The Impact of Quantitative Easing on Bank Loan Supply and Monetary Policy Implementation in the Euro Area

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March 21, 2019

Abstract

In March 2015, the Eurosystem started its large-scale asset purchase programme (quantitative easing, QE). The asset purchases induced a rapid and strong increase in excess reserves, implying a structural liquidity surplus in the euro area banking sector. Developing a theoretical model, we show that increasing excess reserves have no or even a contractionary impact on bank loan supply. As the newly created excess reserves are heterogeneously distributed across euro area countries, the impact of QE on bank loan supply may differ across countries. Moreover, we derive implications for monetary policy implementation when the banking sector operates under a structural liquidity surplus. Increases in the central bank's main refinancing rate as well as in the minimum reserve ratio and decreases in the central bank's deposit rate develop expansionary effects on loan supply – contrary to the case in which banks face a structural liquidity deficit.

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1 Introduction

In March 2015, the Eurosystem[1] started implementing its large-scale asset purchase pro-
gramme – commonly referred to as Quantitative Easing (QE) – to address the risks of a
too prolonged period of low, temporarily even negative, inflation rates since the begin-
ning of 2013. The aim of this programme is to directly lower long-term interest rates
at times when (short-term) monetary policy interest rates are approaching the effective
lower bound, so that expansionary monetary policy stimuli are no longer possible to reach
through conventional interest rate cuts.[2] By directly lowering long-term interest rates, the
Eurosystem wants to improve financing conditions for households and firms so that they
consume and invest more. By this, aggregate demand and thus also the price level are
intended to increase until the target inflation rate of less than but close to 2% is finally
reached again (European Central Bank, 2015).

There are various channels by which QE may be transmitted to the real economy.[3]
In this paper, we focus on the bank lending channel. The focus of early papers dealing
with this channel is on the relationship between bank deposits affected by a monetary
policy shock and bank loan supply (see e.g. Bernanke and Gertler, 1995; Kashyap and
Stein, 1995; Mishkin, 1996). However, recent papers also explicitly consider the banking
sectors' excess reserve holdings in this context (see e.g. Rodnyansky and Darmouni, 2017;
D'Avino, 2018; Lojschova, 2017). Bank reserves consist of bank deposits at the central
bank and currency physically hold by banks. Excess reserves are defined as the amount of
commercial banks' current account balances at their national central bank in excess of the
minimum reserve requirements (MRR). Excess liquidity is a concept different from excess
reserves and is typically significantly larger, since banks' recourse to the deposit facility is
additionally taken into account in the calculation of excess liquidity.

Due to the Eurosystem's asset purchases on a large scale, the amount of aggregate
excess liquidity in the euro area increased from 200 billion euros in March 2015 to 1.9

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[1]The term "Eurosystem" stands for the institutions responsible for monetary policy in the euro area,
i.e. the European Central Bank (ECB) and the national central banks in the euro area. To simplify
matters, the terms ECB and Eurosystem are used synonymously in this paper.

[2]In January 2015, the interest rate on the ECB's main refinancing operations (MROs) was already
located at 0.05%, the interest rate on its deposit facility was already negative at -0.2% and the interest
rate on the marginal lending facility amounted to 0.3% (data source: ECB).

[3]For a general description of different transmission channels in the context of the Eurosystem's large-
scale asset purchase programme, see e.g. Deutsche Bundesbank (2016a).

trillion euros in December 2018 (corresponding to 17% of the annual euro area GDP). This excess liquidity is not homogeneously distributed across euro area countries. About 30% of total excess liquidity in the euro area are held solely in Germany, for example (data source: ECB). Holding excess reserves is costly. Especially the kind of penalty interest rate banks have to pay on excess reserves[4] has caused a debate whether commercial banks may have an incentive to expand lending to reduce their costly excess liquidity holdings. This goes in line with the question of how far a QE-induced increase in deposits and thus also in costly excess reserve holdings leads to higher bank loan supply, i.e. whether there is a bank lending channel of QE.

This paper adds to the debate by developing a theoretical model of a banking sector consisting of commercial banks offering loans to the non-banking sector and a central bank purchasing assets on a large scale from the non-banking sector. The model allows us to discuss three closely related issues: first, the impact of QE-induced increases in bank reserves and deposits on bank loan supply; second, the effect of a QE-induced heterogeneous distribution of excess reserves across banks on bank loan supply; and third, the consequences of a QE-induced structural liquidity surplus in the banking sector for the implementation of other monetary policy instruments.

With respect to the first issue, we cannot document evidence of the presence of a bank lending channel implying a positive impact of central bank asset purchases from the non-banking sector on bank loan supply. Based on our model results, we argue that increasing excess reserves and deposits in the euro area banking sector – provoked by the implementation of QE – have no or even a contractionary impact on bank loan supply. The impact will be contractionary if banks face increasing marginal costs of holding deposits, due to, for example, agency or regulatory costs. Following the literature, we refer to these costs as balance sheet costs (see e.g. Martin et al., 2016). The strength of the contractionary effect increases in the banks' holdings of excess reserves. This leads us to the second issue. The banking sectors' QE-induced excess reserve holdings differ significantly across euro area countries. Consequently, increasing marginal balance sheet costs imply that the negative impact of QE on bank loan supply differs across euro area member

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[4]Since June 2014 excess reserves are remunerated at a negative rate, currently (February 2019) at -0.4%. This interest rate has to be paid independently of whether this liquidity is held in the Eurosystem's deposit facility or on current accounts with the Eurosystem.

states. Concerning the third issue, our model shows that conventional monetary policy measures will work in the opposite direction if the banking sector faces a – for example QE-induced – structural liquidity surplus instead of a structural liquidity deficit.[5] Since October 2015 the reserves exclusively created through the Eurosystem's large-scale asset purchases have exceeded the banking sector's structural liquidity needs. Consequently, banks started to operate in an environment characterized by structural liquidity surplus. Our model reveals that in such an environment commercial banks' incentive to expand their loan supply will be strengthened if the central bank (i) increases its MRO-rate, (ii) implements higher MRR for banks and (iii) decreases its deposit rate.

The rest of the paper is structured as follows. Section 2 proceeds with an overview of commercial banks' liquidity needs and liquidity provision by the Eurosystem in "normal times", "crisis times", and in "times of a too low inflation". Section 3 provides some stylized facts with regard to the effects of the implementation of the Eurosystem's large-scale asset purchase programme. Section 4 describes the model framework and derives banks' optimal loan supply to the non-banking sector whereby banks are exposed to a structural liquidity surplus. Based on the findings in the previous sections, implications for monetary policy implementation are discussed in Section 5. Section 6 concludes.

2 Liquidity Needs of the Euro Area Banking Sector and Liquidity Provision by the Eurosystem

2.1 Normal Times

Central bank liquidity management includes evaluating the liquidity needs in the form of reserves of the banking sector and satisfying these liquidity needs by providing, respectively absorbing the appropriate amount of liquidity.[6] In the euro area, the banking sectors' needs for reserves primarily result from the MRR imposed by the ECB and so-called

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[5]A banking sector facing a structural liquidity deficit has to rely on an ongoing liquidity provision by the central bank to cover its structural liquidity needs resulting from MRR and autonomous factors. In the euro area, banks faced such a structural liquidity deficit until October 2015. The Eurosystem provided the respective liquidity mainly through credit transactions, as its MROs.

[6]For a general description of the ECB's liquidity management, see e.g. European Central Bank (2002).

autonomous factors. Autonomous liquidity factors can be divided into liquidity providing factors, such as net foreign assets, and absorbing factors, such as banknotes in circulation or government deposits. They are called autonomous factors since they are beyond the control of the ECB. Instead, they are determined by the behaviour of the public or by institutional arrangements. In the euro area, net autonomous factors are positive, i.e. the sum of liquidity absorbing factors is larger than the sum of liquidity providing factors. Banknotes in circulation present by far the largest autonomous factor. MRR and positive net autonomous factors imply a structural need for reserves of the euro area banking sector. Interbank transactions due to, for example, deposit transfers between customers of different banks, are settled to a large part via the banks' reserve accounts at the central bank. Consequently, a bank may end up with a reserve deficit, another bank with a surplus. If there is a functioning interbank market for reserves, banks will be able to balance their different individual liquidity needs, so that these transactions will not imply a further need for reserves of the banking sector as a whole. However, if the interbank market does not function properly, banks with a liquidity deficit have to take recourse to the central bank's lending facility. The Eurosystem offers two standing facilities, a lending facility and a deposit facility, which allow banks to balance their overnight liquidity needs with the rate on the deposit facility to be lower than the rate on the lending facility. To avoid the relatively costly use of the lending facility, banks may want to hold precautionary liquidity. This means that there may be a need for reserves beyond the structural need due to MRR and autonomous factors.

The reasons why banks hold reserves reveal that bank deposits are a crucial determinant of bank demand for reserves: bank deposits determine the reserve requirements; they determine the cash withdrawals, as usually people want to hold cash and deposits in a certain ratio; and they determine the demand for precautionary liquidity, as usually banks' demand for precautionary liquidity increases in their deposits. When granting loans, commercial banks create deposits. This means that granting loans goes along with an increase in demand for reserves. This creates a link between monetary policy and bank loan supply, as the central bank, being the monopoly producer of reserves, determines the costs of reserves and the quantity of reserves available to the banking sector.

Until the collapse of the investment bank Lehman Brothers in September 2008, a period to which we refer to as "normal times", the interbank market functioned properly and thus allowed in principle for an efficient distribution of reserves across banks. The liquidity needs of the euro area banking sector thus corresponded to its structural liquidity deficit resulting from MRR and autonomous factors. There was no need for additional reserves, e.g. for precautionary holdings of liquidity due to a malfunctioning interbank market (Eser et al., 2012). Until September 2008, the Eurosystem provided the banking sector in principle with reserves in amounts equal to the banking sector's structural liquidity deficit. It provided this liquidity mainly through its main MROs.[7] MROs are regular liquidity-providing credit transactions with a frequency and maturity of typically one week. They are conducted through standard tenders (variable or fixed rate tenders) in which banks can bid for liquidity against adequate collateral. The interest rate on these credit operations is the MRO-rate. The interest rates on the two central bank's standing facilities form a corridor around the MRO-rate, with the rate on the deposit facility being lower and the rate on the lending facility being higher than the MRO-rate (see Figure 1).[8]

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[7]The Eurosystem provided banks with approximately three quaters of their required central bank liquidity through its MROs (data source: ECB).

[8]For a general documentation on the implementation of standard monetary policy by the Eurosystem, see European Central Bank (2012a).
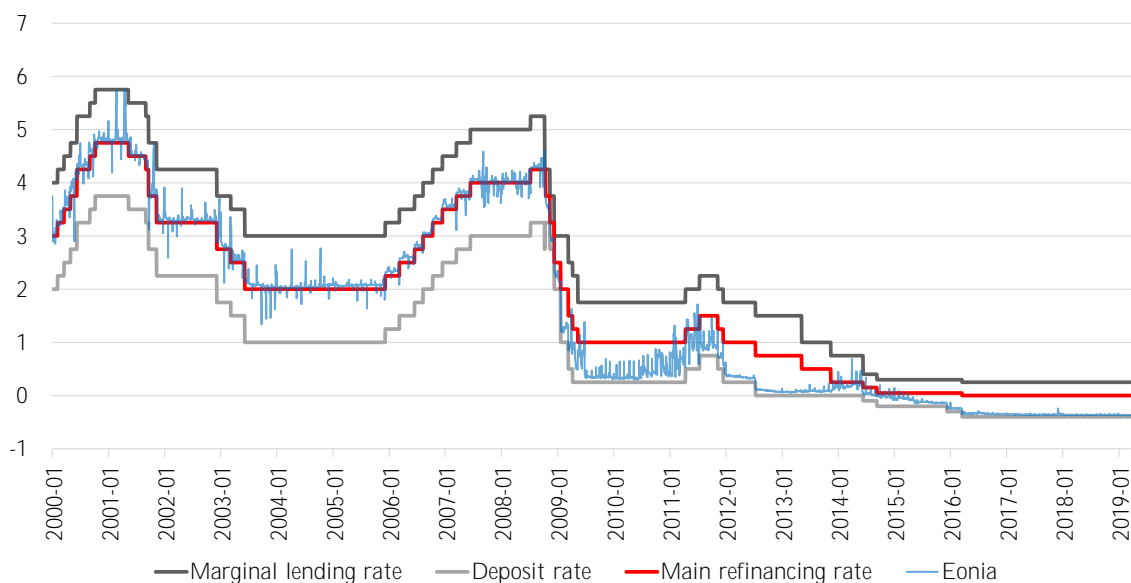
Figure 1: Temporal development of euro area key interest rates including euro interbank offered rate (on a daily basis, %).
Data Source: ECB.

Figure 2 illustrates the development of the central bank balance sheet since 2008. Components providing liquidity to the banking sector are indicated in the upper area, whereas liquidity absorbing components are mapped in the lower area. Prior to September 2008, banks' liquidity needs (pink curve) were quite perfectly covered by the ECB's open market operations (blue curve) so that liquidity conditions in the euro area were balanced.

The facts that, first, the Eurosystem almost exactly satisfied the banking sector's aggregate liquidity needs and that, second, a functioning interbank market smoothly redistributed reserves between banks with an individual surplus and those with an individual deficit, implied that before September 2008, neither the lending nor the deposit facility were used systematically and that the interbank rate (EONIA)[9] fluctuated closely around the MRO-rate. Consequently, there were two main monetary policy instruments influencing bank loan supply in the euro area: the MROs, as the MRO-rate determined the costs of borrowing the necessary reserves when granting loans, and the MRR, as the reserve ratio determined the necessary quantity of reserves when granting loans. In such a "normal-times scenario", an increase in the MRO-rate and/or the reserve ratio makes

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[9]The EONIA (Euro OverNight Index Average) is the effective overnight reference rate for the euro area. It is computed as a weighted average of overnight unsecured lending transactions between banks in the euro area interbank market.

granting bank loans more costly, i.e. it is a contractionary monetary policy impulse. The rates on the central bank's facilities serve to stabilize the interbank rate but they have no systematic effect on bank loan supply.
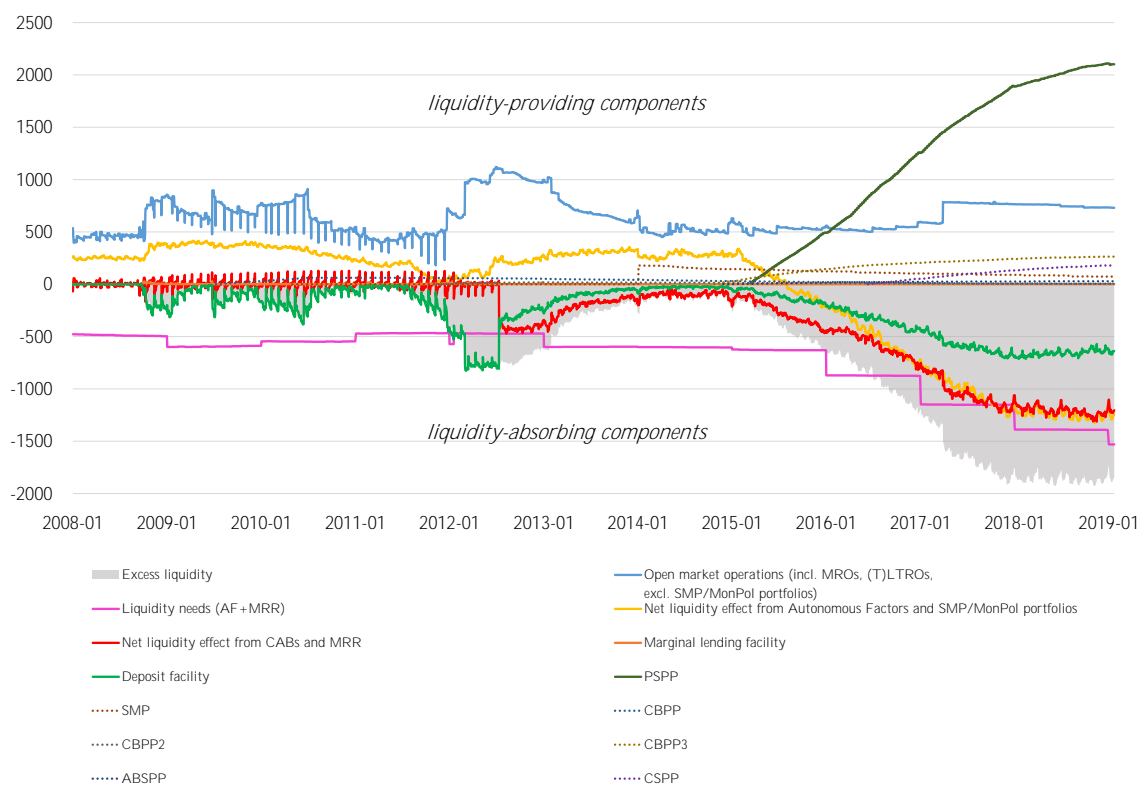

Figure 2: Liquidity provision and absorption through the Eurosystem – Temporal development of the central bank's balance sheet including volumes of non-standard monetary policy measures (on a daily basis, in billion euros).
Data Source: ECB.

2.2 Crisis Times

During the financial crisis which peaked in September 2008 with the collapse of Lehman Brothers and during the subsequent sovereign debt crisis, banks' liquidity needs increased due to funding stress in the euro area banking sector. Increased levels of distrust and risk perception as well as increased informational asymmetries led to capital flight from lower-rated countries to higher-rated countries implying a concentration of liquidity in only a few euro area countries ("save-haven-flows" and "flight-to-quality-phenomena", see Section 3).

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Furthermore, the overnight interbank market did not function properly anymore.[10] Due to the reasons listed above, banks with a surplus of liquidity refused lending in the interbank market to banks with a liquidity deficit. The use of the central bank's deposit facility was instead the more attractive alternative for potential interbank lenders. To substitute for the loss in market-based funding, banks in lower-rated countries participated more significantly in the Eurosystem's refinancing operations to cover their liquidity deficit. The Eurosystem fully satisfied the increased demand for reserves (subject to collateral availability) by implementing a set of non-standard monetary policy measures such as a fixed rate tender procedure with full allotment in all refinancing operations and for different maturities in October 2008 as well as the allotment of two three-year longer-term refinancing operations (LTROs) in the years 2011 and 2012.[11] As a result, aggregate excess liquidity started to emerge. Moreover, as the interbank market was not able anymore to smoothly redistribute liquidity, banks generally built up liquidity buffers. They wanted to hold more reserves than necessary to fulfill the MRR and to cope with autonomous factors, i.e. they started to hold liquidity for precautionary reasons to be able to cover potential additional sudden liquidity needs. The costs and benefits of holding precautionary liquidity are determined by the rates on the central bank's facilities. As banks create deposits by granting loans and since the demand for precautionary liquidity increases in bank deposits, the rates on the central bank's facilities have an influence on bank loan supply. With its facilities the Eurosystem thus had, besides the MROs and the MRR, a further instrument at hand to influence bank loan supply during that crisis time. In such a "crisis-time scenario", narrowing the corridor that the rates on the facilities form around the MRO-rate decreases the costs of holding precautionary liquidity, so that an increase in the rate on the deposit facility has a positive impact on bank loan supply.[12]

Figure 2 illustrates the strong increases in the recourse to the deposit facility (green curve), in the liquidity provided through open market operations (blue curve) and the increased levels of excess liquidity (grey shadowed area). Excess liquidity is the sum of

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[10]For a recent documentation on stress in the overnight interbank market in the euro area over the course of the financial and sovereign debt crisis in Europe, see e.g. Frutos et al. (2016).

[11]For a description of the implementation of monetary policy by the Eurosystem in response to the financial and sovereign debt crisis, see e.g. European Central Bank (2009, 2010, 2011, 2012b, 2014).

[12]For a theoretical analysis of the consequences of interbank market friction-induced holdings of precautionary liquidity on bank loan supply and monetary policy implementation, see Bucher et al. (2014).

commercial banks' current account balances at their national central bank in excess of the MRR (red curve) plus their recourse to the deposit facility of the ECB (green curve). It should be noted that the creation of excess liquidity during the financial crisis and the sovereign debt crisis was entirely demand-driven (Baldo et al., 2017): the ECB satisfied the increased liquidity demand of the banking sector. Until the beginning of 2015 most banks made use of the LTROs premature repayment option which is represented in Figure 2 by a decrease in banks' current account holdings. As a consequence, reserves in excess of the structural liquidity deficit of the banking sector equalled practically zero again.

2.3 Times of "Too Low" Inflation

Due to a persistently low inflation rate in the euro area and monetary policy rates approaching their effective lower bound,[13] the ECB's Governing Council announced the implementation of the so-called Expanded Asset Purchase Programme (APP) in January 2015. The aim of this non-standard monetary policy measure was to safeguard the Eurosystem's primary objective of price stability and to ensure an appropriate monetary policy transmission mechanism (European Central Bank, 2015). The APP includes all programmes under which both private and public sector securities are purchased. It consists of the Corporate Sector Purchase Porgramme (CSPP), the Public Sector Purchase Programme (PSPP), the Asset-Backed Securities Purchase Programme (ABSPP) and the Third Covered Bond Purchase Programme (CBPP3). The PSPP represents by far the largest component of the APP covering a share of approximately 83% of all bought securitites under the APP (European Central Bank, 2019a). The ECB's Governing Council stressed that it intends to carry out securities purchases until a sustained adjustment in the path of inflation is reached that is consistent with its aim of achieving inflation rates below, but close to, 2% over the medium term (European Central Bank, 2017b).[14]

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[13]In January 2015, the MRO-rate was already at 0.05% and the rate on the deposit facility at -0.02%.
[14]Initially, between March 2015 and March 2016 the monthly volume of net purchases of public and private securities amounted to 60 billion euros. Then it increased to 80 billion euros between April 2016 and March 2017. From April 2017 until December 2017 it declined to 60 billion euros again. Between January and September 2018, monthly net purchases in the value of 30 billion euros were conducted. After September 2018, the monthly pace of net asset purchases was reduced to 15 billion euros until the end of December 2018, when net asset purchases were for the time being stopped.

When paying for the acquired APP securities, the Eurosystem creates reserves, meaning that the amount of central bank liquidity in the financial system and therefore already existing excess liquidity mechanically increase. Since the launch of the APP in March 2015, aggregate excess liquidity has increased from 200 billion euros in March 2015 to 1.9 trillion euros in December 2018 (see grey area in Figure 2). The dark green curve in Figure 2 demonstrates that since July 2016, the liquidity exclusively created through the asset purchases within the PSPP has already overcompensated the structural liquidity needs of the banking sector and hence has pushed up continuously the level of aggregate excess liquidity (grey area).[15] This implied that since October/November 2015 the euro area banking sector has been operating in an environment characterized by a structural liquidity surplus. This means that from this date onwards, banks have not had to rely on the central bank's refinancing operations anymore to cover their structural liquidity deficit resulting from MRR and autonomous factors.[16] The banking sector has no longer been able to entirely eliminate excess liquidity by decreasing its borrowing from the ECB. Even if no bank borrowed from the ECB, there would still be excess liquidity despite banks' increased liquidity needs resulting from net autonomous factors.[17] In contrast to the surge of excess liquidity during the sovereign debt crisis, the surge of excess liquidity within the APP period cannot be interpreted primarily as an indicator of financial market stress but is a result of the APP. Compared with the period of the financial and sovereign debt crisis, the creation of excess liquidity under the APP is a supply-driven phenomenon. There is no demand for this liquidity initiated by the banking sector (Baldo et al., 2017).

The model presented in Section 4 of this paper is used to analyse the direct impact of large-scale asset purchases on bank loan supply as well as the consequences of these

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[15]The three dotted lines represent the other components of the APP. They obviously play a subordinate role compared with the PSPP volume.

[16]We determine the date on which the euro area banking sector was exposed to a structural liquidity surplus for the first time by calculating the net liquidity effect from MRR, autonomous factors and the ECB's monetary policy portfolio (consisting of the SMP, CBPP1, CBPP2, CBPP3, ABSPP, PSPP, CSPP). A negative value indicates that the scope of the monetary policy portfolio already exceeds banks' structural liquidity needs so that banks, in general, would not need to demand for additional liquidity in open market operations to cover their liquidity needs. For the first time this was the case in October 2015.

[17]The reasons for the persistent increase in net autonomous factors since January 2016 are numerous. First, shrinking net currency reserves and the temporal appreciation of the euro against the dollar decreased the value of net foreign assets which reduced the liquidity providing component of autonomous factors. Second, banknotes in circulation and government deposits increased which enlarged the liquidity absorbing component of autonomous factors so that in sum, net autonomous factors increased (Deutsche Bundesbank, 2018; European Central Bank, 2018).

asset purchases for the implementation of other monetary policy instruments. We show that the large-scale asset purchases themselves have no or a negative impact on bank loan supply. Furthermore, we argue that operating in an environment characterized by a structural liquidity surplus implies that, contrary to the described "normal-" and "crisis-times scenarios", an increase in the MRO-rate as well as in the minimum reserve ratio have a positive effect on bank loan supply. Increases in these variables correspond therefore to an expansionary monetary policy impulse. An increase in the rate on the deposit facility, also contrary to the described "normal-" and "crisis-times scenarios", leads to higher costs of bank lending and is thus a contractionary monetary policy impulse.

3 Stylized Facts

3.1 Heterogeneous Distribution of Excess Liquidity Across Euro Area Countries

Figure 3 reveals that excess liquidity has been heterogeneously distributed across euro area countries. The reasons for the heterogeneous distribution during the financial and sovereign debt crisis, on the one hand, and during the APP period, on the other hand, are different.

Reasons related to the financial crisis and sovereign debt crisis
During the financial and sovereign debt crisis, the main driver for the heterogeneous distribution of excess liquidity was capital flight (so-called "flight-to-quality" phenomena or "save-haven-flows") from lower-rated euro area countries towards higher-rated euro area countries such as in particular Germany, the Netherlands and France. Domestic households and firms, financial and non-financial, in lower-rated countries preferred to deposit their liquidity abroad and at the same time foreign households and firms, financial and non-financial, refused to provide (further) liquidity due to increased levels of risk and distrust. As a result, banks in lower-rated countries were concerned by difficulties in financing themselves. Funding-stressed banks in these countries participated more significantly in the Eurosystem's refinancing operations to close emerging funding gaps and to build up liquidity buffers. The total amount of excess liquidity increased. However,
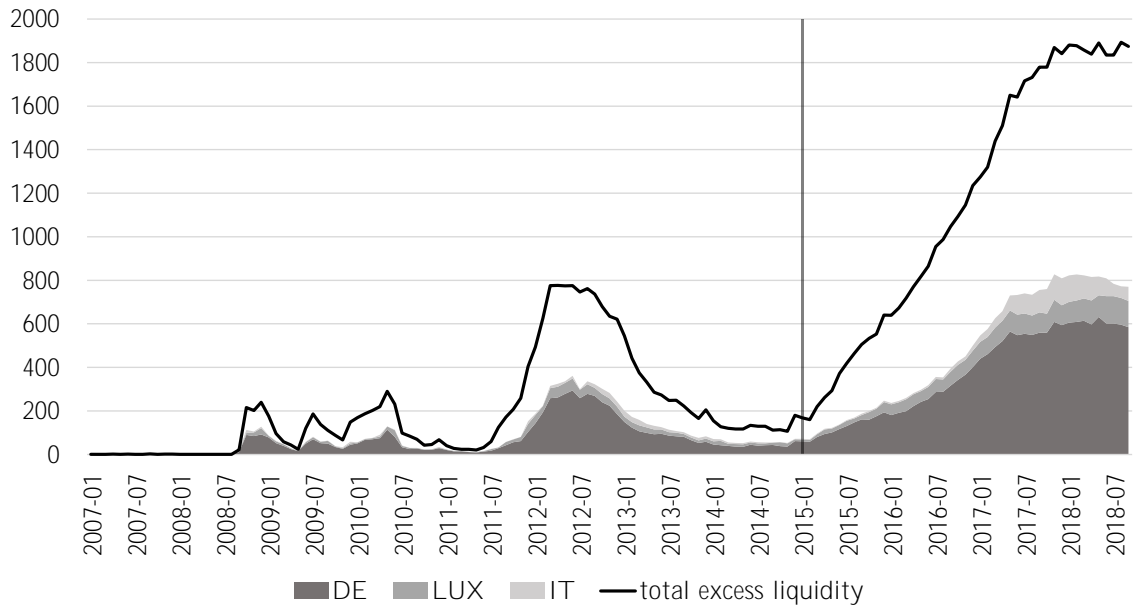
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Figure 3: Accumulation of excess liquidity at specific national central banks in billion euros (maintenance period averages, vertical line indicates the APP start). Data Source: Eurosystem.

the provided liquidity accumulated via cross-border flows in countries that were least concerned by the crisis, thereby inducing a heterogeneous distribution of this excess liquidity.[18]

Reasons related to the APP implementation

Figure 3 demonstrates that during the APP period, i.e. since 2015, about 30% of total excess liquidity is held exclusively in Germany. Alvarez et al. (2017) and Baldo et al. (2017) show that excess liquidity predominantly accumulates in Germany, the Netherlands, France, Finland and Luxembourg with about 80-90% of total excess liquidity being held in these countries, whereas holdings of excess liquidity in Italy, Portugal or Spain, for example, are much less pronounced.

The first reason for the heterogeneous distribution of excess liquidity is that, within the PSPP, national central banks purchase domestic government bonds in accordance with

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[18]For a more detailed description of the heterogeneous distribution of excess liquidity across euro area countries during the financial and sovereign debt crisis, see Baldo et al. (2017).

their share in the ECB's capital key.[19] Since Germany and France are most concerned by the ECB's capital key with 26% and 20% respectively, excess liquidity accumulates especially in these two countries (European Central Bank, 2019b). The second reason for excess liquidity accumulating most in Germany is that the ECB itself (with a share of 10% of the total PSPP purchase volume) purchases securities under the PSPP and that as technical particularity, the ECB's transactions are carried out through the Deutsche Bundesbank. The third reason is that the APP implementation induces a creation of reserves that predominantly takes place in only a few financial centres or financial gateways. By consequence, most of the excess liquidity created through the APP purchases accumulates in only a few countries (Baldo et al., 2017).

With respect to the latter, on which we focus in this paper, consider the following example for illustrative purposes (see Figure 4): the Banca d'Italia purchases Italian government bonds from a counterparty[20] resident outside the euro area. In order to participate in this cross-border transaction, the counterparty needs access to the TARGET2 payment system.[21] As an example, we consider a UK-based counterparty that uses a correspondent German bank as access point for TARGET2.[22] In this case the securities purchase of the Banca d'Italia implies that both the Banca d'Italia and the Bundesbank are involved in a cross-border payment transaction leading to an increase in reserves in the German banking sector. In detail this process can be described as follows. The Banca d'Italia obtains the respective amount of government bonds and the UK-APP-counterparty's deposits increase at the expense of its government bond holdings. As the UK-APP-counterparty has its deposit account with a German commercial bank, the reserves of the German commercial bank and thus the respective liability item of the Bundesbank's balance sheet increase.

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[19]Bonds issued by recognised agencies, regional and local governments, international organisations and multilateral development banks located in the euro area are also allowed to be purchased under the PSPP but play a far less significant role in this context (European Central Bank, 2019a).

[20]APP counterparties are defined as the set of financial institutions from which central banks directly purchase securities. Very often, counterparties act as intermediaries for initial, underlying security owners (Eisenschmidt et al., 2017).

[21]TARGET (Trans-European Automated Real-time Gross Settlement Express Transfer System) balances are intra-Eurosystem assets and liabilities on the central banks' balance sheets. They typically result from net cross-border payments in the form of central bank reserves via the TARGET2 payment system. TARGET2 is the real-time gross settlement system owned and operated by the Eurosystem. It settles euro-denominated payments continuously on an individual transaction-by-transaction basis without netting (Eisenschmidt et al., 2017).

[22]Around 50% of the overall purchase volume is conducted with UK-based banks which access TARGET2 via the Deutsche Bundesbank (Alvarez et al., 2017).

The offsetting asset item of the Bundesbank's balance sheet is a TARGET2 claim on the ECB. The Banca d'Italia on the other hand has a TARGET2 liability towards the ECB. The increase in the Bundesbank's positive TARGET2 balances and the increase in the excess reserves of the German banking sector are thus a consequence of the bond purchases by the Banca d'Italia from non-domestic counterparties which have their deposit account with a German commercial bank. The consolidated balance sheet of the Eurosystem demonstrates that the Eurosystem's government bond holdings and reserves in the euro area have increased.

This example thus illustrates that the location of the TARGET2 account of banks selling securities to the Eurosystem is most indicative of the likely point of origin of reserves and thus excess liquidity. Due to the fact that most of the non-euro area APP counterparties access TARGET2 via the Bundesbank, Germany absorbs a large share of the liquidity created through the asset purchases within the Eurosystem's PSPP.

A	Bundesbank	L		A	Banca d'Italia	L		A	ECB	L		A	Eurosystem	L
TARGET2 ↑		Reserves ↑		Government bonds ↑		TARGET2 ↑		TARGET2 Italy ↑		TARGET2 Germany ↑		Government bonds ↑	Reserves ↑

A	Commercial bank (Germany)	L		A	APP-Counterparty (UK)	L		A	MFI sector consolidated (incl. Eurosystem)	L
Reserves ↑		Deposits^{UK} ↑		Government bonds ↓				Government bonds ↑		Deposits^{UK} ↑
				Deposits^{UK} ↑						

Figure 4: APP implementation – Change in balance sheet positions.

Note in this context that around 80% of APP purchases by volume were purchased from counterparties that are not resident in the same country as the purchasing national central bank and about 50% of APP purchases by volume occurred with counterparties belonging to banking groups whose head institution was located outside the euro area, most of them being resident in the UK (Baldo et al., 2017).

This third reason for the heterogeneous distribution of excess liquidity is closely connected to the development of the TARGET balances that have risen with the strong increase in excess liquidity during the APP period. The residence of the national central bank's counterparty strongly influences the impact of the APP implementation on the development of the TARGET balances. Euro area banks participate in TARGET2 via their local national central bank. Banks located outside the euro area participate in TARGET2 via a branch or subsidiary in the euro area or via a correspondent bank. Central bank asset purchases from non-domestic counterparties, no matter whether they are situated in another euro area country or outside the euro area, result in cross-border payments. The resulting increase in the TARGET claims of countries hosting financial gateways and vice versa, may lead to a segmentation between (rather) liquidity-rich and (rather) liquidity-poor banks and countries. Consequently, compared with the mainly demand-driven surge in TARGET balances during the euro area sovereign debt crisis, the drivers and the interpretation of the increase in TARGET balances in the context of the APP, differ notably since it is a supply-driven phenomenon (Eisenschmidt et al., 2017).

3.2 Creation of Deposits

We observe that with respect to Germany the persistent increase in excess liquidity provoked by the APP implementation is not reflected by a corresponding increase in deposits[23] and money (e.g. measured by the monetary aggregate M3). This is again in conjunction with the fact that a large proportion of securities is purchased in countries outside the euro area. Government bond purchases will only influence M3 if the according central bank ultimately purchases the securities from the domestic money-holding-sector – principally households and private corporations. In this case, such purchases lead to an increase in the item "securities-based lending to euro area general government" on the asset side of the consolidated balance sheet of the MFI sector, while on the liability side, accordingly, overnight deposits increase which boosts M3 (Deutsche Bundesbank, 2016b).

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[23]W.r.t. Germany, the growth rates of deposits of corporations and households in total, overnight, with agreed maturity of less and more than two years as well as with agreed notice of up to three months did not increase since the start of the APP implementation (Deutsche Bundesbank, 2016b).

If the seller is instead located outside the euro area, the asset side of the consolidated balance sheet will be affected in the same way. However, on the liability side, the payment transaction now increases the liabilities of the central bank or a domestic credit institution to the non-resident seller, which reduces the net external asset position of the MFI sector vis-à-vis non-euro-area residents. Thus, M3 remains unchanged because domestic non-banks' money holdings (deposits) have not changed (Deutsche Bundesbank, 2016b). Therefore, in connection with the APP implementation, we observe in particular increasing liabilities of the Bundesbank to non-euro-area residents but no significant increases in growth rates of deposits and monetary aggregates.

3.3 Interbank Market Transactions

The overnight interbank market used to be the most relevant market segment with respect to the trading of reserves. The ECB applies a corridor system for the implementation of monetary policy, which is that the rate for the central bank's deposit facility serves as a 'floor' for overnight interbank rates and the rate for its marginal lending facility serves as a 'ceiling'. Prior to October 2008, refinancing operations of the ECB aimed at keeping excess liquidity close to zero – liquidity provision was quantity-constrained. This allowed the ECB to steer the EONIA close to the MRO-rate. The MRO-rate was typically set at the midpoint of the corridor. Since individual excess liquidity was remunerated at the deposit rate and thus below market rates, commercial banks only held small amounts. In this context, the interbank market smoothly redistributed liquidity from banks facing a liquidity surplus to banks facing a liquidity deficit in order to balance short-term liquidity fluctuations.

However, the APP-induced surge in aggregate excess liquidity has had significant impacts on interbank money market functioning in the euro area. The EONIA approached the floor of the corridor and aggregate interbank trading volume strongly decreased.[24] The interbank money market lost significance with respect to the related implementation and transmission of monetary policy: first, there is weakly pronounced need for liquidity.

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[24]Aggregate daily trading volume in the overnight interbank market currently (January 2019) amounts to below 3 billion euros while it fluctuated around 30 billion euros in January 2015 (data source: ECB).

Second, especially with regard to banks facing liquidity surpluses, gains from trade that banks can realize when trading in the interbank market compared with the alternative recourse to the central bank's standing facilities are only limited.[25] The historically small spread between the MRO-rate and the deposit rate – which ranged between 25 and 40 basis points during the APP period – reduced price incentives for banks facing excess liquidity to trade in the market. More precisely, the smaller this spread, the lesser the incentives for interbank activity since the opportunity costs of holding excess liquidity are reduced. This, in turn, contributes to the persistence of TARGET balances. Despite the heterogeneous distribution of excess liquidity across the euro area, cross-national interest rate differences in the unsecured overnight interbank market are only small. Therefore, a redistribution of reserves from countries with large amounts of excess liquidity to those with smaller amounts via the interbank market is also not realized due to absent price incentives (Eisenschmidt et al., 2017).[26]

3.4 Bank Lending

Since the beginning of 2014, loan growth in general – but in particular the growth of loans to the private sector – has continuously recovered in the euro area, as illustrated by Figures 5 and 6. The observed trend in loan growth has been mainly supported by the significant decline in bank lending rates across the euro area since summer 2014 (European Central Bank, 2017a). However, the heterogeneity with respect to loan growth across the four largest euro area countries slightly started to increase in October 2017 (see Figure 5): while in Germany and France the annual growth rates of loans to non-financial corporations are strictly positive and increase continuously, loan growth rates in Italy

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[25]E.g. Bech and Monnet (2016), show that if aggregate excess liquidity in the system is large, the EONIA will converge to the deposit rate. Hence, realized gains from trade in the interbank market will no longer be sufficiently high to compensate for risks relating to counterparty or settlement risk. A recourse to the central bank's standing facility would then, in relative terms, be advantageous.

[26]Eisenschmidt et al. (2017) show that in a perfectly functioning money market without any fragmentation, country-level rates should only depend on the aggregate level of excess liquidity (not on the domestic level of excess liquidity) and rates should be equal across countries. Consequently, the fact that over 97% of the euro area banking sector trades overnight liquidity at rates equal to or below the rate that would be expected from the aggregate level of excess liquidity indicates, on the one hand, a low level of fragmentation, but on the other hand illustrates the low price incentives in the market for reserves to be redistributed via the interbank market.
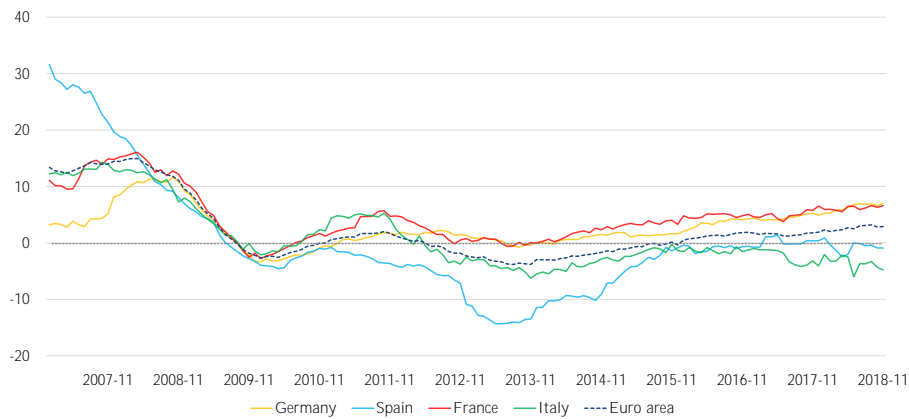
and Spain are negative.

Figure 5: Loans of monetary financial institutions to non-financial corporations in selected euro area countries (annual percentage changes).
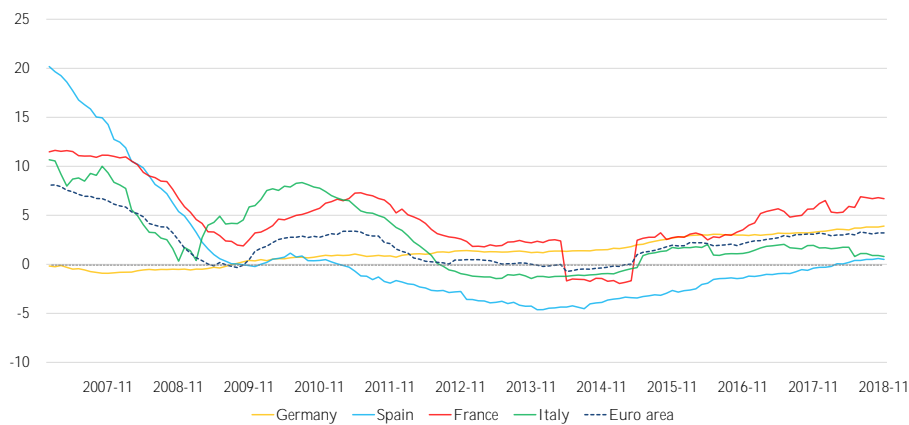Data Source: ECB.

Figure 6: Loans of monetary financial institutions to households in selected euro area countries (annual percentage changes).
Data Source: ECB.

4   Model

The aim of this model is to shed some light on bank loan supply in an environment where the banking sector is exposed to a structural liquidity surplus, i.e. banks' aggregate reserve holdings exceed their need for reserves resulting from autonomous factors, e.g. cash withdrawals, and the MRR. This has been the case in the euro area since October 2015 due to the Eurosystem's large-scale asset purchases (see Section 3). The model reveals that

these asset purchases have no or a contractionary effect on bank loan supply. The effect will be contractionary if there are increasing marginal balance sheet costs. The model shows furthermore, that these costs in combination with specific institutional aspects imply that the impact of this monetary policy measure on loan supply differs across banks. Moreover, the model reveals that the effects of conventional monetary policy measures on bank loan supply exactly turn around when banks operate under a structural liquidity surplus instead of a respective deficit.

4.1 Setup

In our economy, there is a central bank, a continuum of measure one of risk-neutral commercial banks and a large number of bank customers. In a first step, we assume that all commercial banks are identical, which allows us to consider one representative commercial bank. Bank customers can be divided into households, firms and foreign investors. For the sake of simplicity, we subsume them under a non-banking sector. Our model is a one-period model. At the beginning of this period, the non-banking sector is endowed with an amount of government bonds B.

Within the period, the central bank buys the government bonds from the non-banking sector (quantitative easing). These large-scale asset purchases imply an increase in the bank's reserve holdings R as well as in its deposits D, i.e. they imply the creation of money.[27] This creation of money in the form of deposits by the central bank does not take place when conventional monetary policy instruments are employed. Then only commercial banks create money in the form of deposits by granting loans to the non-banking sector. However, the central bank influences this money creation process. The money creation by the commercial banks generates a need for bank reserves, and the costs and the availability of these reserves are determined by the central bank. One part of the newly created money remains as deposits D^{QE} in the banking sector, the other part is withdrawn as cash C^{QE}, so that

$$B = C^{QE} + D^{QE}. \tag{1}$$

---

[27]See Section 3, Figure 4. As illustrated, the deposits increase with the purchases of domestic government bonds by a national central bank from a non-euro area counterparty. In this example, D^{QE} corresponds to $Deposits^{UK}$ in Figure 4.

The non-banking sector wants to hold cash and deposits in a certain ratio. This currency ratio is given by $b = C^{QE}/D^{QE}$, i.e.

$$C^{QE} = bD^{QE}. \tag{2}$$

Considering (1) and (2), we get

$$D^{QE} = \frac{B}{1+b}. \tag{3}$$

The bank makes loans L to the non-banking sector by crediting the respective amount to the deposit account, i.e. also the commercial banks create money. Consequently, the non-banking sector's deposits increase. One part of these deposits remains as deposits D^L in the banking sector, the other part is withdrawn as cash C^L, so that

$$L = C^L + D^L. \tag{4}$$

Again, the non-banking sector wants to hold cash and deposits in a certain ratio. This currency ratio is given by $b = C^L/D^L$, i.e.[28]

$$C^L = bD^L. \tag{5}$$

Considering (4) and (5), we get

$$D^L = \frac{L}{1+b}. \tag{6}$$

For the bank's total deposits D we thus have

$$D = D^L + D^{QE}. \tag{7}$$

Figure 7 illustrates the change in the balance sheets during the period under consideration:

---

[28]Note that $b = \frac{C}{D} = \frac{C^L}{D^L} = \frac{C^{QE}}{D^{QE}}$.

Central bank implements QE:

A	NBS	L		A	Comm. Bank	L		A	Central Bank	L
D^{QE}				$R \begin{cases} ER \\ RR \end{cases}$		D^{QE}		B		R
C										C
(-B)										

Banks grant loans to non-banking sector:

A	NBS	L		A	Comm. Bank	L		A	Central Bank	L
D^{L}	L			L		D^{L}		B		R
D^{QE}				R		D^{QE}				C
C										

Figure 7: Change in balance sheet positions.

At the beginning of the period, the non-banking sector (NBS) is endowed with bonds B. In a next step, by implementing QE the central bank buys these bonds, which leads to an increase in bank deposits D^{QE} and bank reserve holdings R. Furthermore, there is an increase in currency in circulation C. Next, the bank makes loans L to the non-banking sector. As the bank credits the respective amount to its customers' deposit accounts, bank deposits (D^{L}) increase again. This induces higher MRR for the bank so that the bank's excess reserves decrease. Currency in circulation increases as well, since a certain proportion of the created deposits is withdrawn as cash by the bank's customers.

Managing deposits is costly for the bank. These costs are assumed to increase in D at an increasing rate:

$$G = \frac{1}{2}\gamma D^2. \tag{8}$$

This captures the idea of existing agency costs or regulatory requirements for capital or leverage ratios (Martin et al., 2016).[29] As these costs increase in D and thus in the size of the bank's balance sheet, we refer to them as balance sheet costs.

Managing loans generates costs

$$F = \frac{1}{2}qL^2 \tag{9}$$

for a bank. The quadratic form of this cost function captures the idea that loans differ in their complexity so that the bank adds the least complex loans to its portfolio first.

The bank is required to hold compulsory deposits on its account with the central bank. These required reserves depend on the bank's deposits D and the required reserve ratio r which is set by the central bank:

$$RR = rD. \tag{10}$$

The bank's total reserve holdings R consist of required reserves RR and excess reserves ER, i.e.

$$R = RR + ER. \tag{11}$$

The asset side of the bank's balance sheet thus consists of loans and reserves, the liability side of deposits:

$$L + R = D \tag{12}$$

Considering this balance sheet constraint and (3), (6), (7), (10) and (11), we get

$$ER = \frac{1-r}{1+b}B - \frac{b+r}{1+b}L \ . \tag{13}$$

We denote the interest rate on loans L by $i^L > 0$, the interest rate that the central bank pays on required reserves RR by i^{RO}, and the deposit rate at which the central bank

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[29]Using a theoretical microfounded model, Martin et al. (2013) show that marginal bank balance sheet costs increase due to costly equity requirements which were implemented to overcome banks' moral hazard.

remunerates excess reserves ER by i^{DF}, where $i^L > i^{RO} > i^{DF}$.

4.2 Optimal Bank Loan Supply

The bank wants to maximize its profit Π by deciding on its loan supply. The bank's objective function thus becomes

$$
\begin{aligned}
\max_{L} \Pi = \quad & i^L L - F + i^{RO} RR + i^{DF} ER - i^D D - G \\
= \quad & i^L L - \frac{1}{2} q L^2 + i^{RO} r \left(\frac{B+L}{1+b} \right) + i^{DF} \left(\frac{1-r}{1+b} B - \frac{b+r}{1+b} L \right) \\
& - i^D \left(\frac{B+L}{1+b} \right) - \frac{1}{2} \gamma \left(\frac{B+L}{1+b} \right)^2 .
\end{aligned}
\tag{14}
$$

The first term of the objective function shows a bank's interest revenues from making loans to the non-banking sector. The second term describes its management costs. The third and the fourth term reflect the bank's interest revenues/costs from holding reserves. The fifth term represents the bank's interest costs from paying a return on deposits to its customers. The last term describes the bank's balance sheet costs. Solving the optimization problem, the first order condition (FOC) for optimal loan supply becomes

$$
\frac{\partial \Pi}{\partial L} = i^L - q L^* + i^{RO} \frac{r}{1+b} - i^{DF} \frac{b+r}{1+b} - i^D \frac{1}{1+b} - \gamma \frac{B+L^*}{(1+b)^2} \overset{!}{=} 0 .
\tag{15}
$$

The first term of the FOC reflects the direct marginal interest revenues of granting loans, the second term marginal costs in the form of management costs. Granting loans, the bank credits the respective amount to its customers deposit accounts, i.e. it creates money. For those newly created deposits which are not withdrawn as cash, the bank has to hold required reserves which are remunerated at i^{RO}. The third term thus represents indirect marginal interest revenues (or marginal interest costs if $i^{RO} < 0$) of granting loans in the form of interest revenues (costs) from holding required reserves. These marginal interest revenues (costs) increase in the reserve ratio r and decrease in the currency ratio b which can be explained as follows. If a bank grants one additional unit of loan, it creates in a first step one additional unit of deposits. However, as part of these deposits is withdrawn,

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required reserve holdings increase by $r/(1+b)$ per unit of loan. The fourth term represents opportunity costs/revenues in the form of avoided interest payments. As the additional required reserve holdings as well as the cash withdrawals are met by reducing the bank's excess reserves, there will be some kind of opportunity costs of granting loans in the form of a loss in interest revenues on holding excess reserves if $i^{DF} > 0$. However, if $i^{DF} < 0$, granting loans allows the bank to reduce interest costs combined with holding excess reserves. These opportunity costs/revenues also increase in b and r as increasing currency and/or reserve ratios imply a decrease in excess reserve holdings. The fifth term comprises the bank's marginal interest costs of granting loans in the form of interest payments to its depositors. Again, by granting one more unit of loans, the bank creates in a first step one more unit of deposits. For the proportion of this newly created unit of deposits that is not withdrawn as cash, the bank has to pay the return i^D to the non-banking sector. Obviously, these costs decrease in b.[30] Moreover, for the proportion of the created unit of deposits that is not withdrawn, the bank is exposed to balance sheet costs. The respective marginal costs of granting loans are captured by the last term.

Solving (15) for L^* we obtain the bank's optimal loan supply:

$$
L^* = \frac{i^L(1+b)^2}{q(1+b)^2+\gamma} + \frac{r\, i^{RO}(1+b)}{q(1+b)^2+\gamma} - \frac{i^{DF}(b+r)(1+b)}{q(1+b)^2+\gamma}
$$
$$
- \frac{i^D(1+b)}{q(1+b)^2+\gamma} - \frac{\gamma B}{q(1+b)^2+\gamma}\ . \tag{16}
$$

4.3 Monetary Policy and Bank Loan Supply

In the following, we analyze how monetary policy affects bank loan supply. Our model captures four main elements of the ECB's monetary policy toolkit: the minimum reserve ratio, the MRO-rate, the deposit rate and the large-scale asset purchase programme (QE).

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[30]However, due to the structural liquidty surplus in the banking sector, in the following we assume that i^D already reached the zero lower bound and thus can be neglected.

By using comparative statics, we examine how the bank's optimal loan supply is affected by changes in these variables. Starting with the minimum reserve ratio, we get

$$\frac{\partial L^*}{\partial r} = \frac{(i^{RO} - i^{DF})(1 + b)}{q(1 + b)^2 + \gamma} > 0 \ . \tag{17}$$

The effect of an increase in the reserve ratio on the bank's optimal loan supply is positive. This is a crucial result as this means that an increase in this ratio is an expansionary monetary policy impulse, i.e., changes in the reserve ratio will have exactly the opposite effect on bank loan supply if the banking sector faces a structural liquidity surplus instead of a respective deficit. The explanation is as follows. An increase in bank lending implies the creation of bank deposits for which the bank is required to hold reserves. Since $ER = R - RR$, the bank's excess reserves decrease when required reserves increase. Consequently, an increase in loans implies a reserve shifting from excess reserves to required reserves. As the latter are remunerated at a strictly higher rate $(i^{RO} > i^{DF})$, this reserve shifting, that goes hand in hand with granting more loans, is beneficial. An increase in r means a higher, beneficial reserve shifting and thus implies an increase in marginal revenues of granting loans in the form of higher interest revenues (or lower interest costs)[31] from holding reserves. Obviously, the strength of this beneficial reserve shifting effect on bank loan supply increases with the spread between i^{RO} and i^{DF}, so that we get that

$$\frac{\partial L^*}{\partial i^{DF}} = -\frac{(1 + b)(b + r)}{q(1 + b)^2 + \gamma} < 0 \tag{18}$$

and

$$\frac{\partial L^*}{\partial i^{RO}} = \frac{r(1 + b)}{q(1 + b)^2 + \gamma} > 0 \ . \tag{19}$$

Note that the negative effect of i^{DF} on L^* is the stronger the higher r is, as then granting one more unit of loans results in a more pronounced decline in excess reserves. In the same vein the effect also increases in b. If there were neither cash withdrawals nor MRR

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[31]This reserve shifting will imply marginal revenues of granting loans in the form of lower interest *costs* if $i^{DF} < 0$ and if $|i^{DF}| > |i^{RO}|$.

$(b = r = 0)$, there would not be any impact of increases in i^{DF} on L^*, since granting more loans would then not affect excess reserve holdings. The positive impact of an increase in i^{RO} on L^* decreases in b, since increasing cash withdrawals provoke decreasing deposits and hence also decreasing required reserve holdings and thus declining interest revenues.

The impact of QE on bank loan supply is captured by the first derivative of $L^*(\cdot)$ with respect to B:

$$\frac{\partial L^*}{\partial B} = -\frac{\gamma}{q(1+b)^2 + \gamma} < 0 \ . \tag{20}$$

Implementing QE, the central bank purchases government bonds from the non-banking sector which leads to an increase in B on the asset side and R on the liabilities side of its balance sheet (see Figure 7). The negative impact of QE on bank loan supply results from the bank's balance sheet costs. If we abstain from such costs ($\gamma = 0$), QE will not have any effect on bank loan supply. However, the existence of balance sheet costs implies that if the central bank purchases one more unit of government bonds and thus the amount of deposits in the banking sector increases by $\frac{B}{1+b}$, the bank's costs of granting one more unit of loans in the form of balance sheet costs increase. Hence the bank reduces its loan supply to avoid additional costly increases in deposits.

4.4 Consideration of Heterogeneity

So far we assumed that all commercial banks are identical. This included that they are also affected in the same way by the central bank's large-scale asset purchases, i.e. all banks faced the same increase in deposits D and excess reserves ER due to the central bank's asset purchases B. This allowed us to model the commercial banking sector as a representative entity. However, in Section 3, we showed that in the euro area, banks were affected differently by the Eurosystem's large-scale asset purchases, in particular, that there were country-specific differences.

In a next step we thus analyse how far our results will change if we consider this heterogeneity. As argued in Section 3, the Eurosystem's asset purchases from non-domestic (predominantly even non-euro area) counterparties result in liquidity creation in only a

few financial centres, implying a heterogeneous distribution of excess liquidity across euro area countries. For example with respect to the German banking sector, the creation of excess liquidity, and hence as well the creation of deposits, exceeds the level one would expect according to the asset purchases conducted by the Deutsche Bundesbank. By contrast, with regard to the Italian banking sector, the creation of deposits is below the level corresponding to asset purchases conducted by the Banca d'Italia. The main reason of this unbalanced creation of liquidity and deposits is that a non-negligible part of the assets is purchased from non-euro area counterparties. As those non-euro area counterparties mainly have their current accounts with German commercial banks to access TARGET2, the corresponding amount of deposits is created in the German banking sector although the APP assets are purchased by the Italian central bank. To capture this phenomenon in our model, we consider two banking sectors. One banking sector represents the banking sector of euro area countries being home to financial centres. The banking sector of these countries is characterised by an increase in the amount of deposits going beyond the corresponding level of asset purchases conducted by their respective national central banks and thus as well by a more pronounced increase in the amount of excess liquidity. We refer to these countries as high-liquidity countries. The other banking sector belongs to countries not being home to financial centres, which implies that banks in these countries are not selected as TARGET2 access point by counterparties residented in non-euro area countries. The banking sector of these countries is characterised by an increase in the amount of deposits that is below the according level of asset purchases and is therefore characterised by a less pronounced increase in the amount of excess liquidity. We refer to these countries as low-liquidity countries. Each of the two banking sectors is modelled as a representative bank. For simplification reasons, we consider one representative high-liquidity country and one representative low-liquidity country each endowed with a central bank. We denote the amount of deposits created because of the asset purchases by the central bank in the banking sector of the high-liquidity country by $\overline{D}^{QE}$, and those created in the banking sector of the low-liquidity country by $\underline{D}^{QE}$ respectively. Both central banks buy assets equal to an amount B from the non-banking setor, and both national central

banks buy a share β of these assets from counterparties not residenting in one of the two countries. For the deposits created in both countries we then obtain

$$\overline{D^{QE}} \;=\; \frac{B}{1+b} + \frac{\beta B}{1+b} \;=\; \frac{B}{1+b}(1+\beta)\,, \tag{21}$$

and

$$\underline{D^{QE}} \;=\; \frac{B}{1+b} - \frac{\beta B}{1+b} \;=\; \frac{B}{1+b}(1-\beta) \tag{22}$$

with $0 \leq \beta < 1$. The first term of equation (21) represents the deposits created in the high-liquidity country due to the asset purchases by its central bank. Note that it plays no role that a share β of these assets is purchased from residents outside one of the two countries, as these residents have their deposit account in the high-liquidity country. The second term of (21) represents those deposits created in the high-liquidity country because of the asset purchases of the central bank of the low-liquidity country as a part of the respective counterparties have their account with the bank in the high-liquidity country. The first term of (22) represents all the deposits created through the asset purchases by the central bank of the low-liquidity country. However, a part of these deposits is created in the high-liquidity country as the share β of total asset purchases is bought from counterparties having their deposit accounts in the other country. This part of the newly created deposits is represeted by the second term of (22).

Again, each commercial bank maximises its profit Π by deciding on its loan supply. Hence the bank's adjusted objective function in the respective banking sector now becomes

$$\max_{L} \overline{\Pi} = \quad i^{L}L - \frac{1}{2}qL^{2} + i^{RO}r\left(\frac{B(1+\beta)+L}{1+b}\right) + i^{DF}\left(\frac{(1-r)(1+\beta)}{1+b}B - \frac{b+r}{1+b}L\right)$$

$$-i^{D}\left(\frac{B(1+\beta)+L}{1+b}\right) - \frac{1}{2}\gamma\left(\frac{B(1+\beta)+L}{1+b}\right)^{2}, \tag{23}$$

and

$$\max_{L} \underline{\Pi} = \quad i^{L}L - \frac{1}{2}qL^{2} + i^{RO}r\left(\frac{B(1-\beta)+L}{1+b}\right) + i^{DF}\left(\frac{(1-r)(1-\beta)}{1+b}B - \frac{b+r}{1+b}L\right)$$

$$-i^D\left(\frac{B(1-\beta)+L}{1+b}\right)-\frac{1}{2}\gamma\left(\frac{B(1-\beta)+L}{1+b}\right)^2 \tag{24}$$

respectively. Accordingly, we obtain the optimal loan supply of the representative bank of the high-liquidity country

$$\overline{L^*}= \frac{i^L(1+b)^2}{q(1+b)^2+\gamma}+\frac{r\,i^{RO}(1+b)}{q(1+b)^2+\gamma}-\frac{i^{DF}(b+r)(1+b)}{q(1+b)^2+\gamma}$$
$$-\frac{i^D(1+b)}{q(1+b)^2+\gamma}-\frac{\gamma B(1+\beta)}{q(1+b)^2+\gamma}\;, \tag{25}$$

and for the representative bank of the low-liquidity country

$$\underline{L^*}= \frac{i^L(1+b)^2}{q(1+b)^2+\gamma}+\frac{r\,i^{RO}(1+b)}{q(1+b)^2+\gamma}-\frac{i^{DF}(b+r)(1+b)}{q(1+b)^2+\gamma}$$
$$-\frac{i^D(1+b)}{q(1+b)^2+\gamma}-\frac{\gamma B(1-\beta)}{q(1+b)^2+\gamma} \tag{26}$$

respectively. We are now able to compare the impact of QE on loan supply of the two banks. Building the partial derivative of $L^*(\cdot)$ w.r.t. B, we obtain

$$\frac{\partial \overline{L^*}}{\partial B}=-\frac{\gamma(1+\beta)}{q(1+b)^2+\gamma}<0\;, \tag{27}$$

and

$$\frac{\partial \underline{L^*}}{\partial B}=-\frac{\gamma(1-\beta)}{q(1+b)^2+\gamma}<0\;. \tag{28}$$

The effect of QE on the loan supply of both banks is still negative. If the central bank purchases one more unit of government bonds, the amount of deposits in the banking sector will increase. Consequently, the marginal costs of granting loans in the form of balance sheet costs increase in both banking sectors, so that the bank in the high-liquidity as well as in the low-liquidity country will reduce its loan supply. However, the extent of this effect differs between both countries. As the increase in deposits is higher in the high-liquidity country than in the low-liquidity country, the negative effect is stronger in the former country as revealed by equations (27) and (28). The greater β, which means

the greater the share of government bonds purchased from residents outside the considered countries, the larger is the decrease in loan supply in the high-liquidity country and the smaller is the decrease in the low-liquidity country:

$$\frac{\partial^2 \overline{L^*}}{\partial B \ \partial \beta} = - \ \frac{\gamma}{q(1+b)^2 + \gamma} < 0 \ , \tag{29}$$

$$\frac{\partial^2 \underline{L^*}}{\partial B \ \partial \beta} = \ \frac{\gamma}{q(1+b)^2 + \gamma} > 0 \ . \tag{30}$$

5 Implications for Monetary Policy in the Euro Area

Based on the previous findings, we discuss two issues with respect to monetary policy in the euro area. First, we consider the possibility that the Eurosystem's large-scale asset purchases may exert influence on the real economy through the so-called bank lending channel. Second, we analyse consequences of the structural liquidity surplus in the banking sector, induced by the Eurosystem's asset purchases, for the implementation of other monetary policy instruments than QE.

Existence of a Bank Lending Channel

When central banks purchase assets, e.g. government bonds, from commercial banks or from the non-banking sector, excess reserves and bank deposits increase (see Section 2). Our model analyzes whether this leads to an increase in bank loan supply and thus whether there is evidence of existence of a bank lending channel. Traditional approaches to the bank lending channel investigate how bank loan supply responds to monetary shocks that affect the quantity of deposits and thus the liability side of banks' balance sheet. For instance, an expansionary monetary policy that increases bank reserves and bank deposits also increases the quantity of bank loans available. Lojschova (2017) argues that in the euro area excess reserves are remunerated at a relatively low rate and that banks therefore

may benefit from an expansion of lending to reduce their costly excess reserve holdings. This is what she refers to as bank lending channel.

However, in our model, such a bank lending channel does not exist. Asset purchases of the central bank actually increase excess reserves and deposits, but this has no or even a negative effect on bank loan supply. For the negative effect, the banks' increasing marginal costs of holding deposits (balance sheet costs), due to for example regulatory issues or agency costs, play a crucial role. Granting loans implies the creation of deposits. Consequently, the balance sheet costs add to the increasing marginal management costs of granting loans. The central bank's asset purchases imply increasing deposits and hence also increasing marginal costs of granting loans and therefore a reduction in loan supply.

If there are no increasing marginal costs of holding deposits, asset purchases will have no impact on bank loan supply as they do not influence the bank's marginal costs or marginal returns of granting loans: neither marginal interest costs or revenues of granting loans, nor marginal management costs or marginal balance sheet costs of granting loans will change if the bank's excess reserves and deposits increase due to the central bank's large-scale asset purchases (see equation 15). Note that even a negative interest rate on excess reserve holdings will not incentivise banks to grant more loans if their excess reserves increase. The reason is that in the absence of increasing marginal balance sheet costs, APP-induced larger quantities of excess reserves and deposits do not affect marginal costs/marginal revenues of granting loans.

Besides the balance sheet costs, also the management costs play a crucial role for our results. If there are no increasing marginal management costs ($q = 0$), there will be a corner solution. Optimal bank loan supply will be either zero (if constant marginal costs of granting loans are higher than constant marginal revenues of granting loans), or limited by the bank's reserves.[32] If the latter is the case, the central bank's asset purchases will have a positive effect on bank loan supply. However, in the euro area, banks operate under a strucutral surplus of reserves. Thus, there is no binding limit of reserves.

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[32]However, note that an increase in loan supply will not decrease excess reserve holdings to the same extent. For example, assuming a minimum reserve ratio of 1% and cash withdrawals in the amount of 14%, Bucher and Neyer (2016) show that, granting a loan in the amount of 100 euros, the bank creates an additional structural need of reserves amounting to 15 euros. Thus, to entirely eliminate excess reserve holdings, the bank must grant an amount of loans that is almost seven times greater than the amount of its excess reserve holdings.

Furthermore, the APP-induced increased excess reserves are heterogeneously distributed across euro area countries (see Section 3). Concerning our model results, the extent of the negative effect on bank loan supply therefore varies across euro area countries. Countries exposed to larger amounts of excess reserves and bank deposits consequently face larger balance sheet costs and are therefore more concerned by the negative impact on loan supply (see Section 4).

Consequences for Monetary Policy Implementation: MRO-Rate

With respect to the consequences of the structural liquidity surplus in the banking sector for the implementation of other monetary policy instruments than QE, our model shows that some main elements of the ECB's monetary policy toolkit, in particular the MRO-rate, the minimum reserve ratio and the deposit rate, affect bank loan supply differently in times when the banking sector is exposed to a structural liquidity surplus instead of a structural liquidity deficit. Note that when discussing the tools of monetary policy, traditional textbooks usually consider a structural liquidity deficit (see e.g. Mishkin (2018, Section 15)). In the respective models, commercial banks do not hold excess reserves. Thus they rely on an ongoing liquidity provision by the central bank to cover cash withdrawals and MRR.

This means with regard to the euro area that an increase in the MRO-rate – the rate which is applied on the ECB's refinancing operations as well as on required reserve holdings – has a strictly negative impact on bank loan supply as banks' funding costs in the ECB's refinancing operations increase. However when banks face a structural liquidty surplus, they no longer need to take part in refinancing operations. In this context, a higher MRO-rate just positively affects their returns from fulfilling their MRR. Since this implies increasing marginal revenues of granting loans (see Section 4), banks will expand their loan supply. Consequently, according to our model results, the central bank must increase rather than decrease the MRO-rate to boost bank loan supply in times when the banking sector is exposed to a structural liquidity surplus.

Consequences for Monetary Policy Implementation: Minimum Reserve Ratio

The model is also suitable to compare the effect of changes in the MRR, in periods characterized by a structural liquidity deficit in the banking sector with periods in which banks face a structural liquidity surplus. MRR imply a structural demand for reserves (see Section 2). If the euro area banking sector operates under a structural liqudity deficit, it will borrow the respective reserves from the Eurosystem's MROs. Credit expansion leads to the creation of deposits for which banks are required to hold (costly) reserves. Although MRR are remunerated at the same rate at which they are borrowed from the Eurosystem (the MRO-rate), holding required reserves will be costly if additional costs accrue when borrowing from the central bank, for example collateral costs. In this case, increasing the minimum reserve ratio will have a contractionary impact on bank loan supply. Also the very simple and strongly criticized money multiplier underscores the traditionally assumed contractionary impulse of an increase in the minimum reserve ratio. Neglecting for short currency holdings of the non-banking sector ($b = 0$), the money multiplier is defined as $\frac{1}{r}$. For a given amount of reserves (R) supplied by the central bank, due to the binding money multiplier constraint, the whole banking sector can hold a maximum amount of deposits equal to $D = \frac{1}{r}R$. Taking into account a balance sheet restriciton $D = L + R$ for banks, the maximum amount of loans the banking sector can provide is restricted to $L = (\frac{1-r}{r})R$. A higher reserve ratio implies that for any given amount of reserves (monetary base), banks can create less deposits, i.e. they make less loans.

However, in our model the negative relationship between the reserve ratio and bank loan supply does no longer exist. An increase in the minimum reserve ratio implies an increase in banks' structural liquidity needs. But as long as the banking sector still operates under a structural liquidity surplus, there is no need for banks to take part in the ECB's refinancing operations to cover such risen liqudity needs. On the contrary, the increased minimum reserve ratio allows banks to increase their holdings of required reserves at the expense of excess reserve holdings. This reserves shifting is beneficial as required reserves are remunerated at a higher rate than excess reserves, i.e. indirect marginal interest revenues of granting loans increase, so that banks will expand their loan supply. Therefore, in our model, an increase in the minimum reserve ratio corresponds to

an expansionary monetary policy impulse. Consequently, a central bank must increase rather than decrease the minimum reserve ratio to boost bank loan supply at times when banks face a structural liquidity surplus.

Consequences for Monetary Policy Implementation: Deposit Rate

Alternatively, or complementarily, the ECB can reduce its deposit rate – the rate at which excess reserve holdings are remunerated. In an environment characterized by a structural liquidity surplus, the deposit rate has a different meaning or effect than in an environment characterized by a structural liquidity deficit. If there is a structural liquidity deficit which is (exactly) covered by the central bank's MROs and if there is furthermore a functioning interbank market, the deposit rate will have no systematic effect on bank loan supply. If the interbank market does not function properly, banks will hold precautionary liquidity. The respective amount increases in their loan supply. A decrease in the deposit rate makes holding precautionary liquidity more expensive and thus has a negative impact on bank loan supply (Bucher et al., 2014). However, if the banking sector faces a structural liquidity surplus (in this case we even mean banks have more liquidity than they need to cover the structural liquidity deficit resulting from MRR, autonomous factors and their need for precautionary liquidity), an increase in the deposit rate will negatively affect bank loan supply. Holding excess reserves becomes less expensive, so that the incentive to reduce these reserve holdings by granting more loans decreases. This is the case since opportunity costs of granting loans increase (if $i^{DF} > 0$) or since avoided (penalty) interest payments decrease (if $i^{DF} < 0$).

6 Summary

In March 2015, the Eurosystem started implementing its large-scale asset purchase programme, also known as quantitative easing (QE), to address the risks of a too prolonged period of low or even negative inflation rates since the beginning of 2013. As a consequence of these asset purchases, excess liquidity and deposits held by the euro area commercial

banking sector increased to unprecedented levels. Excess liquidity rose from 200 billion euros in March 2015 to 1.9 trillion euros in December 2018.

The large quantity of excess liquidity has generated a great amount of concern and debate. However, there is little analysis whether and to what extent excess liquidity affects bank loan supply. Developing a theoretical model of the euro area banking sector, we show that large quantities of excess liquidity and deposits have no or even a contractionary impact on bank loan supply. The effect will be contractionary if banks have increasing marginal costs of holding deposits, for example due to agency or regulatory costs.

As the – due to the Eurosystem's large-scale asset purchases – newly created excess reserves and deposits are heterogeneously distributed among euro area member states, the impact of QE on bank loan supply may differ across countries. Banks in countries which are exposed to larger amounts of excess liquidity and deposits consequently have larger marginal costs of holding deposits. Banks in those countries will decrease their loan supply to a greater extent than banks in countries with less pronounced amounts of excess liquidity and deposits.

Since October 2015, the reserves exclusively provided through the Eurosystem's large-scale asset purchases have exceeded the banking sector's structural liquidity needs resulting from MRR and autonomous factors. Consequently, since then banks have operated in an environment characterized by a structural liquidity surplus. This has important implications for monetary policy implementation in the euro area. Increases in the central bank's MRO-rate as well as in the minimum reserve ratio and/or decreases in the central bank's deposit rate develop expansionary effects on bank loan supply – contrary to the case in which banks are exposed to a structural liquidity deficit.

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