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

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Abstract

We use bank-level data to examine the behaviour of reserves in the euro area banking system over the course of the ECB QE programme. Previous research on QE has often assumed banks passively absorb the additional reserves generated by asset purchases. However, with a negative deposit rate in place throughout our sample, 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 pushing reserves off their balance sheets 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 that has been the primary emphasis of the existing QE literature.

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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 dataset to examine how euro area banks reacted to the expansion of excess liquidity created by the ECB's Quantitative Easing programme, known officially as the Asset Purchase Programme (APP). In particular, we want to know if banks passively absorbed the liquidity created by these asset purchases or if they individually sought to reduce their own holdings through active management of their reserve balances with the Eurosystem. To understand the implications for both the real economy and the wider financial system, we also want to know *how* banks did this.

Reserve balances are accounts that commercial banks hold with central banks. When a central bank purchases assets, 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 reserves. A defining characteristic of these reserves is that they can only be held by banks. More specifically, reserves held with the Eurosystem can only be held by euro area banks. This creates a closed system within which efforts by one bank to reduce its own reserve account balance will simply result in increased reserve holdings by another institution. If many banks seek to reduce their balances, reserves will 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.

A student of textbook macroeconomics might imagine that this increased supply of reserves has 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 via the actions of the banking system. In this model, reserves earn no interest and are considered an inferior asset to interest-earning loans. 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 larger increase in the broader money supply. This textbook model was probably what many of the early critics of QE programmes had in mind when they predicted large expansions in the supply of base money would trigger significant inflation.[2]

These critics, however, were somewhat behind mainstream thinking in monetary policy circles by the time QE programmes were adopted. By this time, few central bankers believed the money multiplier was necessarily a stable ratio. The money multiplier's implicit model of the banking sector was understood to be highly simplistic, ignoring concerns banks have about default risk on loans and limits arising from capital and liquidity regulations. In addition, with modern central banks generally paying interest on reserves, 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.[3]

[1] Available here: https://www.gpo.gov/fdsys/pkg/CHRG-113shrg81472/pdf/CHRG-113shrg81472.pdf

[2] For example, in an open letter published in the *Wall Street Journal* a number of academic and financial market economists in 2010 warned Ben Bernanke that "*The planned asset purchases risk currency debasement and inflation.*"

[3] See Keister and Andrews (2009) for an articulation of this view from a Federal Reserve perspective.

The outcome of the QE programmes appears 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, leading to a sharp reduction in the money multiplier. 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, 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.[4]

There are three principal exceptions in the empirical literature that have focused on the role played by reserves. Ennis and Wolman (2015) focus on the the evolution of the cross-sectional distribution of reserves across US banks during the QE programmes from 2008 to 2011. Butt et al. (2014) examine whether or not the influx of reserves created by QE in the UK gave rise to a bank lending channel. They find no evidence for this and attribute their finding to the flightiness of the deposits generated by QE purchases. Christensen and Krogstrup (2016) examine the impact of a Swiss programme which raised bank reserves without changing the supply of long-term assets and argue that this programme reduced long-term interest rates.[5]

Our paper examines the behaviour of reserves held by euro area banks during the ECB's APP. We use a monthly bank-level dataset to examine the dynamics of reserve balances and to assess whether the banking system passively absorbed these reserves or whether there was a hot potato effect in which banks attempted to offload reserves. The period we are looking at is of particular interest because there has been a financial incentive for banks to not accumulate reserves. Throughout our sample, from late 2014 to summer 2018, the ECB charged banks for excess reserves, with a negative interest rate that increased from 20 basis points in late 2014 to 40 basis points from March 2017 onward. By the end 2017, this negative remuneration represented 2 per cent of total euro area bank assets but 29 per cent of total equity and was thus large from a return on equity perspective. In this sense, even more than the non-interest-bearing reserves of the textbook model, Eurosystem reserves were a true hot potato because the more reserves they held, the worse off a bank would be.[6]

We find evidence that banks were actively managing their reserve holdings thus creating a high level of "churn" in reserves across the euro area banking system. By examining the adjustments made by banks that 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.

Like Ennis and Wolman (2015), we examine the cross-sectional distribution of reserves but our dataset is monthly instead of quarterly. This allows us to get a more precise sense of the higher-frequency dynamics of reserves in the Eurosystem. In particular, it allows us to get a more precise sense of how banks with relatively high reserve holdings adjust their balance sheets to offload these

[4] 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.

[5] Among other related papers, Baldo et al. (2017) examines the distribution of excess liquidity in the euro area since the financial crisis; Kandrac and Schlusche (2017) examine US regulatory changes which influenced the distribution of reserves; Demiralp et al. (2017) use reserve holdings to study the effects of negative interest rates in the euro area; Altavilla et al. (2018) examine the effect of banks' reported exposure to unconventional policies on their loan supply.

[6] It is, of course, possible for banks to recoup some of the lost profits due to the Eurosystem's negative interest rate if they can pass on negative deposit rates to customers. However, individual banks have very little room to reduce their costs of deposit funding and even if this can be done to some extent, it does not change the fact that holding negative-yielding reserves still represents a relatively poor investment.

reserves. Our findings regarding the absence of lending effects are in line with those of Butt et al. (2014) (who, like us, use monthly data). However, we also examine how banks have used reserves to purchase debt securities.

Given our findings, we believe it is likely that the response of banks to the reserves created through the APP has had an effect in driving down European bond yields. As emphasised by Christensen and Krogstrup (2016) this effect is conceptually separate from the portfolio rebalancing channel which has dominated the literature on QE. The portfolio rebalancing channel results from the reduced availability to the private sector 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. For example, purchases of widgets by a central bank would also result in an expansion of bank reserves, without reducing the available stock of any outstanding financial asset.

The contents of the rest of the paper are as follows. Section 2 briefly describes the use of unconventional monetary policy by the Eurosystem and the implications for aggregate excess liquidity. Section 3 provides an overview of our datasets and then uses them to examines the distribution of excess liquidity across countries and institutions. Section 4 describes the month-to-month dynamics of bank reserves and provides evidence suggesting that the increase in reserves is not being passively absorbed by European banks. Finally, Section 5 provides evidence that, when shifting reserves off their balance sheets, banks are purchasing securities and paying down funding.

2 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 the Eurosystem's balance sheet. As can be seen in Figure 1a, 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 primarily by increased holdings of euro area securities due to the APP. On the liability side, this period has seen expansions in Eurosystem deposit facilities and current accounts, as both loans and purchases are carried out by crediting banks' reserve balances.

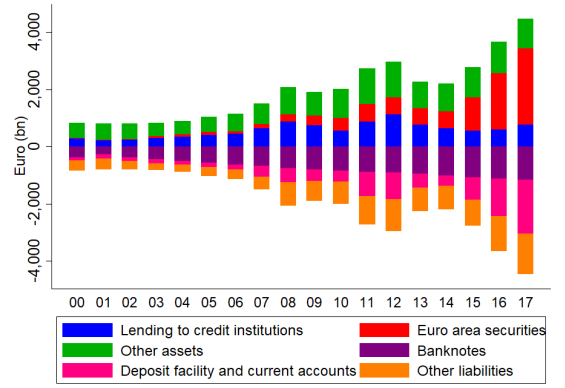
Figure 1b focuses on this aspect of the Eurosystem's liabilities and shows the expansion of total reserves held by euro area banks with the Eurosystem since 2007. Prior to the financial crisis the euro area banking system operated under a "reserve scarcity regime", whereby central bank reserve holdings rarely exceeded their required levels. 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. As such, banks did not generally hold excess liquidity.

With the onset of the financial crisis, in response to the breakdown of interbank markets, the Eurosystem replaced this approach with a fixed rate full allotment 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. This was followed from 2011 onwards by a series of longer-term refinancing operations (LTROs), aiming to support the provision of credit to the real economy.

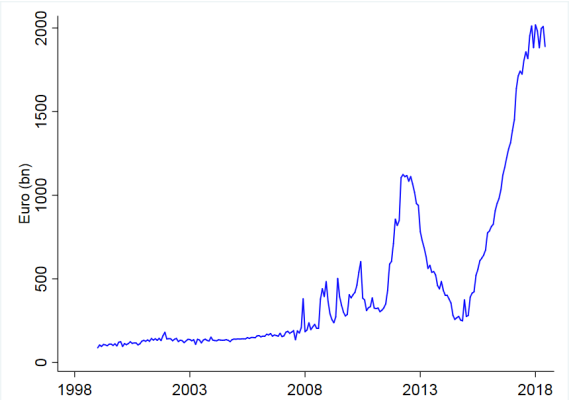
Figure 1a shows that from 2015 onward the ECB balance sheet expansion is driven primarily by increased security holdings as a result of the APP. While a number of smaller programmes were conducted between 2010 and 2012, this policy tool began to be used more intensively in late 2014 with the introduction of the third Covered Bond Purchase Programme and, at a much larger scale

Figure 1: Eurosystem Balance Sheet Expansion

(a) Consolidated Eurosystem Balance Sheet



(b) Total Eurosystem Reserves Over Time



Note: Positive figures show asset holdings and negative figures show liabilities. Full balance sheet source: https://www.ecb.europa.eu/pub/annual/balance/html/index.en.html

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 post-2014 expansion in excess liquidity evident in Figure 1b.[7]

A fundamental difference between excess liquidity created over the two periods should be noted. While the first expansion was driven primarily by policies such as LTRO, which responded to bank demand for liquidity, the liquidity created through the APP is supply driven and has been a mechanical result of Eurosystem purchases.[8] This means that the latter expansion largely does not reflect the actions of the banking sector. We cannot tell from this aggregate series whether banks are passively absorbing these reserves or actively trying to reduce their balances. To assess how banks are responding to the increased supply of reserves, we need to examine bank-level micro data.

[7] Hammermann et al. (2019) Figure 1 provides an overview of the ECB's use of this tool over time.

[8] One exception is that banks can reduce the total amount of reserves held with the Eurosystem if they decide instead to hold cash. However, as Figure 1a above shows, there has been little change in amount of banknotes issued since the beginning of the negative deposit rate policy.

3 Who Is Holding the Excess Liquidity?

In this section, we introduce our dataset and document the basic facts about reserve holdings in the euro area at the country-level and bank-level.

3.1 Data

We use two related datasets to examine the distribution and dynamics of excess liquidity within the Eurosystem. To examine dynamics at the euro area and country-levels we use the Balance Sheet Items (BSI) dataset. This is largely publicly available through the ECB's Statistical Data Warehouse. It contains aggregate balance sheet data for the monetary financial institutions (MFI) sector at both euro area and country-level. Data are collected on a residency basis and are available at a monthly frequency. Our second source is a confidential dataset, providing balance sheet data in line with the BSI but at the bank-level. While this dataset has been available within the Eurosystem since 2012, a recent expansion substantially increased the number of variables available, including a newly available series reflecting bank-level reserve holdings with their national central bank (NCB).

We limit our sample to institutions for which this variable is available, remove institutions operating as branches and remove those that drop out of the sample before 2018 due to mergers, acquisitions or wind-down. This 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 reserve holdings, the dataset also provides information on a number of other balance sheet items.

3.2 Country-Level Patterns

While the disincentive to hold reserves created by the negative interest rate applied to deposits is uniform across euro area countries, Figure 2 shows quite clearly that the build-up in reserves since the financial crisis has not occurred uniformly across countries. Although the impact of ECB policies discussed above can be seen in most cases, both dynamics and magnitude vary substantially across countries. For example while both Italy and Finland experienced 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.

One possible explanation for these discrepancies is that they reflect different amounts of sovereign bonds purchased by the national central banks (NCBs). The PSPP limits NCBs in the euro area to purchasing their own country's sovereign bonds and the size of these purchases are determined by the NCB's capital key, which is calculated as the average of the country's share in the euro area's population and its GDP. Because the capital key is not closely related to the size of a country's banking sector, the "intensity" of QE purchases by NCBs varied widely. For example, the asset purchases by the Banque de France equalled about 5 percent of the total assets of the French banking system. In contrast, by the end of our sample, purchases by the Slovenian central bank were equivalent to almost 20 percent of the assets of their banking system.

Given this wide dispersion in the intensity of QE, one possible explanation for cross-country differences in reserve holdings could be the NCBs buying their own country's sovereign bonds from residents in their country who hold bank accounts within that country. However, Figure 3—which compares changes in reserve holdings by banks over the course of the PSPP to Eurosystem purchases

of government bonds for each country—shows that this does not explain the cross-country pattern of reserve accumulation. While the Eurosystem's asset purchases are clearly driving the accumulation of reserves in the euro area as a whole, there are large discrepancies across countries between APP purchases by NCBs 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. If NCB purchases were all from banks within their own jurisdiction, these charts would indicate that banks in certain jurisdictions (for example, Spain) were pushing reserves created through the APP across borders and banks in receiving countries (for example, the Netherlands) were unable or unwilling to do the same. However this would be a strong assumption. For example, ECB (2017) suggests that the largest counter-parties to APP transactions have been non-resident entities.[9]

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, including non-euro area parents, as discussed in Avdjiev et al. (2019). Thus, cross country differences in Figure 3 could reflect reserves initially being deposited in these countries and remaining there.

3.3 Bank-Level Reserve Holdings

We now use our bank-level dataset to examine reserve accumulation at the individual bank-level. Figure 4a shows the distribution of bank reserve holdings as a share of assets for January 2015 and May 2018. It shows a sharp 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 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.

Figure 4b 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. 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 4a 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.

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

Figure 2: Reserve Developments Across Euro Area Countries

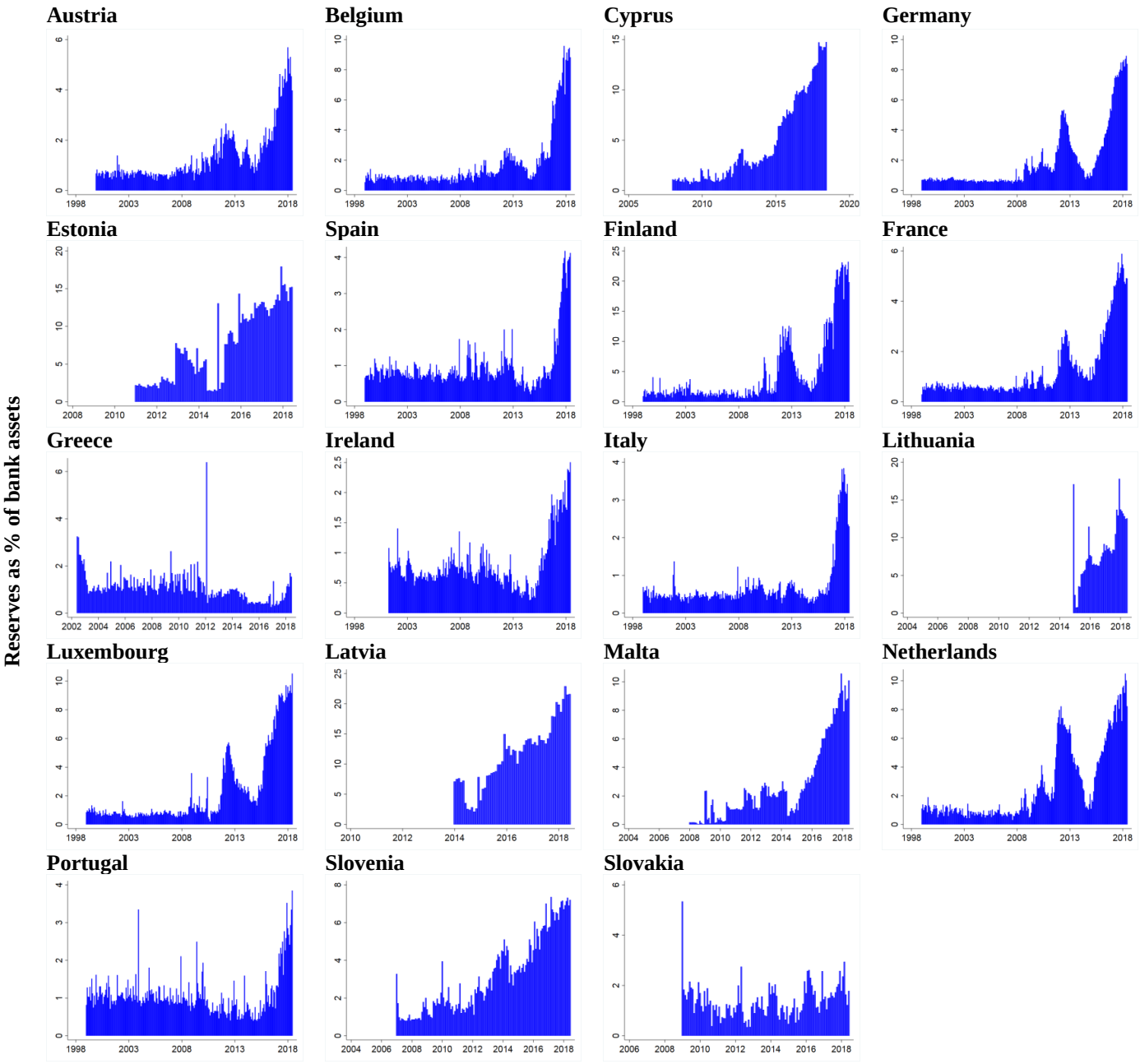
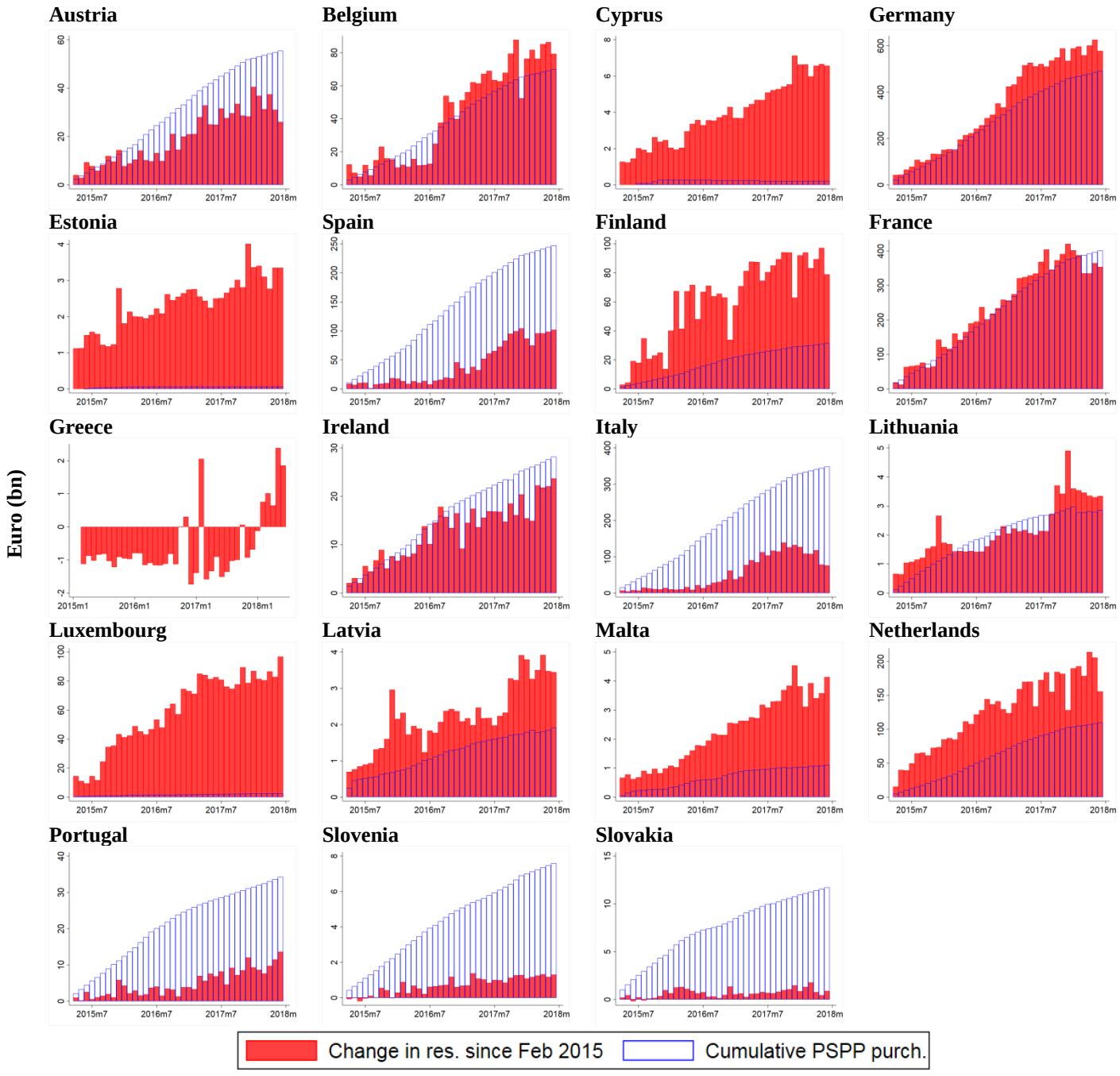


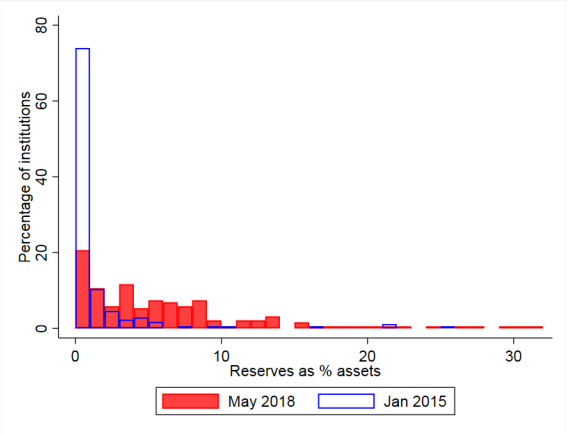
Figure 3: Changes in Reserves over the Course of PSPP vs. NCB Purchase Activity



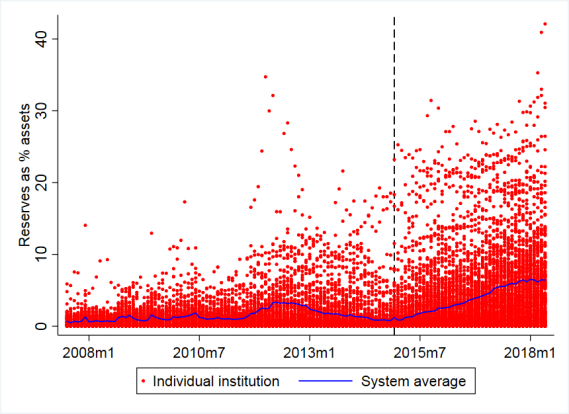
Note: Total purchases of each country's sovereign bonds are corrected to allow for the 10 per cent of these purchases which are carried out directly by the ECB.

Figure 4: Bank-Level Reserve Holdings

(a) Comparing Pre- and Post-APP holdings



(b) Individual Institutions vs. the System Average



Notes: On the left side, 3 outlier institutions are not shown for May 2018. On the right side, 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.

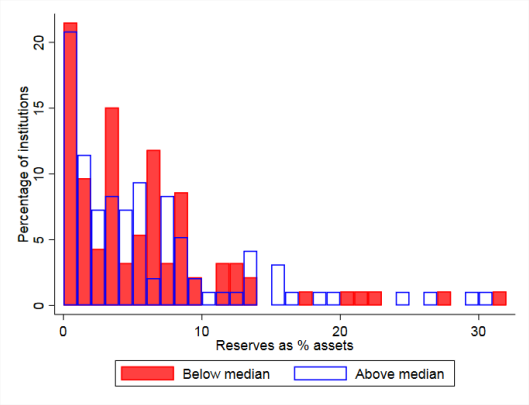
Our bank-level data contain a number of balance sheet items such as total assets, capital ratios, leverage and the extent of real economy loans and deposits. In addition, the data-set also reports whether the bank has a non-euro-area parent institution. Overall, we do not find strong linkages between bank characteristics and reserve levels at the end of our sample, with the exception of the finding that banks with non-euro area parents have tended to build up larger stocks of reserves. See Figure 5.

This finding may reflect the use of these institutions by their parents as a conduit to the Eurosystem (see Baldo et al. (2017) and Avdjiev et al. (2019)). 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. 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.[10]

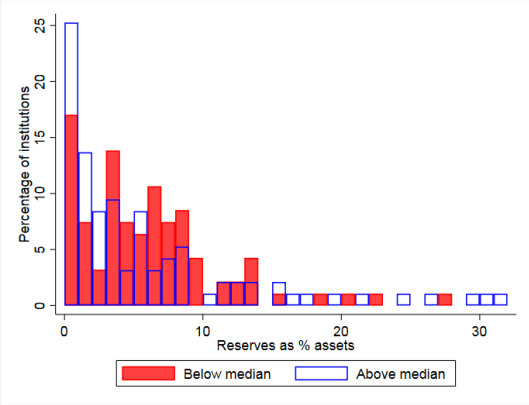
[10]It should also be noted that these banks represent quite a small share of our sample and all our subsequent findings are robust to their exclusion.

Figure 5: Distribution of May 2018 Reserves By Business Model

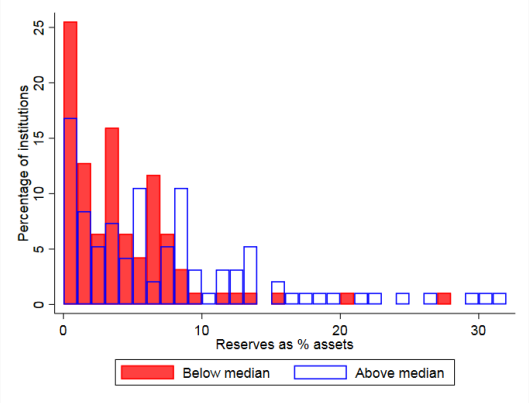
(a) Share of funding from real economy deposits



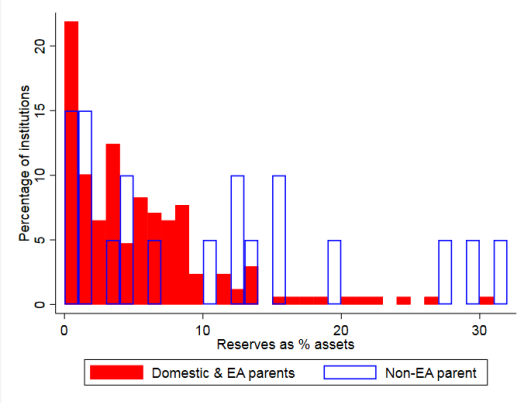
(b) Leverage



(c) Size



(d) Parent location



Notes: Samples are split by median values. Size is defined as total assets as a share of national bank assets. Leverage is defined as capital as a share of bank assets.

4 Bank-Level Dynamics

While the previous evidence provides insight into reserve accumulation over the period examined, it does not tell us whether or not banks are actively managing reserves. 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 the reserve holdings of individual banks 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 report regression analysis illustrating the extent to which banks are adjusting their reserve holdings on a month-to-month basis.

4.1 Illustrating "Churn" in Reserves

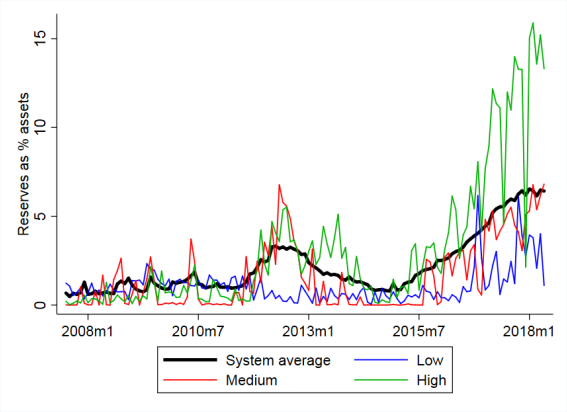
To give a first illustration of the kinds of dynamics determining reserve holdings at an institution-level, Figure 6a plots the build-up of reserve holdings for three individual institutions which are at (or close to) the 30th, 60th and 90th percentile values for reserve holdings as a share of assets 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. The figure also shows a lot of month-to-month volatility in reserve holdings.

For example, consider the green line, our "High Reserves" bank. Prior to the global financial crisis, this bank tended to have slightly lower reserve-to-assets ratios than the system average. This ratio jumped upwards during the period when the ECB began providing credit via LTROs but had eased back to pre-crisis levels by the late 2014. After that, the bank's reserve-to-assets ratio jumped 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 a ratio of reserves to assets of about 13 percent. Similar patterns are evident for the other banks shown here. The "Low Reserves" 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 Reserves" bank) before ending up well below the system average. These figures seem inconsistent with the idea that banks are passively absorbing the reserves created by the APP, in which case you would expect to see a steady accumulation of reserves over time.

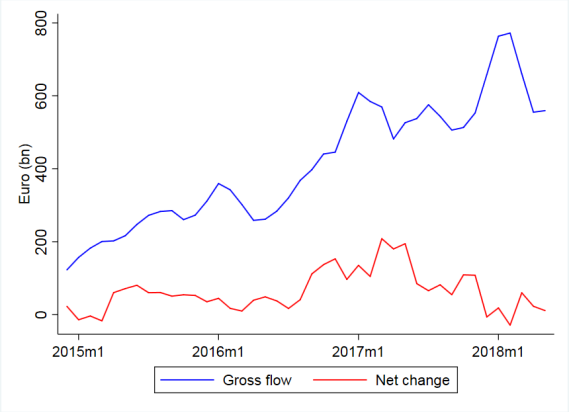
In line with Ennis and Wolman (2012) and Butt et al. (2014), we also calculate a simple measure to illustrate the level of "churn" in reserves throughout the system. This measure is constructed by comparing the sum of net changes in reserve holdings across banks with the sum of the gross changes (i.e. the absolute values) of the changes for a given period. If banks passively absorbed the 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 gross flow figure can be expected to exceed the net flow. For this reason, the ratio of total gross flows to total net flows gives an indication of the amount of churn in reserves. As such, it may provide an illustration of the extent of active balance sheet management aimed at shifting reserves onto other banks.

Figure 6: Examining Reserve Dynamics

(a) Individual institutions



(b) Net vs. gross flows



Note: Flow measures are smoothed using one quarter rolling sum.

Figure 6b shows the net and gross flow series 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. These findings are in line with those of Ennis and Wolman (2012) and Butt et al. (2014).

4.2 Regression Analysis of Reserve Dynamics

We provide a more formal examination of this idea by looking at how banks respond to having high reserve balances. In particular, we want to know if banks respond to a high reserve balance in one period by decreasing their reserves in the next. Ideally, this type of exercise should be carried out using daily 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 failing to detect active management of reserves in the case where banks manage reserves efficiently on a daily basis so it cannot be picked up with our data. Our results do point towards active management of reserves but it is likely they underestimate the extent of this activity that is occurring on a daily basis. Nonetheless, 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 an improvement on this.

Defining "high reserve balances" presents a challenge due to the upward trend in overall reserve balances over the period. For example, Figure 4a 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 this category. To allow for this we define "high reserve balances" based on the distance of the bank's reserve to asset ratio from the system average for each period and enter this into our specification as the variable $distance_{it}$. Specifically, 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 a regression of the form.

$$\Delta reserves_{it} = \alpha + \beta distance_{i,t-1} + \gamma \Delta total\,Eurosystem\,reserves_t + \epsilon \quad (1)$$

Table 1: Baseline Specification and Influence of Above and Below System Average Samples

VARIABLES	(1) Baseline	(2) Baseline Above Avg	(3) Baseline Below Avg
$distance_{it-1}$	-0.171***	-0.420***	-0.352***
	(0.0176)	(0.0463)	(0.0345)
$\Delta system\ average_t$	0.914***	1.125***	0.911***
	(0.130)	(0.142)	(0.143)
Constant	-0.123***	0.431***	-0.572***
	(0.0244)	(0.0277)	(0.0490)
Observations	7,515	2,492	5,023
R^2	0.092	0.430	0.205

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable, $\Delta reserves_{it}$ is the monthly change in the log of reserve holdings by bank i for time t.

$\Delta reserves_{it}$ reflects the month-on-month change in the log of reserve holdings by bank i for time t, $\Delta\ total\ Eurosystem\ reserves_t$ is the month-on-month change in log of total Eurosystem reserves and α is an intercept. β is the main coefficient of interest: If banks are passively absorbing reserves produced by the APP we would not expect this coefficient to be statistically significant. However, a negative and statistically significant coefficient would be consistent with banks actively managing reserves.

Column 1 of Table 1 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 specification is repeated in Columns 2 and 3 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. The R^2 also becomes substantially larger. 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 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 in which reserves operate; 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.[11]

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 the implicit assumption that all banks are "targeting" the system average level of reserves and thus allow for this "target" to vary across different types of banks. Tables 2 and 3 show that the β coefficient remains negative and statistically significant throughout.

Coefficients for interaction variables are also of interest because they reflect characteristics which are

[11] Observation numbers for Columns 2 and 3 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 3 and 2 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.

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.[12] 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 the impact of the bank's previous reserve to assets ratio except that this impact 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.

Table 3 examines whether a number bank characteristics (bank size, leverage, capital ratios, fraction of real economy deposits, fraction of real economy loans, whether the bank has a non-euro-area parent) have an influence on the coefficient of interest. Logs are applied to all non-dummy variables and all variables are lagged by one period. The results show the impact of the previous reserve to assets ratio is weakest among banks with non-euro area parents. This is consistent with our earlier discussion of how these banks appear to differ from other banks in our sample. We find no evidence of statistically significant interaction effects for other bank characteristics.

We also checked whether our results could be driven by the operation of the LTRO, with some banks building up reserves by taking large loans from the operations and then subsequently using these funds, and confirmed that this pattern was not what is behind our findings: Banks that borrowed heavily in LTROs did not have statistically different behaviour in relation to the coefficient of interest. Finally, we can confirm all the results here are robust to the exclusion of countries such as Luxembourg, Malta and Cyprus where reserve accumulation is well above asset purchases by the national central bank and to the exclusion of banks with non-euro-area parents.

One question is whether our finding—that banks that are above the mean level of reserve-to-assets ratios tend to revert back to the mean—is simply a mechanical result due to the closed system of reserves. However, this result would not hold if banks were passively absorbing reserves received from APP sales. In this case, 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 evidence against the idea that banks passively absorb the reserves created via the APP.

[12] Bond yield data are sourced from the ECB's Statistical Data Warehouse, where it is classified as "harmonised long-term interest rates for convergence assessment purposes". 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 2: Examining the Role of Macroeconomic Variables

VARIABLES	(1) Macro variables	(2) DFR and time
$distance_{it-1}$	-0.199***	-0.206***
	(0.0401)	(0.0271)
$\Delta system\,average_t$	0.775***	0.475**
	(0.145)	(0.223)
$yield\,quintile_{j,t-1} = 2$	0.00938	
	(0.0258)	
$yield\,quintile_{j,t-1} = 3$	0.00235	
	(0.0356)	
$yield\,quintile_{j,t-1} = 4$	-0.0500	
	(0.0567)	
$yield\,quintile_{j,t-1} = 5$	-0.0565	
	(0.0695)	
$yield\,quintile_{j,t-1} = 2$*$distance_{it-1}$	-0.0195	
	(0.0270)	
$yield\,quintile_{j,t-1} = 3$*$distance_{it-1}$	0.0107	
	(0.0309)	
$yield\,quintile_{j,t-1} = 4$*$distance_{it-1}$	-0.0221	
	(0.0417)	
$yield\,quintile_{j,t-1} = 5$*$distance_{it-1}$	-0.00796	
	(0.0511)	
$DFR = -30bps_{t-1}$	0.0339	0.00980
	(0.0330)	(0.0317)
$DFR = -40bps_{t-1}$	0.0153	-0.0243
	(0.0263)	(0.0282)
$DFR = -30bps_{t-1}$*$distance_{it-1}$t	0.0500	0.0511*
	(0.0308)	(0.0309)
$DFR = -40bps_{t-1}$*$distance_{it-1}$	0.0473**	0.0499
	(0.0206)	(0.0313)
$time\,(continuous)_t$		0.00100
		(0.00149)
$time\,(continuous)_t$*$distance_{it-1}$		6.05e-05
		(0.00135)
Constant	-0.116**	-0.105**
	(0.0484)	(0.0437)
Observations	7,337	7,093
R^2	0.093	0.087

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variable, $\Delta reserves_{it}$, reflects the month-on-month change in the log of reserve holdings by bank i for time t. Regional dummies show reserve 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.

Table 3: Examining the Role of Bank Characteristics

VARIABLES	(1) Bank variables
$distance_{it-1}$	-0.151**
	(0.0661)
$\Delta system\ average_t$	0.924***
	(0.132)
$real\ ec.\ deposits_{it-1}$	0.0295*
	(0.0174)
$distance_{it-1}$*$real\ ec.\ deposits_{it-1}$	0.0132
	(0.0117)
$real\ ec.\ loans_{it-1}$	-0.0354*
	(0.0190)
$distance_{it-1}$*$real\ ec.\ loans_{it-1}$	-0.00259
	(0.00991)
$size_{it-1}$	0.0288**
	(0.0141)
$distance_{it-1}$*$size_{it-1}$	0.0103
	(0.0102)
$leverage_{it-1}$	-0.0787
	(0.0592)
$distance_{it-1}$*$leverage_{it-1}$	-0.0300
	(0.0308)
$parent\ other\ ea_i$	-0.000445
	(0.0706)
$parent\ non\ ea_i$	0.203***
	(0.0599)
$distance_{it-1}$*$parent\ other\ ea_i$	-0.0374
	(0.0422)
$distance_{it-1}$*$parent\ non\ ea_i$	0.113***
	(0.0376)
Constant	0.0600
	(0.112)
Observations	7,151
R^2	0.111

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Dependent variable, $\Delta reserves_{it}$, reflects the month-on-month change in the log of reserve holdings by bank i for time t. Parent location dummies are relative to domestically owned institutions. Size is defined as total assets as a share of national bank assets.

5 How Are Banks Getting Rid of Reserves?

To take a closer look at whether our findings are driven by active balance sheet management to reduce reserves, we now examine the processes by which banks are shifting reserves off their balance sheets. Where reserve dynamics are associated with changes in parts of the balance sheet the bank has direct control over, such as holdings of debt securities, this provides further support to the hypothesis of active management by banks. In particular, it provides evidence that findings from the previous Section are not simply driven by temporary changes in deposits as discussed in Butt et al. (2014).

Section 5.1 looks at the asset side of the balance sheet and whether banks that are reducing their reserve holdings are 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 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 that differs from the portfolio rebalancing and signalling channels that are usually covered in the QE literature. Section 5.2 then examines changes to the liability side of the balance sheets.

5.1 Asset Adjustments

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, because it assumes a symmetry that may not hold. Banks reducing reserve holdings 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.

To answer this question, we define a dummy variable that equals one if a bank has had reserve growth below that of the Eurosystem:

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

We then examine the relationship between *low growth* and changes in other parts of the balance sheet. Specifically, we look at the log-difference in real economy loans and in bond holdings. A simple univariate regression of these dependent variables on *low growth* for the same period, reported in Table 4, finds a highly statistically significant result for accumulation of bonds but no statistical significance for real economy loans. These results are robust to the inclusion of bank-level and time

Table 4: OLS Regression of Dependent Variables on *low growth* Variable

VARIABLES	(1) Loans	(2) Bonds
$low\ growth_{it} = 1$	-0.00136	0.00886**
	(0.00164)	(0.00344)
Constant	0.00344***	-0.00950***
	(0.00120)	(0.00251)
Observations	7,381	7,294
R^2	0.000	0.001

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

Note: Dependent variables are log changes in the stock of real economy loans and debt securities held by individual banks.

fixed effects.

A more nuanced result may also be found by replacing *low growth* with dummy variables for each quartile of reserve growth in a given period.[13] This allows us to see whether or not the banks that are reducing reserve holdings the most have notably different behaviour in other parts of their balance sheets. As can be seen from Table 5 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 of reserve accumulations are accumulating more debt securities than those in the top quartile.

Finally, our data allows us to break down debt securities into a number of sub-categories and to repeat our analysis with each. Table 6 shows that banks with low reserve growth appear to be buying almost exclusively domestic government bonds. Repeating the process with a range of other asset-side balance sheet items, we find 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.

[13]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.

Table 5: Using a Quartile-Based Approach

VARIABLES	(1) $\Delta loans$	(2) $\Delta loans$ (Bank FE)	(3) $\Delta bonds$	(4) $\Delta bonds$(Bank FE)
$growth\,quart_{it} = 1$	0.000380	0.000518	0.0106**	0.0104**
	(0.00231)	(0.00243)	(0.00420)	(0.00422)
$growth\,quart_{it} = 2$	-0.000751	-0.000867	0.0135***	0.0141***
	(0.00241)	(0.00229)	(0.00434)	(0.00530)
$growth\,quart_{it} = 3$	0.000288	-0.000379	0.0107*	0.0114*
	(0.00244)	(0.00238)	(0.00572)	(0.00579)
Constant	0.00275	0.00291*	-0.0134***	-0.0137***
	(0.00223)	(0.00155)	(0.00282)	(0.00310)
Observations	7,350	7,350	7,263	7,263
R^2	0.000	0.000	0.001	0.001

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variables are log changes in the stock of real economy loans and debt securities held by individual banks.

Table 6: Banks are Mostly Buying Domestic Government Bonds When Managing Reserves

VARIABLES	(1) $\Delta gov\,bonds$	(2) $\Delta domestic\,gov\,bonds$	(3) $\Delta other\,EA\,gov\,bonds$	(4) $\Delta other\,bonds$
$growth\,quart_{it} = 1$	0.0203***	0.0214***	0.0110	0.00413
	(0.00555)	(0.00518)	(0.00960)	(0.00687)
$growth\,quart_{it} = 2$	0.0203***	0.0184***	0.0147	0.00922
	(0.00575)	(0.00549)	(0.0130)	(0.00860)
$growth\,quart_{it} = 3$	0.0196***	0.0118**	0.00244	0.00603
	(0.00746)	(0.00457)	(0.0116)	(0.00660)
Constant	-0.0147***	-0.0169***	0.00171	-0.0146**
	(0.00390)	(0.00401)	(0.00821)	(0.00574)
Observations	5,819	6,661	5,571	5,837
R^2	0.003	0.004	0.001	0.000

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Notes: Dependent variables are log changes in the stock of debt securities held by individual banks. Given Hausman tests do not support the use of fixed effects, none are used here.

Table 7: Examining Changes in Funding Volumes

VARIABLES	(1) $\Delta assets$	(2) $\Delta debt\ sec.\ issued$	(3) $\Delta real\ ec.\ deposits$	(4) $\Delta non\ EA\ deposits$	(5) $\Delta mfi\ deposits$
$growth\ quart_{it} = 1$	-0.0231***	-0.0132***	-0.0248***	-0.0522***	0.0340
	(0.00388)	(0.00503)	(0.00798)	(0.0104)	(0.0420)
$growth\ quart_{it} = 2$	-0.0145***	-0.0155*	-0.0142**	-0.0365***	-0.0164
	(0.00265)	(0.00808)	(0.00710)	(0.00838)	(0.0259)
$growth\ quart_{it} = 3$	-0.00679***	-0.000129	-0.00686	-0.0143**	0.0214
	(0.00174)	(0.00697)	(0.00572)	(0.00712)	(0.0195)
Constant	0.0115***	-0.00274	0.000465	0.0220***	-0.0236
	(0.00203)	(0.00365)	(0.00474)	(0.00603)	(0.0208)
Observations	7,484	6,074	7,118	7,366	4,124
R^2	0.030	0.002	0.002	0.011	0.001

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Dependent variables are log changes in outstanding stock of indicated balance sheet items. Given Hausman tests do not support the use of fixed effects, none are used here.

5.2 Liability Adjustments

Another mechanism through which banks with surplus reserves may adjust their balance sheet is to pay down liabilities. Table 5 examines liability adjustments. 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. The results indicate that banks with the lowest reserve growth see reductions in various categories of deposits, most notably non-euro-area deposits, and also see reductions in funding via debt securities.

6 Conclusions

Despite the prominence given to the role of 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 out of fashion in academic and policy circles prior to the implementation of QE programmes. Some cental bankers and 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 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 alternative 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 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 non-deposit funding. 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.

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