary Policy at Very Low Short-Term Interest Rates," *American Economic Association Papers and Proceedings*, 2005, *94*.

Bojaruniec, P. and G. Morandi, "Setting-up the transmission of individual MFI statistics on balance sheet items and interest rates across the Eurosystem," Technical Report, Bank of International Settlements 2016.

Choulet, C., "QE and Bank Balance Sheets: the American Experience," ECO Conjoncture, BNP Paribas 2015.

Christensen, J. and G. Rudebusch, "The Response of Interest Rates to U.S. and U.K. Quantitative Easing," *Economic Journal*, 2012, *122*.

__ and S. Krogstrup, "A Portfolio Model of Quantitative Easing," Working Papers 19, Swiss National Bank 2016.

__ and __ , "Transmission of Quantitative Easing: The Role of Central Bank Reserves," Working Paper Series 2014-18, Federal Reserve Bank of San Francisco 2016.

Ciccarelli, M., J. Angel Garcia, and C. Montes-Galdon, "Unconventional monetary policy and the anchoring of inflation expectations," Working Paper Series 1995, European Central Bank January 2017.

CPSS, "The Role of Central Bank Money in Payments Systems," Technical Report, Committee on Payment and Settlement Systems 2003.

D'Amico, S. and T. King, "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply," *Journal of Financial Economics*, 2013, *108*.

Demiralp, S., J. Eisenschmidt, and T. Vlassopoulos, "Negative Interest Rates, Excess Liquidity and Bank Business Models: Banks' Reaction to Unconventional Monetary Policy in the Euro Area," Working Paper Series 1708, Koc University-Tusiad Economic Research Forum 2017.

ECB, "Recent developments in excess liquidity and money markets," Monthly Bulletin, European Central Bank 2014.

__ , "Base money, broad money and the APP," Economic Bulletin Focus, European Central Bank 2017.

__ , "Which sectors sold the government securities purchased by the Eurosystem?," Economic Bulletin Focus, European Central Bank 2017.

Ennis, H. and A. Wolman, "Large Excess Reserves in the U.S.: A View from the Cross-Section of Banks," Working Paper Series WP 12-05, Federal Reserve Bank of Richmond 2012.

__ and __ , "Large Excess Reserves in the U.S.: A View from the Cross-Section of Banks," *International Journal of Central Banking*, 2015, *11*.

Eser, F. and B. Schwaab, "Evaluating the Impact of Unconventional Monetary Policy Measures: Empirical Evidence from the ECB's Securities Markets Programme," *Journal of Financial Economics*, 2016, *119*.

Gagnon, J., M. Raskin, J. Remache, and B. Sack, "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking*, 2011, *7*.

Gambetti, L. and A. Musso, "The macroeconomic impact of the ECB's expanded asset purchase programme (APP)," Working Paper Series 2075, European Central Bank 2017.

Joyce, M., A. Lasaosa, I. Stevens, and M. Tong, "The Financial Market Impact of Quantitative Easing in the United Kingdom," *International Journal of Central Banking*, 2011, *7*.

Kandrac, J. and B. Schlusche, "Quantitative Easing and Bank Risk Taking: Evidence from Lending," Working Paper Series, FEDS 2017.

Keister, T. and J. Mc Andrews, "Why Are Banks Holding So Many Excess Reserves?," Staff Reports 380, Federal Reserve Bank of New York 2009.

Koijen, R., F. Koulischer, B. Nguyen, and M. Yogo, "Euro-Area Quantitative Easing and Portfolio Rebalancing," *American Economic Review: Papers and Proceedings*, 2017, *107*.

Krishnamurthy, A. and A. Vissing-Jorgensen, "The Effects of Quantitative Easing on Long-term Interest Rates," *Brookings Papers on Economic Activity*, 2011, *Fall 2011*.

Rodnyanksky, A. and O. Darmouni, "The Effects of Quantitative Easing on Bank Lending Behavior," *The Review of Financial Studies*, 2017, *30*.

Vayanos, D. and J. Vila, "A Preferred-Habitat Model of the Term Structure of Interest Rates," 2009.

Veyrune, R., G. della Valle, and S. Guo, "Relationship Between Short-Term Interest Rates and Excess Reserves: A Logistic Approach," Working Paper, IMF 2018.

Wieladek, T. and A. I. Garcia Pascual, "The European Central Bank's QE: A New Hope," Technical Report 2016.

A Data Cleaning

Our approach to data cleaning follows five steps. Most of these steps aim to remove reserves which may be double counted otherwise and to remove institutions where reserve data is not provided (as this makes the data easier to use) or where reserve data may not reflect the activities of the specific institution. In all cases we try to preserve the granular detail provided in the uncleaned data set as this is crucial to effectively carrying out our analysis.

First, banks dropping out of the sample between 2007 and 2016 (due for example to mergers, acquisitions or wind-down) are removed. All French banks are also removed as reserve data is available for none of these institutions.

Second,where both subsidiaries and *consolidated* parent data is provided (e.g. one country includes data for both a group as a whole and a number of its larger subsidiaries), subsidiaries are dropped from the sample to avoid double-counting of the same reserves. This does not affect parent institutions whose data is provided excluding that of their subsidiaries.

In a number of cases pooled figures are provided for a certain type of institution (e.g. savings or cooperative banks) and individual contributors to this pooled figure are also included in the data set. To avoid double counting of reserves we subtract the individual institutions from pooled figures. Where individual institutions make up the majority of the pooled figure it is removed from the sample.

In many cases where a parent and its domestic subsidiary are both included in the data set, the subsidiary consistently holds no reserves. This indicates that the subsidiary is accessing the Eurosystem via its parent. To account for this we add parent and subsidiary values for all relevant variables to produce a merged institution. This avoids treating institutions whose activities do result in reserve accumulation as if they did not (in the case of the subsidiary) and underestimating the size of an institution holding a given value of reserves (in the case of the parent).[36]

Finally, our bank-level data set also includes a number of large cross-border branches of both euro area and non-euro area institutions. In terms of reserve holdings these behave in three ways;

1. Many branches consistently hold no reserves. In this case we assume they are accessing the Eurosystem through the country in which their parent is domiciled and as such their reserves are included for this institution;
2. Many branches consistently hold a very high share of assets as reserves (often over 80 per cent). These generally have non-euro area parents and are functioning almost purely as a mechanism for their parent to access the Eurosystem and;
3. Some branches hold a more normal share of assets as reserves (above zero and below 30 per cent of assets).

We take the decision to remove all branches from our sample as types 1 and 2 above are not relevant to our analysis. Regarding type 3, due to the ease with which reserves can be transferred from the branch to the parent or vice versa, as they are effectively the same institution, we do not think that they are relevant to our analysis. Movement in this case is unlikely to reflect effort by either entity to actively manage reserve holdings. As the number of branches relative to the size of the data set as a whole is small we do not expect this to affect our results.

[36] This relates to cases where there is no overlap in the assets or reserves covered by the parent and subsidiary entries because the parent data does not include its subsidiary.

B The ECB's use of asset purchase programmes over time

Programme	Dates	Volume	Detail
Current Programmes			
Corporate Sector Purchase Programme (CSPP)	Jun-16	€7.8bn per month (June 2016 - September 2018 average)	The Eurosystem started to buy corporate sector bonds under the corporate sector purchase programme (CSPP) on 8 June 2016. The measure helps to further strengthen the pass-through of the Eurosystem's asset purchases to financing conditions of the real economy, and, in conjunction with the other non-standard monetary policy measures in place, provides further monetary policy accommodation.
Public Sector Purchase Programme (PSPP)	Mar-15	Mar 2015 to Mar 2016 - €50.3bn per month Apr 2016 to Mar 2017 – €68.9bn per month Apr 2017 to Dec 2017 – €50.0bn per month Jan 2018 to Sep 2018 -€23.0bn per month	On 9 March 2015 the Eurosystem started to buy public sector securities under the public sector purchase programme (PSPP). The securities covered by the PSPP include: - nominal and inflation-linked central government bonds - bonds issued by recognised agencies, regional and local governments, international organisations and multilateral development banks located in the euro area The Eurosystem intends to allocate 90% of the total purchases to government bonds and recognised agencies, and 10% to securities issued by international organisations and multilateral development banks (from March 2015 until March 2016 these figures were 88% and 12% respectively).
Asset-backed Securities Purchase Programme (ABSPP)	Nov-14	€0.6bn per month (November 2016 - September 2018 average)	The ABSPP helps banks to diversify funding sources and stimulates the issuance of new securities. Asset-backed securities can help banks to fulfil their main role: providing credit to the real economy. For instance, securitising loans and selling them can provide banks with the necessary funds to provide new lending to the real economy. This will further ease funding and credit conditions and help the transmission of monetary policy.
Covered Bond Purchase Programme 3 (CBPP3)	Oct-14	€5.4bn per month (October 2014 - September 2018 average)	On 20 October 2014 the Eurosystem started to buy covered bonds under a third covered bond purchase programme (CBPP3). The measure helps to enhance the functioning of the monetary policy transmission mechanism, supports financing conditions in the euro area, facilitates credit provision to the real economy and generates positive spillovers to other markets.
Terminated Programmes			
Securities Markets Programme	May 2010 - September 2012 (absorbed related liquidity up to June 2014)		On 10 May 2010, the central banks of the Eurosystem started purchasing securities in the context of the Securities Markets Programme (SMP), with a view to addressing the severe tensions in certain market segments which had been hampering the monetary policy transmission mechanism. With a view to leaving liquidity conditions unaffected by the programme, the Eurosystem re-absorbed the liquidity provided through the SMP by means of weekly liquidity-absorbing operations until June 2014.
Covered Bond Purchase Programme (CBPP)	July 2009 - July 2010	€60bn	On 2 July 2009, the Eurosystem launched its first covered bond purchase programme (CBPP1). The programme ended, as planned, on 30 June 2010 when it reached a nominal amount of €60 billion. The Eurosystem intends to hold the assets bought under this programme until maturity.
Covered Bond Purchase Programme 2 (CBPP2)	November 2001 - October 2012	€16.4bn	In November 2011, the Eurosystem launched a second covered bond purchase programme (CBPP2). The programme ended, as planned, on 31 October 2012 when it reached a nominal amount of €16.4 billion. The Eurosystem intends to hold the assets bought under this programme until maturity.

Source: ECB.

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