# Asymmetric Effects of Monetary Policy in the Euro Area

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# Contents

# General Introduction

The European Central Bank (ECB) pursues the primary objective of ensuring price stability. According to the ECB's Governing Council, price stability is best maintained by aiming for a symmetric 2% inflation target in the medium term (European Central Bank, 2021a). Considering times of too low inflation rates, the ECB implements conventional expansionary monetary policy by decreasing its short-term monetary policy key interest rates.[1] The intention in doing so is to directly lower commercial banks refinancing costs so that commercial banks pass on their improved refinancing conditions to the real economy resulting in an increase in households' consumption and firms' investment spending and thus in higher credit lending in the economy (European Central Bank, 2002, 2012). Consequently, aggregate demand and thus overall prices in the economy are supposed to increase (traditional *interest rate channel* of monetary policy).

However, when short-term interest rates have reached the *effective lower bound*, further interest rate cuts – and hence also expansionary monetary policy stimuli via the traditional interest rate channel – are no longer feasible. Then, the ECB introduces unconventional monetary policy instruments to directly reduce longer-term interest rates. In this context, the ECB launched its large-scale asset purchase program, commonly referred to as quantitative easing (QE), in March 2015 to address the risks of a too prolonged period of low, temporarily even negative, inflation rates. When the ECB purchases assets on a large scale, it creates a scarcity of these assets, implying that the respective asset prices increase and yields drop. Long-term interest rates are intended to decrease on a broad scale as a consequence. This should finally trigger economic activity by improving financing conditions for households and firms, and thus increase prices (European Central Bank, 2015).

The ECB's large-scale asset purchases are funded by the creation of new reserves (central bank money). Therefore, as a side effect, the amount of excess liquidity in the euro area banking sector has increased continuously since implementation of the QE program

[1] The ECB's short-term monetary policy key interest rates involve (i) the rate on its main refinancing operations with euro area commercial banks, (ii) the rate on its overnight deposit facility, and (iii) the rate on its marginal lending facility (European Central Bank, 2002).

began.[2] In March 2020, the ECB decided to expand its large-scale asset purchases in response to the COVID-19 pandemic. As a consequence, the amount of excess liquidity in the euro area banking sector has continued to increase, reaching unprecedented levels. Moreover, excess liquidity is distributed heterogeneously across euro area member states. The bulk of this liquidity is held by only a few countries. The overall increase in excess liquidity has been accompanied by a similarly strong and heterogeneous increase in TARGET2 balances.[3]

The large quantity of excess liquidity in the euro area banking sector has generated a great amount of concern and debate. However, there has been very little analysis of whether and to what extent large quantities of excess liquidity affect macroeconomic variables (in different countries of a monetary union). Against this background, all three papers of this thesis deal with the consequences of the implementation of the ECB's large-scale asset purchases (QE), especially with large amounts of heterogeneously distributed excess liquidity in the euro area banking sector. The content of all three papers in the thesis are summarized briefly in the following.

The **first** paper entitled 'The Impact of Quantitative Easing on Bank Loan Supply and Monetary Policy Implementation in the Euro Area' (co-authored by Ulrike Neyer) contributes to the existing literature in two ways. The first part of the paper analyzes and compares the Eurosystem's liquidity management during *normal times*, *crisis times* and *times of too low inflation*. Focussing on the latter and considering specific institutional characteristics of the implementation of QE in the euro area, we describe the QE-induced creation of bank reserves and deposits as well as the causes of their heterogeneous distribution across euro area countries. Building on this, the second part of the paper develops a theoretical model to investigate whether QE may be transmitted to the real economy via the so-called *bank lending channel*. Against this background, it is analyzed whether the QE-induced increases in excess liquidity and bank deposits have a positive impact on bank loan supply, and if so, whether the effects differ across euro area countries due to the

[2]Excess liquidity is defined as the amount of commercial banks' current account balances at their national central bank beyond the minimum reserve requirements (excess reserves) plus their recourse to the ECB's overnight deposit facility.

[3]TARGET2 stands for *Trans-European Automated Real-time Gross Settlement Express Transfer System 2*. TARGET2 balances are claims and liabilities of euro area national central banks vis-à-vis the ECB and measure the net amount of cross-border payments in central bank money (reserves) between euro area national central banks (European Central Bank, 2021b).

existing heterogeneous distribution of excess liquidity and bank deposits. At the model's centre is 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. Moreover, the model allows for a discussion of the consequences of a QE-induced structural liquidity surplus in the banking sector on the implementation of other (conventional) monetary policy instruments.[4]

We find that increasing excess reserves and bank deposits have no or even a contractionary effect on bank loan supply. The impact will be contractionary if banks face increasing marginal costs of holding deposits, for instance due to agency or regulatory costs. Following the literature, we refer to these costs as balance sheet costs (see, for example, Martin et al. (2013, 2016), Ennis (2018), Kumhof and Wang (2021), and Williamson (2019)). Thus, we cannot document evidence of the presence of a bank lending channel in the sense that a QE-induced increase in bank deposits and reserves implies a positive effect on bank loan supply. Our model moreover shows that the strength of the contractionary effect on bank loan supply increases in the banks' holdings of excess reserves. Hence the negative impact of QE on bank loan supply differs across euro area countries in accordance with the asymmetric distribution of excess reserves and deposits in the euro area. Last but not least, our model reveals that conventional monetary policy measures such as changes in the central bank's main refinancing and deposit rates or changes in the required minimum reserve ratio will have the opposite effect if the banking sector is exposed to a – for example QE-induced – structural liquidity surplus instead of a structural liquidity deficit. A decrease in the ECB's main refinancing rate then has contractionary effects on bank loan supply, for instance.

The **second** paper entitled 'Asymmetric Macroeconomic Effects of QE and Excess Reserves in a Monetary Union' (co-authored by Ulrike Neyer and Daniel Stempel) develops a two-country New Keynesian model to analyze the macroeconomic effects of QE, explicitly considering the QE-induced strong and heterogeneous increases in excess reserves and

[4]In contrast to the situation of a structural liquidity surplus, a banking sector which is exposed to a structural liquidity deficit has to rely on ongoing liquidity provision by the central bank to cover its structural liquidity needs resulting from minimum reserve requirements imposed by the central bank and autonomous factors, e.g., cash withdrawals. Since October 2015, the reserves created through the ECB's large-scale asset purchases have exceeded the banking sector's structural liquidity needs (data source: ECB). Consequently, banks started operating in an environment characterized by a structural liquidity surplus.

deposits in a monetary union. The model is calibrated to represent a high- and a low-liquidity euro area country. This allows us to capture the observed consequences of the specific implementation of QE in the euro area. The core model framework of each country partly resembles the setup of the closed economy modeled by Gertler and Karadi (2011, 2013). Each country consists of five types of agents: Households, intermediate goods firms, capital producing firms, retail firms, and banks. In addition, there is a union-wide central bank which implements monetary policy. In our model, we assume that the short-term interest rates have already reached the effective lower bound so that the central bank uses QE as its main monetary policy tool to directly lower long-term interest rates. Banks create deposits by granting loans to the intermediate goods firms. Moreover, they are exposed to an increase in deposits due to the central bank's asset purchases (QE). The increase in QE-created deposits implies additional costs for banks which rise in the size of the banks' balance sheets (balance sheet costs). We analyze the model responses to two different shocks: a preference shock and a deposit shift shock (sudden deposit shift between the two countries).

After a negative preference shock that implies a decrease in household consumption, for instance driven by the COVID-19 pandemic, the central bank reacts to the shock-induced decreasing union-wide inflation with QE. The long-term interest rates decrease, triggering economic activity and thus an increase in the union-wide consumer price inflation (*interest rate channel of QE*). Hence, we find that QE works as expected as an expansionary monetary policy tool. However, the QE-induced increase in excess reserves and deposits leads to higher (balance sheet) costs for banks, implying a dampening effect on bank lending. The interest rate channel of QE is therefore dampened by a *reverse bank lending channel*. These weakening effects are more pronounced in the high-liquidity country. The deposit shift shock implies that deposits and thus (excess) reserves are moved from the low- to the high-liquidity country, which can be interpreted as capital flight, for instance. This increase in deposits and excess reserves leads to higher balance sheet costs for banks in the high-liquidity country. Consequently, in that country, the deposit shift has a dampening effect on economic activities. Conversely, the low-liquidity country benefits from the deposit shift.

The **third** paper entitled 'Asymmetries in TARGET2 Balances in the Euro Area' (co-authored by Ulrike Neyer) deals with the large and asymmetric increases in TARGET2 balances in the euro area since 2008. TARGET2 balances emerge as a result of cross-border payments in central bank money (reserves) between euro area national central banks. There is an ongoing debate about the appropriate interpretation and policy reaction of asymmetric TARGET2 balances across euro area countries. Against this background, the first part of the paper examines the drivers of the asymmetric increases in TARGET2 balances that have emerged in the context of the financial and sovereign debt crises as well as in the context of the ECB's implementation of QE and the COVID-19 pandemic. The second part of the paper analyzes the potential risks for euro area member states in the case of (i) the unchanged continuity of the monetary union, (ii) the withdrawal of a member state with (large) TARGET2 liabilities, and (iii) the break-up of the whole monetary union.

It is shown that the drivers and interpretation of large and asymmetric TARGET2 balances change over time and depend on different scenarios. While the emergence of TARGET2 balances in the context of the financial and sovereign debt crises can be interpreted as a sign of crises, their emergence in the context of the ECB's QE program and the COVID-19 pandemic is mainly a consequence of the technical particularities with regard to the ECB's implementation of large-scale asset purchases and thus no longer a sign of crises. In particular, (large) TARGET2 imbalances are a symptom of the decentralized implementation of monetary policy by the respective euro area national central banks.

We find that, depending on the outcome of exit negotiations and the subsequent operational handling, direct risks in the form of default losses of TARGET2 balances and indirect risks in the form of threat potentials, if TARGET2 debtor countries pretend to plan to leave the euro area, may not be excluded. Based on this, we discuss adaption options for the TARGET2 payment system such as the introduction of progressively rising penalty rates for TARGET2 balances, a mandatory cap limiting the TARGET2 balances, or a collateralization of TARGET2 balances, for example. However, since (large) TARGET2 imbalances are not a reason but a symptom of an asymmetric creation of reserves between euro area national central banks, solutions that do not address the TARGET2 payment system directly and exclusively but rather concern the ECB's general monetary policy are potentially more appropriate. Therefore, we discuss an exit from the ECB's accommodative monetary policy in order to scale back the high amount of excess liquidity in the euro area banking sector which is an essential prerequisite for the emergence of TARGET2 balances. As soon as the ECB starts to scale back its unconventional expansionary monetary policy measures and the amount of excess liquidity created by those measures decreases, TARGET2 balances are also expected to drop.

## Bibliography


Ennis, H. M. (2018). A simple general equilibrium model of large excess reserves. *Journal of Monetary Economics 98*, 50–65.

European Central Bank (2002). The liquidity management of the ECB in the context of the operational framework of the Eurosystem. *ECB Monthly Bulletin, May 2002*, 41–52.

European Central Bank (2012). The implementation of monetary policy in the euro area. General documentation on Eurosystem monetary policy instruments and procedures. *European Central Bank, Frankfurt a.M., 2012*.

European Central Bank (2015). ECB announces Expanded Asset Purchase Programme. *Press release, 22 January 2015*.

European Central Bank (2021a). ECB's Governing Council approves its new monetary policy strategy. *Press release, 8 July 2021*.

European Central Bank (2021b). What is TARGET2? `https://www.ecb.europa.eu/paym/target/target2/html/index.en.html`. [Online; accessed 17-October-2021].

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Gertler, M. and P. Karadi (2013). QE 1 vs. 2 vs. 3...: A framework for analyzing large-scale asset purchases as a monetary policy tool. *International Journal of Central Banking 9*(1), 5–53.

Kumhof, M. and X. Wang (2021). Banks, money and the zero lower bound on deposit rates. *Journal of Economic Dynamics and Control*, 104–208.

Martin, A., J. McAndrews, A. Palida, and D. Skeie (2013). Federal Reserve tools for managing rates and reserves. *Federal Reserve Bank of New York, Staff Report No. 642*.

Martin, A., J. McAndrews, and D. Skeie (2016). Bank lending in times of large bank reserves. *International Journal of Central Banking 12*(4), 193–222.

Williamson, S. D. (2019). Interest on reserves, interbank lending, and monetary policy. *Journal of Monetary Economics 101*, 14–30.

# Paper I:

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

Maximilian Horst Ulrike Neyer

**Abstract**

In March 2015, the Eurosystem launched its QE programme. The asset purchases induced a rapid and strong increase in excess reserves, implying a structural liquidity surplus in the euro area banking sector. Against this background, the first part of this paper analyses the Eurosystem's liquidity management during *normal times*, *crisis times* and *times of too low inflation*. With a focus on the latter, the second part of this paper develops a relatively simple theoretical model in which banks operate under a structural liquidity surplus. The model shows 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. 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.

*JEL classification:* E43, E51, E52, E58, G21.

*Keywords:* monetary policy, quantitative easing (QE), monetary policy implementation, excess liquidity, loan supply, bank lending channel.

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# 1 Introduction[1]

In March 2015, the Eurosystem[2] started implementing its large-scale asset purchase programme – 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 beginning 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 it is no longer possible to reach expansionary monetary policy stimuli through conventional interest rate cuts.[3] 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. Hereby, 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).[4]

There are various channels by which QE may be transmitted to the real economy.[5] 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 deposits on banks' current accounts with the central bank and currency physically held by banks. Excess reserves are defined as the amount of commercial banks' current account balances (CAB) at their national central bank in excess of the minimum reserve requirements (MRR). Excess liquidity is a concept different from excess reserves and can be significantly larger, since banks' recourse to the

[1]This version of the paper has been published in the *Review of Economics*, Vol. 70(3), Dec 2019, pp. 229–265.

[2]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.

[3]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).

[4]Note that the ECB updated its quantitative definition of price stability in the context of its monetary policy strategy review in July 2021. Accordingly, the Governing Council stressed that it will aim for a symmetric 2% inflation target over the medium term to provide a safety margin against the risk of deflation (for detailed information, see European Central Bank (2021b)).

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

deposit facility is additionally taken into account in the calculation of excess liquidity. However, to simplify matters, for our analysis we use the terms *excess liquidity* and *excess reserves* interchangeably. We refer to them as all central bank overnight deposits beyond the MRR and hence do not make a distinction between whether they are held on a current account or in the deposit facility.

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 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 liquidity is costly. In particular, the kind of "penalty interest rate" banks have to pay on excess liquidity[6] has caused a debate as to whether commercial banks may have an incentive to expand lending to reduce their costly excess liquidity holdings (see e.g., Keister and McAndrews, 2009). This is in line with the question of how far a QE-induced increase in bank 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.

The contribution of our paper to this debate is twofold. First, it analyses and compares the Eurosystem's liquidity management during *normal times*, *crisis times* and *times of too low inflation*. Focussing on the latter and considering the specific institutional characteristics of the QE-implementation in the euro area, we describe and analyse in detail the QE-induced creation of bank reserves and deposits and the causes of their heterogeneous distribution across euro area countries. Second, focussing on the *times of too low inflation*, the paper develops 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

[6]Since June 2014 excess liquidity has been remunerated at a negative rate, currently (since September 2019) at -0.5%. 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.

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 in the sense that a QE-induced increase in bank deposits and reserves implies a positive impact on bank loan supply. We find that increasing excess reserves and deposits in the euro area banking sector 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 states. Concerning the third issue, our model shows that conventional monetary policy measures will work in the opposite direction if the banking sector faces – for example, a QE-induced – structural liquidity surplus instead of a structural liquidity deficit.[7] Since October 2015 the reserves 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 characterised 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 the rate on its MROs, (ii) implements higher MRR for banks, and (iii) decreases the rate on its deposit facility.

The paper is organised as follows. Section 2 presents related literature. Section 3 proceeds with an overview of commercial banks' liquidity needs and liquidity provision by the Eurosystem in *normal times*, *crisis times* and in *times of too low inflation* and, with a focus on the latter, provides some stylised facts with regard to the effects of the implementation of the Eurosystem's QE programme. Section 4 describes the model framework and

[7]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.

derives banks' optimal loan supply to the non-banking sector. Implications for monetary policy implementation are discussed in Section 5. Section 6 concludes.

## 2 Related Literature

Our paper contributes to two strands of literature. The first strand is primarily related to the literature on the bank lending channel of monetary policy transmission which is a subchannel within the credit channel. The credit channel theory states that credit market frictions, especially in the form of asymmetric information between lenders and borrowers, amplify conventional interest rate effects. The frictions drive a wedge between the cost of funds generated internally and the cost of funds raised externally, i.e., there is an external finance premium.[8] According to the credit channel theory, the direct effects of monetary policy on interest rates are amplified by changes in the external finance premium. The credit channel theory offers two explanation for this amplification: the balance sheet channel and the bank lending channel. While the former focusses on the impact of monetary policy on the borrowers' balance sheets,[9] the latter focusses on bank loan supply. The bank lending channel stresses that, for example, a contractionary monetary policy leads to a loss of deposits, forcing banks to rely on other, more costly liabilities. The bank loan supply curve shifts to the left, raising the external finance premium.[10]

More recent work attempts to assess the effects of central banks' large-scale asset purchase programmes (QE) in this context. There are various empirical studies that

[8]The external finance premium reflects deadweight costs linked with the principal-agent problem that typically exists between borrowers and lenders, such as the lender's expected costs of evaluation and monitoring, or the "lemons" premium that results from the fact that the borrower has better information than the lender with regard to its own prospects (Bernanke and Gertler, 1995).

[9]The main idea is that, e.g., a contractionary monetary policy deteriorates the borrower's financial position (lower cash flow due to higher interest payments, lower collateral value due to declining asset prices). The deterioration of the financial position increases agency costs, and thus the external finance premium.

[10]For a detailed description and discussion of the credit channel of monetary policy, see e.g., Bernanke and Blinder (1988) and Bernanke and Gertler (1995). Kashyap and Stein (1995) show that monetary tightening reduces lending by relatively small banks which have a very simple capital structure and are financed almost exclusively with deposits and common equity. Analogously, Campello (2002) provides evidence that contractionary monetary policy reduces the amount of loans made by banks that are unrelated to a large banking group. Kashyap and Stein (2000) and Kashyap et al. (2002) explain the same mechanisms for banks that hold fewer liquid assets, showing that such banks cannot protect their loan portfolio against monetary tightening simply by drawing down cash and securities. Kishan and Opiela (2000) and Gambacorta and Mistrulli (2004) carry out the analysis for banks with higher leverage ratios. They provide evidence that small, undercapitalised banks may not be able to offset a drain in demand deposits. Consequently, their loan supply will be more responsive to monetary policy shocks than that of larger, well-capitalised banks.

investigate the impact of QE on bank lending in general. Examples include Bowman et al. (2015) for Japan, Garcia-Posada and Marchetti (2016) for Spain, and Rodnyansky and Darmouni (2017) for the US showing different results. However, only limited attention has been paid to assessing whether QE has worked its way through the economy via the bank lending channel, i.e., whether QE-induced increased levels of bank reserves and deposits imply an expansion of bank loan suply. For instance, Butt et al. (2014), looking at the UK experience, do not find significant effects of QE-induced increasing deposits in banks' balance sheets on bank lending. They argue that the deposits created through QE had a rather flighty nature. Giansante et al. (2020) employ a difference-in-differences estimation to assess the impact of QE-induced increases of bank reserves and deposits on bank lending. By comparing UK banks that received deposit injections due to the Bank of England's asset purchases, with those that did not, they find that "QE-banks" show no increase in bank lending compared to the "non-QE-banks". They even find a reduction of about 50% of customer/retail loans for "QE-banks" compared to "non-QE-banks".

The second strand of related literature deals with monetary policy implementation.[11] There is a long tradition of developing models to analyse monetary policy implementation in an environment with *scarce reserves*. The seminal contribution by Poole (1968) posits a downward-sloping demand curve for reserves and analyses how the Federal Reserve could target the desired Federal Funds Rate by manipulating the supply of reserves. Poole's idea of using a late payment shock, to which banks are exposed to, to introduce uncertainty into his stochastic bank reserve management model, has been used in various papers.[12] However, to date, only very few papers have attempted to study the effects of monetary policy in an environment with *excess reserves*, induced, for instance, by the central bank's large-scale asset purchases. Examples include Martin et al. (2013, 2016), Ennis (2018), and Williamson (2019). These papers consider so-called balance sheet costs of commercial banks. These costs, e.g., in the form of agency or regulatory costs, may occur and increase if a commercial bank's balance sheet increases, e.g., as a consequence of the central bank's large-scale asset purchases. Developing a general equilibrium macroeconomic model Ennis

[11] For a survey, see e.g., Friedman and Kuttner (2011). By describing and discussing different parts of a central bank's operational framework, Bindseil (2014) gives a broad survey of monetary policy implementation in times of non-crisis and crisis.

[12] See e.g., Furfine (2000), Bindseil et al. (2006), Whitesell (2006), Bech and Monnet (2016), and Bucher et al. (2020).

(2018) shows that due to these costs sufficiently large asset purchases imply that the tight link between bank reserves and the price level in the economy reemerges. Williamson (2019) uses a general equilibrium model with two banking sectors in which one banking sector is exposed to balance sheet costs due to capital requirements. He shows, inter alia, that then the large-scale asset purchases can have redistributive effects and reduce welfare. The work by Martin et al. (2016), which is a very close reference to our paper, finds that due to bank balance sheet costs, large-scale asset purchases by the central bank may reduce bank lending. In their model, the government issues a fixed amount of bonds which are bought by the central bank and by households. The central bank funds its government bond purchases by issuing an equal amount of reserves. Households are endowed with a fixed amount of wealth which they invest in deposits, government bonds and/or storage. Households buy all the bonds not being purchased by the central bank. As long as commercial banks face no additional costs related to their deposit holdings and thus to the size of their balance sheet (balance sheet costs), the households' return on deposits is higher than their return on storage. Consequently, households invest the difference between their total wealth and their government bond holdings only in deposits, they hold no storage. An increase in the central bank's purchases of government bonds thus implies an increase in reserves, a decrease in the households' bond purchases and thus an increase in deposits. The increase in the households' deposits is equal to the increase in reserves issued by the central bank. The quantity of bank loans remains constant. However, if banks face balance sheet costs, they pass on these costs to the households by paying a lower return on deposits. For sufficiently large bond purchases by the central bank and thus sufficiently large reserves and deposit holdings, the balance sheet costs become so high and the return on deposits so low that households prefer to hold storage instead of deposits. In this case, bank reserves increase more than deposits and, considering the bank balance sheet constraint, hence partially crowd out bank lending. In contrast to the paper by Martin et al. (2016), we consider that the central bank as well as commercial banks create money in the form of deposits. Commercial banks create deposits by granting loans to the non-banking sector, the central bank creates deposits by purchasing bonds from the non-banking sector (QE). The induced increases in bank deposits imply higher balance sheet costs for banks. As a result, banks will reduce their loan supply to avoid additional increases in costly deposits.

Our paper combines these two described strands of literature. The novelty of our paper is that it provides a detailed description of the consequences of the specific QE implementation in the euro area for the commercial banks' liquidity situation which constitutes the base of a theoretical model that we develop. Considering main elements of the Eurosystem's operational framework, the model allows us to analyse the impact of QE-induced increasing excess liquidity on bank loan supply, as well as the implications for the implementation of conventional monetary policy instruments in an environment characterised by a structural liquidity surplus in the banking sector. We show that QE-induced increases in excess liquidity have no or a contractionary effect on bank loan supply and that, for instance, increases in the minimum reserve ratio and the MRO-rate as well as decreases in the deposit rate incentivise banks to expand their loan supply – contrary to the situation in which banks face a structural liquidity deficit.

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

The Eurosystem's large-scale asset purchases (QE) lead to the creation of bank reserves and bank deposits. This implies that since October 2015 the euro area banking sector has faced a structural liquidity surplus. The newly created reserves and deposits are heterogeneously distributed across euro area countries. Both the structural surplus and the heterogeneous distribution has important implications for bank loan supply and for the effects of conventional monetary policy as revealed by our model analysis in Section 4. To get a better understanding of the institutional environment thus used in Section 4, Section 3.4 describes and analyses in detail how bank reserves and deposits are created in the context of the Eurosystem's QE-programme and why they are heterogeneously distributed across euro area countries. To emphasise the importance of the QE-induced change in the institutional environment for the euro area banks' liquidity management and thus for their loan supply as well as for the effects of conventional monetary policy, Section 3.1 gives a brief overview of the euro area banking sector's liquidity needs in general, whereas Section 3.2 and Section 3.3 briefly describe the banks' specific liquidity needs and the liquidity provision by the Eurosystem before QE was introduced.

## 3.1 Liquidity Needs of the Euro Area Banking Sector

In the euro area, the banking sectors' needs for reserves primarily result from the MRR imposed by the ECB and so-called autonomous factors. Note that MRR are remunerated at the ECB's main refinancing rate. 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. 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, i.e., there will be no need for reserves going beyond the structural need of the banking sector. 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 being 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 demand for reserves beyond the structural need due to MRR and autonomous factors.[13]

The reasons why banks want to hold reserves (MRR, cash withdrawals, precautionary liquidity) reveal that bank deposits are a crucial determinant of bank demand for reserves: bank deposits determine the reserve requirements; they determine the cash withdrawals,

[13]Developing a theoretical model, Bucher et al. (2020) show that interbank market frictions may imply that banks will start to hold precautionary liquidity.

as people usually 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 (see Bucher et al. (2020)). 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.

### 3.2 Normal Times

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 for an efficient distribution of reserves across banks, in principle. 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 MROs. MROs are regular liquidity-providing credit transactions with a frequency and maturity of typically one week. These credit transactions have to be based on 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, see Figure 1.[14]

[14] For a general documentation on the implementation of standard monetary policy by the Eurosystem, see European Central Bank (2012a).

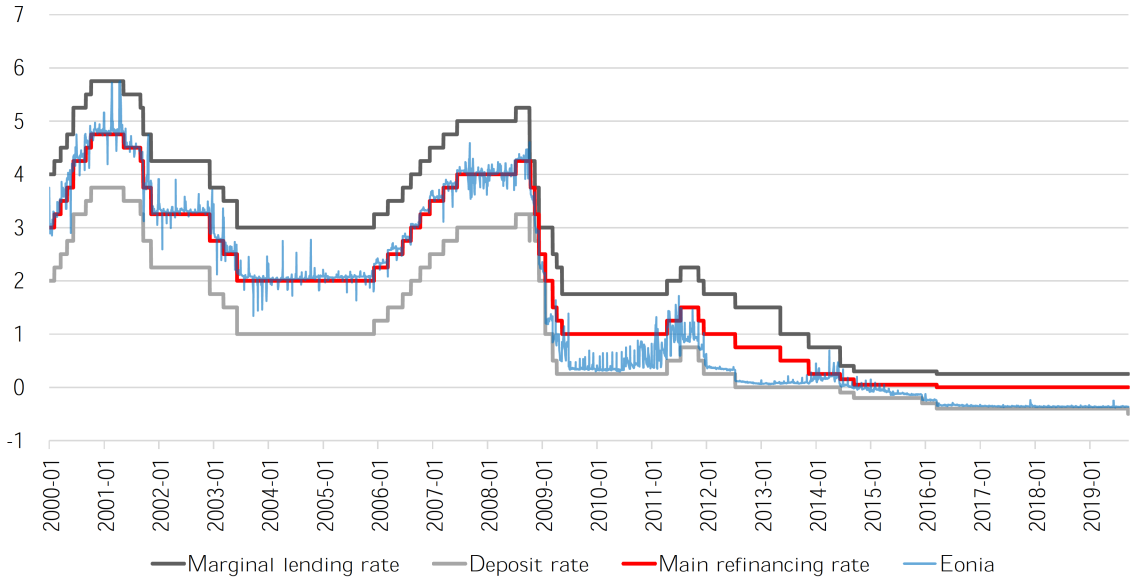


Figure 1: ECB key interest rates and the euro overnight unsecured interbank rate (on a daily basis, in %). Data source: ECB.

Figure 2 illustrates the development of the Eurosystem's 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, the banking sector's structural liquidity deficit (pink line) was quite perfectly covered by the ECB's open market operations (blue line) 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 prior to September 2008 neither the lending nor the deposit facility were used systematically and that the interbank rate (EONIA)[15] fluctuated closely around the MRO-rate (see Figure 1). 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, and the MRR, as the reserve ratio determined the necessary quantity of reserves. In such a "normal-times scenario", an increase in the MRO-rate and/or the reserve ratio makes granting bank loans more

[15]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.

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

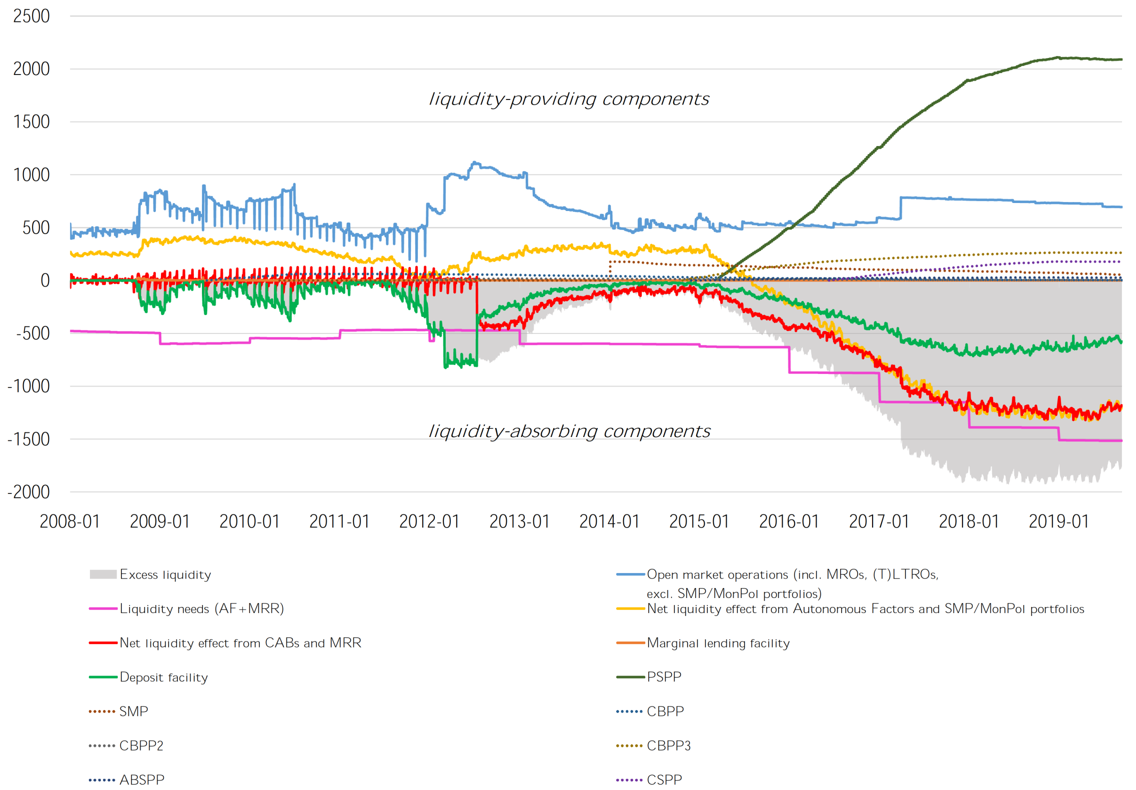


Figure 2: Liquidity provision and absorption through the Eurosystem – The central bank's balance sheet including volumes of non-standard monetary policy measures (on a daily basis, in billion euros). Data source: ECB.

### 3.3 Crisis Times

During the financial crisis, which peaked in September 2008 with the collapse of Lehman Brothers, and during the subsequent sovereign debt crisis, the banks' aggregate demand for reserves significantly exceeded their structural need for reserves. One reason was that increased levels of distrust and risk perception plus increased informational asymmetries led to funding stress in the banking sector. Especially during the sovereign debt crisis, capital flight from banks in lower-rated countries to banks in higher-rated countries ("safe-haven-flows" and "flight-to-quality-phenomena") led to funding stress in the banking sectors of lower-rated countries. To substitute for the loss in market-based funding, banks in lower-rated countries participated more significantly in the Eurosystem's refinancing operations. Another reason for the banks' aggregate demand for reserves going beyond their structural need for reserves was that the overnight interbank market was no longer functioning properly.[16] Also, due to increased levels of distrust and risk perception as well as increased informational asymmetries, banks with a surplus of liquidity refused to lend 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. Moreover, as the interbank market was no longer able 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. 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 fixed rate tender procedures with full allotment in its refinancing operations from October 2008 onwards as well as by launching two three-year longer-term refinancing operations (LTROs) in the years 2011 and 2012.[17] As a result, aggregate excess liquidity started to emerge.

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.[18]

Figure 2 illustrates the strong increases in the recourse to the deposit facility (green line), in the liquidity provided through open market operations (blue line) and the in-

[16]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).

[17]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).

[18]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. (2020).

creased levels of excess liquidity (grey shadowed area). Excess liquidity is the sum of commercial banks' current account balances at their national central bank in excess of the MRR (red line) plus their recourse to the deposit facility of the ECB (green line). 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 decreased significantly.

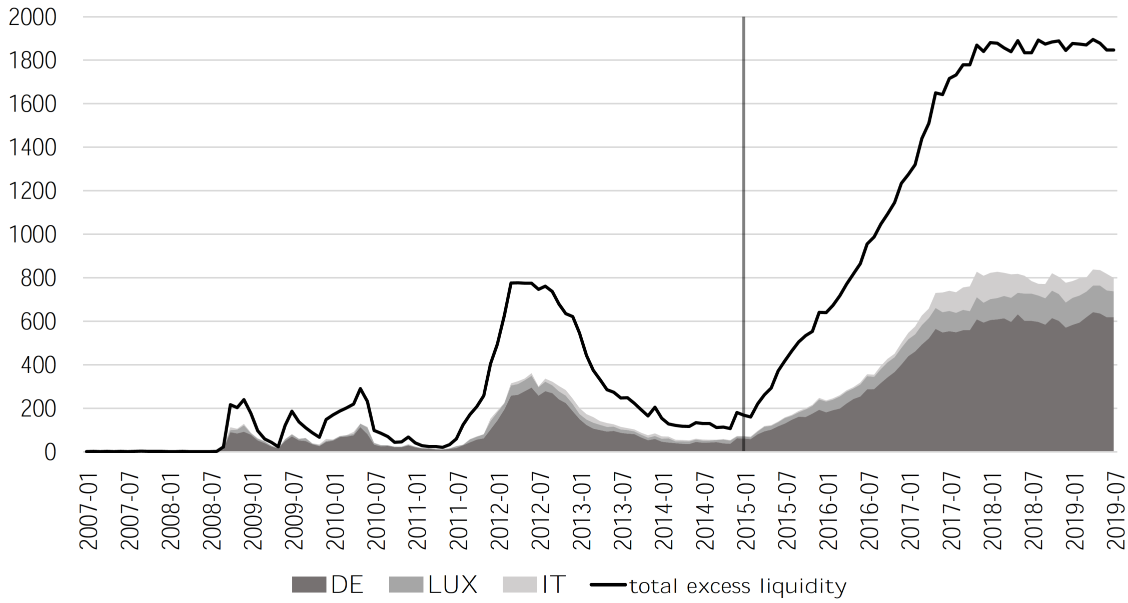


Figure 3: Accumulation of excess liquidity at specific national central banks in billion euros (maintenance period averages, vertical line indicates the APP start).
Data source: Eurosystem.

Figure 3 reveals that during crisis times excess liquidity was heterogeneously distributed across euro area countries. The main driver for the heterogeneous distribution of excess liquidity was capital flight (so-called "flight-to-quality" phenomena or "safe-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 hold their deposits 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, the provided liquidity accumulated via cross-border flows of this liquidity from lower-rated countries towards higher-rated countries in countries that were least concerned by the crisis, thereby inducing a heterogeneous distribution of this excess liquidity.[19]

## 3.4 Times of "Too Low" Inflation

### 3.4.1 Implementation of QE

Due to a persistently low inflation rate in the euro area and monetary policy rates approaching their effective lower bound,[20] 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 is 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 Programme (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 securities 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 to achieve inflation rates below, but close to, 2% over the medium term (European Central Bank, 2017).[21]

[19]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).

[20]In January 2015 the MRO-rate was already at 0.05% and the rate on the deposit facility at -0.02% (see Figure 1).

[21]Initially, between March 2015 and March 2016 the monthly volume of net purchases of public and private securities amounted to 60 billion euros. It then increased to 80 billion euros between April 2016 and March 2017. From April 2017 until December 2017 it declined again to 60 billion euros. Between January and September 2018 monthly net purchases to 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 stopped for the time being. In September 2019 the ECB's

### 3.4.2 QE-Induced Creation of Excess Liquidity

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. From the launch of the APP in March 2015 until December 2018, aggregate excess liquidity increased from 200 billion euros to 1.9 trillion euros (see grey area in Figure 2). The dark green line 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 has hence continuously pushed up the level of aggregate excess liquidity (grey area).[22] This implied that since October/November 2015 the euro area banking sector has been operating in an environment characterised 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.[23] 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.[24] In contrast to the surge of excess liquidity during the financial and 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

Governing Council decided to relaunch the APP by purchasing again private and public sector securities at a monthly net volume of 20 billion euros. For further technical information concerning the implementation of the APP, see e.g., Hammermann et al. (2019).

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

[23]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 additional liquidity in open market operations to cover their liquidity needs. This was the case, for the first time, in October 2015.

[24]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).

creation of excess liquidity under the APP is a supply-driven phenomenon (Baldo et al., 2017).

### 3.4.3 Heterogeneous Distribution of Excess Liquidity

Figure 3 demonstrates that also during the APP period, i.e., since 2015, excess liquidity has been heterogeneously distributed across euro area countries. 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 reason for this heterogeneous distribution of excess liquidity across euro area countries is threefold.

First, within the PSPP, national central banks purchase domestic government bonds in accordance with their share in the ECB's capital key.[25] 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 mostly 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 a technical particularity, the ECB's transactions are carried out through the Deutsche Bundesbank. The third reason is that the APP transactions are predominantly settled via only a few financial centres or financial gateways, in which the APP-induced creation of reserves consequently takes place. Thus, 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[26] resident outside the euro area. In order to participate in this cross-border transaction, the counterparty needs access to the TARGET2 payment

[25] 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).

[26] 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).

system.[27] As an example, we consider a UK-based counterparty that uses a correspondent German bank as an access point for TARGET2.[28] 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. This process can be described in detail 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. 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 balance 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 QE-induced 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.

[27] 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).

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

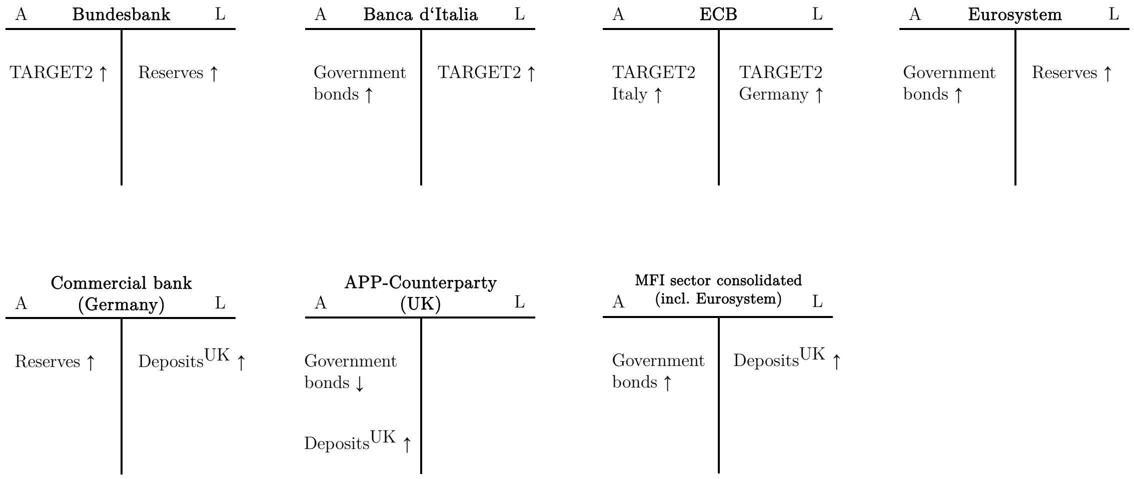


Figure 4: APP implementation – Stylised balance sheets of key financial market participants.

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). Note that this third reason for the heterogeneous distribution of excess liquidity is closely connected to the development of the TARGET2 balances that rose with the strong increase in excess liquidity during the APP period.[29]

### 3.4.4 Creation of Bank Deposits

Figure 4 also shows that the increase in excess reserves of the commercial bank that has the TARGET2 access (in our example the German commercial bank), is in line with an increase in deposits of that bank. If the Italian central bank buys Italian government bonds from a UK counterparty, and if this counterparty has its TARGET2 access via a German commercial bank, the German bank will receive the respective payment in the form of reserves from the Italian central bank via the German central bank and will credit the amount on the counterparty's deposit account. Consequently, the asset purchase of the Italian central bank implies the creation of deposits in the German banking sector.

[29] For details see e.g., (Eisenschmidt et al., 2017).

If a national central bank purchases assets from the domestic money-holding sector – principally private households and private corporations – domestic bank deposits are created. If, for example, the Italian central bank buys government bonds from the Italian non-banking private sector, the commercial bank of the respective household/firm is involved. The commercial bank will receive the respective payment in the form of reserves from the Italian central bank and will credit the respective amount to the household's/firm's current account, i.e., the deposits of the Italian banking sector will increase (see also Deutsche Bundesbank, 2016b).

Consequently, if the Eurosystem buys government bonds from the non-banking sector, the deposits and reserves of the euro area banking sector will increase. If the assets are bought by a national central bank from the domestic non-banking sector, reserves and deposits in the domestic banking sector will increase. If they are bought outside the respective country, reserves and bank deposits will increase in the banking sector of that country in which the respective counterparty (or its bank) has access to the TARGET2 system. Note that in the ECB statistics, here, the MFI balance sheet statistics including the Eurosystem, QE purchases of government bonds from the non-banking sector 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. We argued above that on the liability side the purchases imply an increase in bank deposits. However, the MFI statistics distinguish between bank deposits of euro area and non-euro area residents. If the seller is a resident of the euro area, the liability item "deposits of euro area residents held at euro area commercial banks" will be affected. If the seller is a non-euro area resident, the liability item "liabilities of euro area MFIs (excluding the Eurosystem) towards non-euro area residents" will be concerned (see also Avdjiev et al., 2019; Deutsche Bundesbank, 2016b). Both items have increased since 2015 which indicates the positive relationship between QE-asset purchases and the increase in deposits of euro area and non-euro area residents at euro area commercial banks. Note that the "liabilities of euro area MFIs (excluding the Eurosystem) towards non-euro area residents" have especially shown a pronounced increase since 2015.[30]

[30] For the respective time series see Deutsche Bundesbank statistics at: `https://www.bundesbank.de/dynamic/action/en/statistics/time-series-databases/time-series-databases/745564/745564?`

# 4 Model

The aim of our model analysis is to shed some light on how QE-induced increases in bank reserves and deposits affect bank loan supply and to discuss the implications of these increases for the implementation of monetary policy instruments other than QE. The model reveals that the QE-induced increases in reserves and deposits have no, or a contractionary effect, on bank loan supply. The effect will be contractionary if banks are facing increasing marginal balance sheet costs. Furthermore, the model shows that these costs in combination with a specific implementation of QE imply that the impact of this monetary policy measure on loan supply differs across banks. Moreover, the model reveals that conventional monetary policy measures, such as changes in key central bank interest rates and in the required reserve ratio, will have the exact opposite effect on bank loan supply if banks operate under a structural liquidity surplus instead of a respective deficit.

## 4.1 Institutional Environment

Our model considers main institutional aspects described in the previous sections relevant for euro area banks: banks are required to hold minimum reserves and have to cope with cash withdrawals, i.e., the banking sector faces a structural need for reserves. However, there are excess reserves in the banking sector which imply that banks do not have to borrow additional liquidity from the central bank. The structural need for reserves can be more than satisfied by the already existing reserves in the banking sector, i.e., banks operate in an environment characterised by a structural liquidity surplus. The QE-induced large amounts of excess reserves in the euro area banking sector imply that neither the interbank market for reserves nor the Eurosystem's MROs play a significant role for the banks' liquidity management anymore.[31] Therefore, we refrain from modelling an interbank market or refinancing operations with the central bank. In our model, the central bank buys assets from the non-banking sector on a large scale (QE). These asset pur-

listId=outstanding_amounts_30 and https://www.bundesbank.de/dynamic/action/en/statistics/time-series-databases/time-series-databases/745564/745564?listId=outstanding_amounts_49.

[31] The aggregate daily trading volume in the overnight interbank market decreased to below 2 billion euros (September 2019) while it fluctuated around 30 billion euros in January 2015. The volume of the ECB's main refinancing operations decreased from about 300 billion euros at the peaks of the financial and sovereign debt crises to 120 billion euros in January 2015 and to below 5.5 billion euros in September 2019 (data source: ECB).

chases imply the creation of bank reserves and deposits. The structural liquidity surplus in the banking sector increases. In an extension of our model, we also consider the case in which two national central banks (within a currency union) buy government bonds from institutions outside the union, whereas the settlement of both purchases takes place in only one country. Consequently, in our model analysis, we also capture the case of a QE-induced heterogeneous distribution of bank reserves and deposits across euro area countries described in Sections 3.4.3 and 3.4.4.

## 4.2 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 the term 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 (QE). These asset purchases imply an increase in the bank's reserve holdings $R$ as well as in its deposits $D^{QE}$, i.e., they imply the creation of money (see also Section 3.4.4).[32] Note that 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. 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

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

[32] Euro area statistics distinguish between bank deposits of euro area and non-euro area residents (see Section 3.4.4). However, in our model we do not make this distinction – $D^{QE}$ are QE-created bank deposits independently of their owner.

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., the commercial banks also 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.,[33]

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

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 5 illustrates the change in the balance sheets during the period under consideration:

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

*The central bank implements QE:*

| A | NBS | L |
|---|---|---|
| $D^{QE}$ | | |
| C | | |
| (-B) | | |

| A | Comm. Bank | L |
|---|---|---|
| R { ER | | $D^{QE}$ |
| R { RR | | |

| A | Central Bank | L |
|---|---|---|
| B | | R |
| | | C |

*The commercial bank grants loans to the non-banking sector (NBS):*

| A | NBS | L |
|---|---|---|
| $D^{L}$ | | L |
| $D^{QE}$ | | |
| C | | |

| A | Comm. Bank | L |
|---|---|---|
| L | | $D^{L}$ |
| R | | $D^{QE}$ |

| A | Central Bank | L |
|---|---|---|
| B | | R |
| | | C |

Figure 5: Change in balance sheet positions of financial market participants.

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 the 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 incremental rate:

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

This captures the idea of existing agency and/or regulatory costs, e.g., requirements for capital or leverage ratios.[34] As these costs increase in $D$ and thus in the size of the bank's balance sheet, we follow Martin et al. (2016) and refer to them as balance sheet costs.

Managing loans generates costs

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

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

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

[34] Using a theoretical model, Martin et al. (2013) already showed that marginal bank balance sheet costs increase due to costly equity requirements.

i.e., excess reserves increase in the asset purchases $B$ by the central bank and decrease in the commercial bank's lending to the non-banking sector $L$. The strength of these effects are determined by the currency and reserve ratio.

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 remunerates excess reserves $ER$ by $i^{DF}$, where $i^L > i^{RO} > i^{DF}$.[35]

### 4.3 Optimal Bank Loan Supply

The bank seeks to maximise its profit $\Pi$ 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 the bank's interest revenues from making loans to the non-banking sector. The second term describes its management costs. The third and fourth terms 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 optimisation problem, the first-order condition (FOC) for the optimal loan supply is given by

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

The first term of the FOC reflects the direct marginal interest revenues from granting loans, the second term the marginal costs in the form of management costs. Granting loans, the bank credits the respective amount to its customers' deposit accounts, i.e., it

[35] To allow for $i^L \leq 0$ would not change our model results, but for the sake of simplicity we assume that $i^L > 0$, as it allows us to speak only of interest revenues and avoids talking about revenues/costs in this context.

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 $b$: If a bank grants one additional unit of loan, it creates in a first step one additional unit of deposits. However, as a part of these deposits is withdrawn, required reserve holdings only increase by $r/(1+b)$ per unit of loan. The fourth term of equation (15) represents either marginal costs of granting loans in the form of opportunity costs or marginal revenues of granting loans in the form of avoided interest payments: As the additional required reserve holdings and 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 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 interest at the rate $i^D$ to the non-banking sector. Obviously, these interest costs decrease in $b$. 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:

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

### 4.4 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 large-scale asset purchases (QE), the minimum reserve ratio, the MRO-rate, and the deposit rate. By using comparative statics, we examine how the bank's optimal loan supply is affected by changes in these variables. Starting with QE, its impact on bank loan supply is captured by the first derivative of $L^*(\cdot)$ with respect to $B$:

$$\frac{\partial L^*}{\partial B} = -\frac{\gamma}{q(1+b)^2+\gamma} < 0 \; . \tag{17}$$

Implementing QE, the central bank purchases government bonds from the non-banking sector which leads to an increase in $B$ on the asset side of the central bank's balance sheet and in $R$ on the liability side (see Figure 5). 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 the commercial bank's marginal costs of granting loans will increase if the central bank purchases government bonds as these purchases imply the creation of costly deposits. Hence, the bank reduces its loan supply.

For the impact of a change in the minimum reserve ratio on bank loan supply, we get

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

The effect of an increase in the reserve ratio on the bank's optimal loan supply is positive. This means that an increase in this ratio is an expansionary monetary policy impulse, i.e., changes in the reserve ratio will have the exact 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)[36] of 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

$$\frac{\partial L^*}{\partial i^{DF}} = -\frac{(1+b)(b+r)}{q(1+b)^2+\gamma} < 0 \tag{19}$$

and

$$\frac{\partial L^*}{\partial i^{RO}} = \frac{r(1+b)}{q(1+b)^2+\gamma} > 0 \; . \tag{20}$$

Note that the effect of a change in $i^{DF}$ on $L^*$ is 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 ($b = r = 0$), 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.

### 4.5 Consideration of Heterogeneity

So far we have assumed identical commercial banks. This means that all banks were 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 3.4.3, we showed that in the euro area, banks were affected differently by the Eurosystem's large-scale asset purchases and, in particular, there were country-specific differences.

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

In a next step we account for this heterogeneity. As argued in Section 3.4.3, 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 also 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 reserves and deposits is below the level corresponding to asset purchases conducted by the Banca d'Italia. To capture this phenomenon in our model, we consider two banking sectors. One banking sector represents the banking sector of euro area countries that are home to financial centres. The banking sector of these countries is characterised by an increase in the amounts of excess reserves and deposits going beyond the corresponding level of asset purchases conducted by their respective national central banks. We refer to these countries as high-liquidity countries. The other banking sector belongs to countries that are not home to financial centres, which implies that banks in these countries are not selected as TARGET2 access point by counterparties that are resident in non-euro area countries. The banking sector of these countries is characterised by an increase in the amounts of excess reserves and deposits that is below the according level of asset purchases by their national central banks. We refer to these countries as low-liquidity countries. For simplification reasons, we consider one representative high-liquidity country and one representative low-liquidity country each endowed with a central bank and a commercial bank representing the country's commercial banking sector. We denote the QE-created amount of deposits in 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 national central banks buy assets equal to an amount $B$ from the non-banking sector, and both national central banks buy a share $0 \leq \beta < 1$ of these assets from counterparties not residing 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

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

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 $\beta$ of these assets is purchased from residents outside one of the two countries, as these residents hold 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 number 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 $\beta$ of total asset purchases is bought from counterparties having their deposit account in the other country. This part of the newly created deposits is represented by the second term of (22).

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

$$\begin{aligned}\max_L \overline{\Pi} = \quad & i^L L - \frac{1}{2}qL^2 + i^{RO} r\left(\frac{B(1+\beta)+L}{1+b}\right) + i^{DF}\left(\frac{(1-r)(1+\beta)}{1+b}B - \frac{b+r}{1+b}L\right) \\ & -i^D\left(\frac{B(1+\beta)+L}{1+b}\right) - \frac{1}{2}\gamma\left(\frac{B(1+\beta)+L}{1+b}\right)^2\,,\end{aligned} \tag{23}$$

and

$$\begin{aligned}\max_L \underline{\Pi} = \quad & i^L L - \frac{1}{2}qL^2 + i^{RO} r\left(\frac{B(1-\beta)+L}{1+b}\right) + i^{DF}\left(\frac{(1-r)(1-\beta)}{1+b}B - \frac{b+r}{1+b}L\right) \\ & -i^D\left(\frac{B(1-\beta)+L}{1+b}\right) - \frac{1}{2}\gamma\left(\frac{B(1-\beta)+L}{1+b}\right)^2\end{aligned} \tag{24}$$

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

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

and for the representative bank of the low-liquidity country

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

respectively. We are now able to compare the impact of QE on the 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 both the high-liquidity and 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). Obviously, the greater $\beta$, which means the greater the share of government bonds purchased from residents outside the considered countries, the larger the decrease in loan supply in the high-liquidity country and the smaller 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 discuss the existence of a possible bank lending channel of the Eurosystem's large-scale asset purchases. Second, we analyse consequences of the QE-induced structural liquidity surplus in the euro area banking sector for the implementation of monetary policy instruments other than QE.

*Existence of a Bank Lending Channel*

In Sections 3 and 4 we show that if central banks purchase assets, e.g., government bonds, from commercial banks or from the non-banking sector, excess reserves and bank deposits will increase. The literature survey in Section 2 reveals that 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 sheets. However, recent papers also explicitly consider the asset side of banks' balance sheets when investigating how bank loan supply responds to QE-induced increases in excess reserves. For instance, as already pointed out in the literature survey, Lojschova (2017) argues that in the euro area excess reserves are remunerated at a relatively low rate and that banks may therefore benefit from an expansion of lending to reduce their costly excess reserve holdings. This is what she refers to as a bank lending channel.

However, referring to our model results, such a bank lending channel does not exist for the euro area. The Eurosystem's large-scale asset purchases 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 are one component of the increasing marginal 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 marginal costs of holding deposits are constant, asset purchases will have no impact on bank loan supply as they do not influence the bank's marginal costs or revenues of granting loans (see equation (15)). Note that even a negative interest rate on excess reserve holdings will not incentivise banks to grant more loans if they face a QE-induced increase in costly excess reserves as, in the absence of increasing marginal balance sheet costs, larger quantities of excess reserves and deposits do not affect marginal costs or revenues of granting loans.

Furthermore, the APP-induced increased excess reserves are heterogeneously distributed across euro area countries (see Section 3.4.3). 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 4.5).

*Consequences for Monetary Policy Implementation: MRO-Rate*

With respect to the implementation of monetary policy instruments other than QE in the euro area, we can infer from our model results that main elements of the ECB's monetary policy toolkit affect bank loan supply differently in times when the banking sector is exposed to a structural liquidity surplus instead of a structural liquidity deficit. If the banking sector faces a structural liquidity deficit, banks have to rely on an ongoing liquidity provision by the central bank to cover cash withdrawals and MRR.[37] This means 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 liquidity surplus, they no longer need to take part in refinancing operations so that 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 ECB must increase rather than decrease the MRO-rate to boost bank

[37]Note that when discussing the tools of monetary policy, traditional textbooks usually consider a structural liquidity deficit (see e.g., Mishkin (2018, Section 15)).

loan supply in times when the banking sector is exposed to a structural liquidity surplus.

*Consequences for Monetary Policy Implementation: Minimum Reserve Ratio*

MRR imply a structural demand for reserves (see Section 3). If the euro area banking sector operates under a structural liquidity deficit, it will borrow the respective reserves from the ECB's MROs. Credit expansion leads to the creation of deposits for which banks are required to hold (costly) reserves. Although minimum reserve holdings are remunerated at the same rate at which the respective liquidity is borrowed from the Eurosystem (the MRO-rate), holding required reserves is costly as central bank credits have to be based on adequate collateral, i.e., additional costs in the form of collateral costs accrue. Consequently, increasing the minimum reserve ratio will have a contractionary impact on bank loan supply. Also, the simple money multiplier underscores the traditionally assumed contractionary impulse of an increase in the minimum reserve ratio. Neglecting the 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, the whole banking sector can hold a maximum amount of deposits equal to $D = \frac{1}{r}R$ . Taking into account a bank balance sheet constraint $D = L + R$, 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 fewer deposits, i.e., they make fewer loans.

However, we can infer from our model results that in the presence of a structural liquidity surplus in the banking sector, the negative relationship between the reserve ratio and bank loan supply no longer exists.[38] An increase in the minimum reserve ratio implies an increase in banks' structural liquidity needs. But as the banking sector 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 liquidity needs. On the contrary, the increased minimum reserve ratio implies that banks have to increase their holdings of required reserves at the expense of excess reserve holdings. This reserve shifting is beneficial as required reserves are remunerated at a higher rate than excess reserves,

[38] The absence of the traditional money-multiplier effect in the case that banks face a structural liquidity surplus, is also discussed by Keister and McAndrews (2009).

i.e., indirect marginal interest revenues of granting loans increase, so that banks expand their loan supply. Therefore, an increase in the minimum reserve ratio corresponds to an expansionary monetary policy impulse. Consequently, the ECB 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 characterised by a structural liquidity surplus, the deposit rate has a different meaning and effect than in an environment characterised 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., 2020). However, if the banking sector faces a structural liquidity surplus, an increase in the deposit rate will negatively affect bank loan supply. The incentive to reduce the excess reserve holdings by granting more loans decreases, since the opportunity costs of granting loans increase (if $i^{DF} > 0$) or since avoided (penalty) interest payments decrease (if $i^{DF} < 0$).[39]

# 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

[39]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 for 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.

of these asset purchases, excess liquidity and deposits held by the euro area commercial banking sector increased to unprecedented levels.

The large quantity of excess liquidity has generated a great amount of concern and debate. However, there is little analysis of whether and to what extent excess liquidity affects bank loan supply, i.e., whether there is a bank lending channel in the sense that QE-induced increases in bank reserves and deposits have a positive impact on bank loan supply. Against this background, the first part of this paper describes and analyses the Eurosystem's liquidity management in *normal times*, in *crisis times* and in *times of too low inflation*. Focussing on the latter, the QE-induced creation of bank reserves and bank deposits as well as their heterogeneous distribution across euro area countries are analysed. Building on this analysis, the paper's second part develops a theoretical model of the euro area banking sector. Using this model 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 face increasing marginal costs of holding deposits, for example, due to agency or regulatory costs.

As – due to the Eurosystem's large-scale asset purchases – the 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 that 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 characterised 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.

## Supplement

This supplement updates the paper's main findings focussing on the recent developments in the context of the COVID-19 pandemic. In response to the outbreak of the pandemic at the beginning of 2020 and the negative implications for the euro area economy,[40] the ECB decided in March 2020 first to expand its large-scale asset purchase programme (APP) by an additional envelope of 120 billion euros to counter serious risks to the monetary policy transmission mechanism (European Central Bank, 2021a). Second, the ECB launched a new temporary asset purchase programme, namely the Pandemic Emergency Purchase Programme (PEPP), with an overall envelope of 750 billion euros (European Central Bank, 2020a).[41] This amount has been increased by 600 billion euros on 4 June 2020 and by 500 billion euros on 10 December 2020 for a new total of 1,850 billion euros. The ECB will not terminate asset purchases under the PEPP before the end of March 2022 (European Central Bank, 2021c). While the PEPP has a dual objective, i.e., (i) to increase inflation to levels closer to 2% over the medium term and (ii) to counter the pandemic-induced fragmentation and malfunctioning of euro area financial markets (Schnabel, 2020), it is implemented in the same way as the Public Sector Purchase Programme (PSPP). In particular, the vast majority of assets (predominantly government bonds) is purchased from non-euro area counterparties. This means that, as pointed out in Section 3, the same technical particularities exist regarding the creation and heterogeneous distribution of (excess) reserves and bank deposits in the euro area banking sector.

Figure 6 reveals that the additional large-scale asset purchases relating to the COVID-19 pandemic have led to a continuous increase in excess liquidity in the euro area banking sector reaching unprecedented levels. The current amount (in October 2021) is more than twice as high as before the outbreak of the COVID-19 pandemic. Moreover, this liquidity is heterogeneously distributed across euro area countries. This strengthens our model results with regard to the scenario of *times of too low inflation*. The model allowed us

[40]For example, the euro area gross domestic product declined by 3.6% in the first quarter of 2020 and the ECB staff projections predicted notable downward pressure on inflation arising from a shortfall in aggregate demand (Schnabel, 2020).

[41]Moreover, the ECB introduced additional series of Targeted Longer-Term Refinancing Operations (TLTROs) and new series of Pandemic Emergency Longer-Term Refinancing Operations (PELTROs). The implementation of the TLTROs and the PELTROs creates additional excess liquidity in the euro area banking sector. For more detailed information, see European Central Bank (2020b).

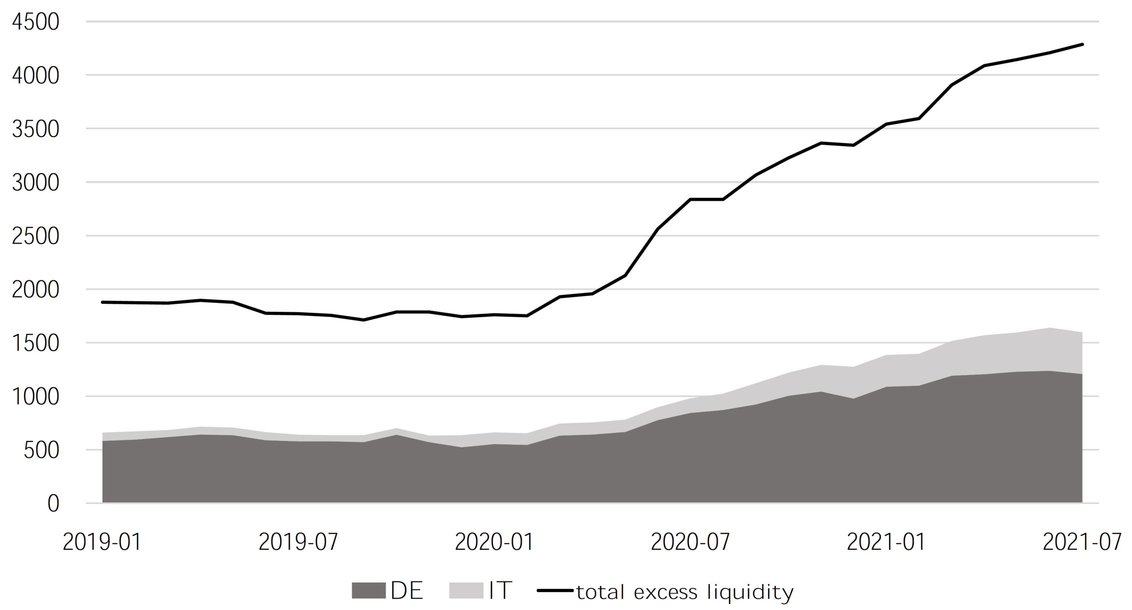


Figure 6: Increase in excess liquidity in the context of the COVID-19 pandemic (in billion euros, maintenance period averages). Data source: Eurosystem.

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 (conventional) monetary policy instruments.

With respect to the first issue, we found that increasing excess reserves and deposits in the euro area banking sector have a contractionary effect on bank loan supply under the assumption that banks face increasing marginal costs of holding deposits (balance sheet costs). The extent of the contractionary effect increases in the banks' holdings of excess reserves and deposits. Thus, the renewed increase in excess reserves and bank deposits during the COVID-19 pandemic implies larger balance sheet costs for banks and thus a more contractionary effect on bank loan supply.

This leads to the second issue, namely that the banking sectors' QE-induced excess reserve and deposit holdings differ significantly across euro area countries. Although the differences between the country-specific shares of total excess reserve holdings have remained constant in relative terms in the context of the COVID-19 pandemic,[42] they have

[42]About 30% of total excess reserves are held in the German banking sector, while roughly 8% are held in the Italian banking sector, for example (data source: ECB).

increased in absolute terms. This implies larger balance sheet costs for banks in high-liquidity countries compared to banks in low-liquidity countries and consequently leads to a more contractionary impact on bank loan supply in high-liquidity countries compared to low-liquidity countries.

Concerning the third issue, the model revealed that conventional monetary policy measures have the opposite effect if the banking sector faces – for example, a QE-induced – structural liquidity surplus instead of a structural liquidity deficit. The continuous increase in excess reserves during the COVID-19 pandemic has enlarged the structural liquidity surplus in the euro area banking sector. Hence our model conclusions are confirmed that in such an environment, banks' incentive to expand their loan supply can be strengthened if the central bank (i) increases the rate on its main refinancing operations, (ii) introduces higher minimum reserve requirements for banks, or (iii) decreases the rate on its overnight deposit facility.

# Bibliography


Alvarez, I., F. Casavecchia, M. De Luca, A. Duering, F. Eser, C. Helmus, C. Hemous, N. Herrala, J. Jakovicka, M. Lo Russo, F. Pasqualone, M. Rubens, R. Soares, and F. Zennaro (2017). The use of the Eurosystem's monetary policy instruments and operational framework since 2012. *ECB Occasional Paper 188, May 2017*.

Avdjiev, S., M. Everett, and H. S. Shin (2019). Following the imprint of the ECB's asset purchase programme on global bond and deposit flows. *BIS Quaterly Review, March 2019*, 69–81.

Baldo, L., B. Hallinger, C. Helmus, N. Herrala, D. Martins, F. Mohing, F. Petroulakis, M. Resinek, O. Vergote, B. Usciati, and Y. Wang (2017). The distribution of excess liquidity in the euro area. *ECB Occasional Paper 200, November 2017*.

Bech, M. and C. Monnet (2016). A search-based model of the interbank money market and monetary policy implementation. *Journal of Economic Theory 164*, 32–67.

Bernanke, B. S. and A. S. Blinder (1988). Credit, money, and aggregate demand. *American Economic Review 78*, 435–439.

Bernanke, B. S. and M. Gertler (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives 9*(4), 27–48.

Bindseil, U. (2014). Monetary policy operations and the financial system. *Oxford University Press*.

Bindseil, U., G. Camba-Mendez, A. Hirsch, and B. Weller (2006). Excess reserves and the implementation of monetary policy of the ECB. *Journal of Policy Modeling 28*(5), 491–510.

Bowman, D., F. Cai, S. Davies, and S. Kamin (2015). Quantitative easing and bank lending: Evidence from Japan. *Journal of International Money and Finance 57*, 15–30.

Bucher, M., A. Hauck, and U. Neyer (2020). Interbank market friction-induced holdings of precautionary liquidity - implications for bank loan supply and monetary policy implementation. *Economic Theory 70*(1), 165–222.

Bucher, M. and U. Neyer (2016). The influence of the Eurosystem's deposit rate on bank loan supply. *Credit and Capital Markets 49*(2), 221–244.

Butt, N., R. Churm, M. F. McMahon, A. Morotz, and J. F. Schanz (2014). QE and the bank lending channel in the United Kingdom. *Bank of England Working Paper 511*.

Campello, M. (2002). Internal capital markets in financial conglomerates: Evidence from small bank responses to monetary policy. *The Journal of Finance 57*(6), 2773–2805.

D'Avino, C. (2018). Quantitative easing, global banks and the international bank lending channel. *Economic Modelling 71*, 234–246.

Deutsche Bundesbank (2016a). The macroeconomic impact of quantitative easing in the euro area. *Deutsche Bundesbank Monthly Report, June 2016*, 29–54.

Deutsche Bundesbank (2016b). Monetary policy and banking business. *Deutsche Bundesbank Monthly Report, November 2016*, 20–38.

Deutsche Bundesbank (2018). Monetary policy and banking business. *Deutsche Bundesbank Monthly Report, August 2018*, 21–38.

Eisenschmidt, J., D. Kedan, M. Schmitz, R. Adalid, and P. Papsdorf (2017). The Eurosystem's asset purchase programme and TARGET balances. *ECB Occasional Paper 196, September 2017*.

Ennis, H. M. (2018). A simple general equilibrium model of large excess reserves. *Journal of Monetary Economics 98*, 50–65.

Eser, F., M. C. Amaro, S. Iacobelli, and M. Rubens (2012). The use of the Eurosystem's monetary policy instruments and operational framework since 2009. *ECB Occasional Paper 135, August 2012*.

European Central Bank (2009). The implementation of monetary policy since August 2007. *Monthly Bulletin, July 2009*, 75–89.

European Central Bank (2010). The ECB's response to the financial crisis. *Monthly Bulletin, October 2010*, 59–74.

European Central Bank (2011). The ECB's non-standard measures – impact and phasing-out. *Monthly Bulletin, July 2011*, 55–69.

European Central Bank (2012a). The implementation of monetary policy in the euro area. General documentation on Eurosystem monetary policy instruments and procedures. *European Central Bank, Frankfurt a.M., 2012*.

European Central Bank (2012b). Monetary policy measures decided by the Governing Council on 6 September 2012. *Monthly Bulletin, September 2012*, 7–11.

European Central Bank (2014). The targeted longer-term refinancing operation of September 2014. *Monthly Bulletin, October 2014*, 21–23.

European Central Bank (2015). ECB announces Expanded Asset Purchase Programme. *Press release, 22 January 2015*.

European Central Bank (2017). Monetary policy decisions. *Press release, 26 October 2017*.

European Central Bank (2018). Liquidity conditions and monetary policy operations in the period from 31 January to 2 May 2018. *Economic Bulletin 4, June 2018*.

European Central Bank (2019a). Asset purchase programmes. `https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html`. [Online; accessed 05-October-2021].

European Central Bank (2019b). Capital subscription. `https://www.ecb.europa.eu/ecb/orga/capital/html/index.en.html`. [Online; accessed 05-October-2021].

European Central Bank (2020a). ECB announces 750 billion euros Pandemic Emergency Purchase Programme (PEPP). *Press release, 18 March 2020*.

European Central Bank (2020b). Monetary policy decisions. *Press release, 10 December 2020*.

European Central Bank (2021a). Asset purchase programmes. `https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html`. [Online; accessed 05-October-2021].

European Central Bank (2021b). An overview of the ECB's monetary policy strategy. https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_overview.en.html. [Online; accessed 18-October-2021].

European Central Bank (2021c). Pandemic Emergency Purchase Programme (PEPP). https://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html. [Online; accessed 05-October-2021].

Friedman, B. M. and K. N. Kuttner (2011). Implementation of monetary policy: How do central banks set interest rates? *Handbook of Monetary Economics 3*, 1345–1438.

Frutos, J. C., C. Garcia-de Andoain, F. Heider, and P. Papsdorf (2016). Stressed interbank markets: Evidence from the European financial and sovereign debt crisis. *ECB Working Paper 1925*.

Furfine, C. H. (2000). Interbank payments and the daily federal funds rate. *Journal of Monetary Economics 46*(2), 535–553.

Gambacorta, L. and P. E. Mistrulli (2004). Does bank capital affect lending behavior? *Journal of Financial Intermediation 13*(4), 436–457.

Garcia-Posada, M. and M. Marchetti (2016). The bank lending channel of unconventional monetary policy: The impact of the VLTROs on credit supply in Spain. *Economic Modelling 58*, 427–441.

Giansante, S., M. Fatouh, and S. Ongena (2020). Does quantitative easing boost bank lending to the real economy or cause other bank asset reallocation? The case of the UK. *Bank of England Staff Working Paper 883*.

Hammermann, F., K. Leonard, S. Nardelli, and J. von Landesberger (2019). Taking stock of the Eurosystem's asset purchase programme after the end of net asset purchases. *Economic Bulletin 2, March 2019*.

Kashyap, A. K., R. Rajan, and J. C. Stein (2002). Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking. *The Journal of Finance 57*(1), 33–73.

Kashyap, A. K. and J. C. Stein (1995). The impact of monetary policy on bank balance sheets. *Carnegie-Rochester Conference Series on Public Policy 42*, 151–195.

Kashyap, A. K. and J. C. Stein (2000). What do a million observations on banks say about the transmission of monetary policy? *American Economic Review 90*(3), 407–428.

Keister, T. and J. McAndrews (2009). Why are banks holding so many excess reserves? *Current Issues in Economics and Finance 15*(8).

Kishan, R. P. and T. P. Opiela (2000). Bank size, bank capital, and the bank lending channel. *Journal of Money, Credit, and Banking 32*(1), 121–141.

Lojschova, A. (2017). Did quantitative easing boost bank lending? The Slovak experience. *National Bank of Slovakia Working Paper 1*.

Martin, A., J. McAndrews, A. Palida, and D. Skeie (2013). Federal Reserve tools for managing rates and reserves. *Federal Reserve Bank of New York Staff Report 642*.

Martin, A., J. McAndrews, and D. Skeie (2016). Bank lending in times of large bank reserves. *International Journal of Central Banking 12*(4), 193–222.

Mishkin, F. S. (1996). The channels of monetary transmission: Lessons for monetary policy. *NBER Working Paper 5464*.

Mishkin, F. S. (2018). The economics of money, banking, and financial markets. *Pearson 12th edition*.

Poole, W. (1968). Commercial bank reserve management in a stochastic model: Implications for monetary policy. *The Journal of Finance 23*(5), 769–791.

Rodnyansky, A. and O. M. Darmouni (2017). The effects of quantitative easing on bank lending behavior. *The Review of Financial Studies 30*(11), 3858–3887.

Schnabel, I. (2020). The ECB's policy in the COVID-19 crisis – a medium-term perspective. `https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200610%7Ea16c903e5c.en.html`. [Online; accessed 05-October-2021].

Whitesell, W. (2006). Interest rate corridors and reserves. *Journal of Monetary Economics 53*(6), 1177–1195.

Williamson, S. D. (2019). Interest on reserves, interbank lending, and monetary policy. *Journal of Monetary Economics 101*, 14–30.

# **Paper II**:

## Asymmetric Macroeconomic Effects of QE and Excess Reserves in a Monetary Union*

Maximilian Horst  Ulrike Neyer  Daniel Stempel

**Abstract**

Large-scale asset purchases by a central bank (quantitative easing, QE) induce a strong and persistent increase in excess reserves in the banking sector. In the euro area, these excess reserves are heterogeneously distributed across the member states. This paper develops a two-country New Keynesian model – calibrated to represent a high- and a low-liquidity euro area country – to analyze the macroeconomic effects of QE, specifically considering strong and heterogeneous increases in excess reserves and deposits in a monetary union. QE triggers economic activity and increases the union-wide consumer price level after a negative preference shock. However, its efficacy is dampened by a *reverse bank lending channel* that weakens the *interest rate channel* of QE. These dampening effects are higher in the high-liquidity country. Furthermore, we show that a shock in the form of a deposit shift of QE-created deposits between the two countries, interpreted as capital flight, has negative (positive) effects for the economy of the country receiving (losing) the deposits.

*JEL classification:* E51, E52, E58, F41, F45.

*Keywords:* unconventional monetary policy, quantitative easing (QE), monetary policy transmission, excess liquidity, credit lending, heterogeneous monetary union, New Keynesian model.

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# 1 Introduction

At times when short-term monetary policy rates approach their effective lower bound, central banks may engage in quantitative easing (QE). In doing so, they buy assets at a large scale to directly lower long-term interest rates to stimulate economic activities. The Eurosystem launched its first QE program in January 2015 to address the risks of too low inflation for a too prolonged period.[1] However, large-scale asset purchases do not only decrease long-term interest rates but also create large amounts of bank reserves, implying that excess reserves in the euro area banking sector increased to unprecedented levels.[2] Due to the specific QE implementation, these excess reserves are distributed heterogeneously across euro area countries.

Against this background, we analyze the macroeconomic effects of QE in a monetary union within a two-country New Keynesian model, considering explicitly how it is implemented. This includes the analysis of whether the QE-induced large increases in excess reserves and their heterogenous distribution across countries are just a technical feature or whether they have real effects. We find that, by lowering long-term interest rates, QE triggers economic activities, implying that aggregate consumption and investment increase (*interest rate channel of QE*). We distinguish between two different long-term interest rates: the bond rate and the bank loan rate. Crucially, the decrease of the latter is weakened by QE-induced increases in excess reserves and deposits. In particular, these increases imply higher bank balance sheet costs, e.g., in the form of agency or regulatory costs. Consequently, bank lending, and thus the stimulating effects of QE on economic

[1] The term "Eurosystem" includes the institutions responsible for monetary policy in the euro area, i.e., the European Central Bank (ECB) and all euro area national central banks (NCBs). For simplicity, we use the terms ECB and Eurosystem synonymously in this paper. Note that in January 2015 the interest rate on the ECB's main refinancing operations (MROs) already amounted to .05%, the interest rate on its deposit facility was already negative at -.2%, and the interest rate on the marginal lending facility was at .3% (data source: ECB). For the respective announcement of the QE program, see European Central Bank (2015).

[2] Excess reserves are here defined as the sum of (i) commercial banks' current account balances at their national central bank in excess of those contributing to minimum reserve requirements, and (ii) deposits held at the ECB's overnight deposit facility. In ECB parlance this quantity is defined as "excess liquidity" since the ECB uses the term "excess reserves" to define the narrower concept of current account balances in excess of reserve requirements. We refer to excess reserves as all central bank overnight deposits beyond required reserves and hence do not distinguish between whether they are held on a current account or at the deposit facility.

activities, are dampened (*reverse bank lending channel of QE*).[3] Hence, we identify two channels of QE, an interest rate channel and a reverse bank lending channel, with the latter weakening the former. Therefore, the QE-induced increases in excess reserves and their heterogeneous distribution are not just a technical feature but indeed have real effects. Depending on the way QE is implemented, these channels may affect monetary union members asymmetrically.

In particular, we calibrate our model to represent a high- and a low-liquidity euro area country (Germany and Italy). Thus, in steady state, excess reserves and deposits are already asymmetrically distributed between the two countries. Considering the specific QE implementation in the euro area, that reinforces this heterogeneous liquidity distribution, we find that the two channels indeed have asymmetric macroeconomic effects in these countries. We analyze the model responses to two shocks: a preference shock and a deposit shift shock (sudden deposit shift between the two countries). After a symmetric, negative preference shock that implies a decrease in household consumption, for instance due to the COVID-19 pandemic, the central bank reacts to the shock-induced decreasing union-wide inflation with QE. The long-term interest rates decrease, triggering economic activity and thus an increase in the union-wide consumer price inflation. However, the QE-induced increase in excess reserves and deposits leads to higher bank balance sheet costs, implying a dampening effect on bank lending. The interest rate channel of QE is therefore dampened by a reverse bank lending channel. These weakening effects are more pronounced in the high-liquidity country.

The deposit shift shock implies that deposits and thus (excess) reserves are moved from the low-liquidity country to the high-liquidity country, which can be interpreted as capital flight ("safe-haven-flows" or "flight-to-quality" phenomena), for instance. This increase in deposits and excess reserves leads to higher balance sheet costs for banks in the high-liquidity country. Consequently, in that country, the deposit shift has a dampening effect on economic activities. Analogously, the low-liquidity country benefits from the deposit shift.

[3]This stands in contrast to Bernanke and Gertler (1995) who introduced a bank lending channel into the literature that *reinforces* the traditional interest rate channel. Therefore, we call it *reverse* bank lending channel.

Our paper primarily builds on three strands of literature. First, we contribute to the literature on DSGE models that include a banking sector to analyze the effects of unconventional monetary policy measures, such as QE. Respective examples are Gerali et al. (2010), Cúrdia and Woodford (2011), Gertler and Karadi (2011, 2013), Chen et al. (2012), Brunnermeier and Koby (2018), Kumhof and Wang (2021), and Wu and Zhang (2019a,b). Note that, as in Jakab and Kumhof (2019), Kumhof and Wang (2021), and Mendizábal (2020), we assume that banks create deposits endogenously by granting loans (i.e., banks provide "financing through deposit creation"). Second, our work is related to several papers that develop DSGE models to analyze monetary policy effects in a monetary union such as in Benigno (2004), Beetsma and Jensen (2005), Galí and Monacelli (2005, 2008), Ferrero (2009), Bhattarai et al. (2015), and Saraceno and Tamborini (2020). Third, our work is based on literature investigating the relationship between the implementation of QE and the creation of excess reserves. Examples include Keister and McAndrews (2009), Alvarez et al. (2017), and Baldo et al. (2017).

Our paper contributes to these strands by explicitly considering crucial technical particularities of the QE implementation in a realistically calibrated New Keynesian model of two representative euro area countries. QE is modelled more realistically compared to its presentation in other papers with respect to its aim (reducing long-term interest rates that are the relevant rates for households' consumption and for firms' investment decisions) and with respect to the technical particularities of its implementation (large increases in excess bank reserves that are heterogeneously distributed across monetary union countries). To the best of our knowledge, our paper is the first one to endogenously implement the development of excess reserves accompanying QE and to analyze the macroeconomic effects of this mechanical relationship in a monetary union model.

The remainder of this paper is organized as follows. Section 2 presents some notable fundamentals with regard to the implementation of QE in the euro area. In Section 3, we develop the model and derive the corresponding equilibrium. Section 4 describes the model calibration and derives and analyzes the results with regard to two different shocks. Section 5 concludes.

## 2 A Note on the Implementation of QE in the Euro Area

The ECB's large-scale asset purchase program (APP), commonly referred to as QE, involves four programs under which both private and public sector securities are purchased.[4] As a consequence of the implementation of QE, aggregate excess reserves[5] in the euro area increased from 200 billion euros in March 2015 to a temporary record high of 1.9 trillion euros in December 2018.[6] This value has increased significantly in the aftermath of the introduction of the Pandemic Emergency Purchase Programme (PEPP) that was launched by the ECB as a reaction to the COVID-19 pandemic.[7] The excess reserves are asymmetrically distributed across euro area countries. Since the beginning of QE, about 30% of overall excess reserves are, for example, held solely in Germany (see Figure 1). Alvarez et al. (2017) and Baldo et al. (2017) show that approximately 80-90% of total excess reserves predominantly accumulate in Germany, the Netherlands, France, Finland, and Luxembourg, whereas such holdings are much less pronounced in Italy, Portugal or Spain, for example.

Note that both an increase in excess reserves as well as a very similar heterogeneous distribution of this liquidity among euro area countries could already be observed during the financial and sovereign debt crisis (see Figure 1). However, compared to the QE period the reason for the heterogeneous distribution during these periods was different. In particular, capital flight (so-called "safe-haven-flows" and "flight-to-quality" phenomena) from lower-rated to higher-rated euro area countries was the main provoking factor at that periods (Baldo et al., 2017).

[4]The APP consists of the Corporate Sector Purchase Programme (CSPP), the Public Sector Purchase Programme (PSPP), the Asset-Backed Securities Purchase Programme (ABSPP) and the Third Covered Bond Purchase Programme (CBPP3). Covering a share of more than 80% of all assets bought under the APP (until October 2021), the PSPP represents by far the largest component of the APP (European Central Bank, 2021a).

[5]For the definition of excess reserves used in this paper see footnote 2.

[6]Note that between March 2015 and December 2018, the average amount of monthly net asset purchases varied between 15 and 80 billion euros. Between January 2019 and October 2019, net asset purchases were for the time being stopped. In November 2019, the ECB restarted its net asset purchases at a monthly pace of 20 billion euros. In March 2020, the ECB announced additional net asset purchases of 120 billion euros in combination with the existing APP purchases until the end of 2020 as a reaction to the COVID-19 pandemic (for more detailed information, see European Central Bank (2021a)).

[7]The PEPP is implemented in the same way as the PSPP and can thus technically be viewed as a further expansion of QE. For details with regard to its introduction, its objective and its volumes, see for example, European Central Bank (2021c).

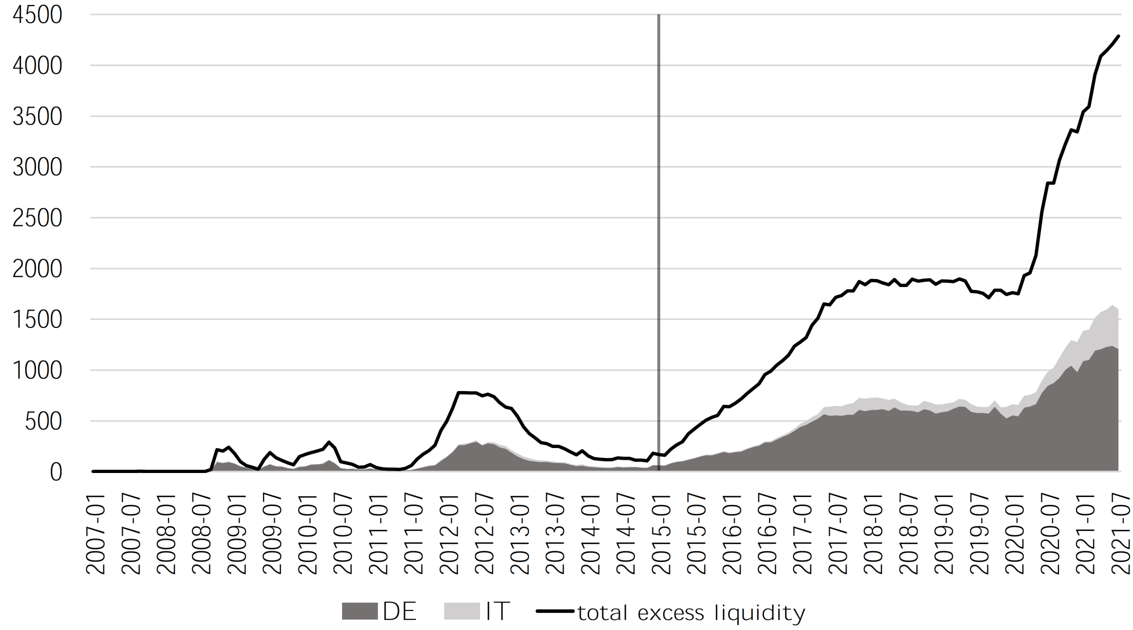


Figure 1: Excess reserve holdings of selected euro area national central banks in billion euros (maintenance period averages, vertical line indicates the launch of the QE program). Data Source: Eurosystem.

By implementing QE, each euro area national central bank purchases, inter alia, domestic government bonds according to its share in the ECB's capital key. The asset purchases are funded through the creation of reserves by the Eurosystem, implying that total excess reserves in the banking sector mechanically increase. As a consequence of the QE-induced increases in reserves, the euro area banking sector has been subjected to a structural liquidity surplus since October 2015, i.e., since then the banking sector has held so much reserves that it can cover its structural liquidity needs occurring from minimum reserve requirements and autonomous factors, such as cash withdrawals, without borrowing from the central bank.[8]

There are different reasons for the observed heterogeneous distribution of QE-created bank reserves across euro area countries. By buying assets from the non-banking sector, the Eurosystem does not only create bank reserves but also bank deposits.[9] The individual creation of bank reserves and deposits in each country depends on the seller-type of the

[8]For detailed information with respect to the banking sector's liquidity needs and liquidity provision by the Eurosystem during different periods (*normal times, crisis times, times of too low inflation*), see e.g., Horst and Neyer (2019).

[9]For a more profound analysis of the creation and distribution of bank reserves and deposits within the implementation of QE in the euro area, see e.g., Baldo et al. (2017) and Horst and Neyer (2019).

asset and its location. For example, if (i) a national central bank purchases assets from a domestic commercial bank, reserves in the domestic banking sector will increase. If (ii) a national central bank purchases assets from the domestic non-banking-sector (private households and private corporations), reserves and deposits in the domestic banking sector will increase. Lastly, if (iii) a national central bank purchases assets from a counterparty residing outside the respective country, reserves and bank deposits will increase in the banking sector of that euro area country in which the respective counterparty (or its bank) has its current account in order to get access to the TARGET2 system.[10] Case (iii) is the main reason for the QE-induced heterogeneous distribution of reserves and deposits between euro area countries. About 80% of overall central bank asset purchases are bought outside the respective country and about 50% of overall central bank asset purchases are conducted with counterparties residing outside the euro area (see also Baldo et al., 2017). As those counterparties have their current accounts predominantly with commercial banks in only a few selected countries, such as Germany, France, the Netherlands, Luxembourg, and Finland (which serve as so-called financial centers or gateways), the QE-induced creation of excess reserves and deposits takes place in these countries. Thus, the majority of the excess reserves and deposits created through the QE purchases accumulates in only a few countries. This consequence of the technical particularity of the implementation of QE plays an essential role in our model setup.

## 3 Model

We consider a monetary union consisting of two countries indexed by $k \in \{A, B\}$, where $-k$ denotes the respective other country. The core model framework of each country partly resembles the setup of the closed economy modeled by Gertler and Karadi (2011, 2013). In each country, there are five types of agents: households, intermediate goods firms, capital producing firms, retail firms, and banks. In both countries, each type forms a continuum of identical agents of measure unity, allowing us to consider representative agents. We denote the respective representative agent in each country by agent $k$. In addition, there

[10] TARGET2 (Trans-European Automated Real-time Gross Settlement Express Transfer system) is the real-time gross settlement system owned and operated by the Eurosystem. It settles euro-denominated domestic and cross-border payments in central bank money continuously on an individual transaction-by-transaction basis without netting (European Central Bank, 2021f).

is a union-wide central bank. Banks in each country face such large amounts of excess reserves that fulfilling reserve requirements is not a binding constraint.[11] In order to capture the heterogeneous distribution of this liquidity in the euro area as outlined in Section 2, we specify country $A$ as being a high-liquidity and country $B$ as a low-liquidity country. The model contains a nominal rigidity in the form of price stickiness as well as real rigidities in the form of consumer habit formation and capital adjustment costs. In the following, we characterize the basic ingredients of the model.

### 3.1 Households

The infinitely lived household $k$ consumes, saves, and supplies labor to intermediate goods firms. Household $k$ seeks to maximize its expected discounted lifetime utility. Its objective function is

$$\max \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ Z_\tau ln \left( C_\tau^k - \Psi_k C_{\tau-1}^k \right) - \frac{\chi_k}{1+\varphi_k} (N_\tau^k)^{1+\varphi_k} \right] \right] , \tag{1}$$

where the household draws period-$t$ utility from consumption $C_t^k - \Psi_k C_{t-1}^k$ and period-$t$ disutility from work $N_t^k$, where $N_t^k$ denotes the number of hours worked. The variable $Z_t$ is a preference shock[12] following an AR(1) process. The parameter $\Psi_k$ is a habit parameter capturing consumption dynamics, $\chi_k$ determines the weight of labor disutility, and $\varphi_k$ captures the inverse Frisch elasticity of labor supply.

Household $k$'s total consumption $C_t^k$ consists of the consumption of final goods produced in its home country $C_{k,t}^k$ and of those produced in the foreign country $C_{-k,t}^k$. Henceforth, we denote domestically produced goods as domestic goods and those produced abroad as foreign goods. The parameter $\sigma_k$ can be interpreted as the share of foreign goods and $(1-\sigma_k)$ as the share of domestic goods in the household's total consumption. The respective consumption index is given by

$$C_t^k \equiv \frac{\left(C_{k,t}^k\right)^{1-\sigma_k} \left(C_{-k,t}^k\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k} (\sigma_k)^{\sigma_k}} , \tag{2}$$

[11] Other potential liquidity requirements, such as a liquidity coverage ratio for instance, play no role in our model. Banks face such a high liquidity surplus that those requirements are not a binding constraint when granting loans.

[12] Other works specifying preference shocks in this fashion include Ireland (2004), Dennis (2005), and Bekaert et al. (2010).

where $C^k_{k,t}$ and $C^k_{-k,t}$ are composite goods defined by the indices

$$C^k_{k,t} \equiv \left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1}} \tag{3}$$

and

$$C^k_{-k,t} \equiv \left( \int_0^1 C^k_{-k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1}} , \tag{4}$$

with $C^k_{k,t}(j)$ denoting the quantity of the domestic good $j$ and $C^k_{-k,t}(j)$ denoting the quantity of the foreign good $j$ consumed by household $k$ in period $t$. The parameter $\epsilon_k$ represents the elasticity of substitution between differentiated goods (produced in the same country). The household's budget constraint is given by

$$\begin{aligned} &\int_0^1 P_{k,t}(j) C^k_{k,t}(j) dj + \int_0^1 P_{-k,t}(j) C^k_{-k,t}(j) dj + B^k_t \\ &\qquad = (1 + i_{t-1}) B^k_{t-1} + W_{k,t} N^k_t + \Upsilon^k_t \, . \end{aligned} \tag{5}$$

The left-hand side (LHS) of equation (5) describes the household's nominal expenses. They include its consumption spending in countries $k$ and $-k$ as well as its savings in nominally risk-free bonds. The price $P_{k,t}(j)$ is the price for product $j$ produced in country $k$, and $P_{-k,t}(j)$ is the price for product $j$ produced in country $-k$. $B^k_t$ represents the quantity of one-period, nominally risk-free bonds purchased in period $t$ and maturing in $t+1$. Bonds purchased in period $t-1$ pay a long-term rate of interest, i.e., the bond rate $i_{t-1}$ in period $t$. The right-hand side (RHS) of equation (5) thus shows household $k$'s nominal income. It includes its gross return on bonds, its wage earnings (with $W_{k,t}$ being the nominal wage), and exogenous (net) income $\Upsilon^k_t$ from the ownership of firms and banks. The budget constraint reveals that household $k$ is connected with country $-k$ via the consumption of goods produced in country $-k$ and the shared bond market. Labor markets and equity incomes are separated between the two countries.

Household $k$ faces five optimization problems: (i) the optimal composition of its domestic composite consumption good, (ii) the optimal composition of its foreign composite consumption good, (iii) the optimal allocation of its overall consumption between domestic and foreign goods, (iv) its optimal labor supply, and (v) the optimal intertemporal allocation of consumption.

Starting with the optimal composition of the domestic consumption good, household $k$ seeks to maximize the consumption index given by equation (3) for any given level of expenditures $\int_0^1 P_{k,t}(j) C_{k,t}^k(j) dj$. Solving this optimization problem, the household's optimal consumption of the domestic good $j$ becomes

$$C_{k,t}^k(j) = \left( \frac{P_{k,t}(j)}{P_{k,t}} \right)^{-\epsilon_k} C_{k,t}^k \,, \tag{6}$$

where $P_{k,t} \equiv \left( \int_0^1 P_{k,t}(j)^{1-\epsilon_k} dj \right)^{\frac{1}{1-\epsilon_k}}$ is a price index of the goods produced in country $k$. Analogously, we obtain for its optimal consumption of the foreign good $j$

$$C_{-k,t}^k(j) = \left( \frac{P_{-k,t}(j)}{P_{-k,t}} \right)^{-\epsilon_k} C_{-k,t}^k \,, \tag{7}$$

where $P_{-k,t} \equiv \left( \int_0^1 P_{-k,t}(j)^{1-\epsilon_{-k}} dj \right)^{\frac{1}{1-\epsilon_{-k}}}$ is a price index for foreign goods.

In the same vein, we derive household $k$'s optimal allocation of its overall consumption between domestic and foreign goods. The household seeks to maximize the consumption index given by equation (2) for any given level of expenditures $P_{k,t}C_{k,t}^k + P_{-k,t}C_{-k,t}^k$. Solving this optimization problem, the optimal consumption of domestic and foreign goods become

$$C_{k,t}^k = (1-\sigma_k) \left( \frac{P_{k,t}}{P_{k,t}^C} \right)^{-1} C_t^k \tag{8}$$

and

$$C_{-k,t}^k = \sigma_k \left( \frac{P_{-k,t}}{P_{k,t}^C} \right)^{-1} C_t^k \,, \tag{9}$$

where $P_{k,t}^C \equiv {P_{k,t}}^{1-\sigma_k} {P_{-k,t}}^{\sigma_k}$ is the consumer price index in country $k$. Thus,

$$P_{k,t}C_{k,t}^k + P_{-k,t}C_{-k,t}^k = (1-\sigma_k) P_{k,t}^C C_t^k + \sigma_k P_{k,t}^C C_t^k = P_{k,t}^C C_t^k,$$

and the budget constraint (5) becomes

$$P_{k,t}^{C}C_t^k + B_t^k = (1+i_{t-1})B_{t-1}^k + W_{k,t}N_t^k + \Upsilon_t^k \,. \tag{10}$$

In order to obtain the household's optimal labor supply and its optimal intertemporal consumption, we maximize equation (1) with respect to $N_t^k$ and $C_t^k$ subject to equation (10). Denoting the marginal utility of consumption by

$$U_{c,t}^k \equiv \left( \frac{Z_t}{C_t^k - \Psi_k C_{t-1}^k} - \frac{\mathbb{E}_t\left[Z_{t+1}\right]\Psi_k \beta}{\mathbb{E}_t\left[C_{t+1}^k\right] - \Psi_k C_t^k} \right) ,$$

solving the optimization problem yields the following standard first-order conditions (FOCs):

$$\chi_k (N_t^k)^{\varphi_k} = w_{k,t} U_{c,t}^k \,, \tag{11}$$

$$\beta(1+i_t)\,\mathbb{E}_t\left[\frac{P_{k,t}^C}{P_{k,t+1}^C}\right]\Lambda_{t,t+1}^k = 1 \,, \tag{12}$$

with

$$\Lambda_{t,t+1}^k \equiv \mathbb{E}_t\left[\frac{U_{c,t+1}^k}{U_{c,t}^k}\right] \,. \tag{13}$$

Equation (11) shows that optimal labor supply requires the marginal disutility of working (LHS) to be equal to the marginal utility of working (RHS). The latter results from the additional possible consumption which is determined by the real wage $w_{k,t} \equiv W_{k,t}/P_{k,t}^C$. Equation (12) represents the Euler equation governing optimal intertemporal consumption.

Finally, we rewrite some identities in terms of relative prices. Defining the terms of trade of country $k$ with country $-k$ as $V_{-k,t}^k \equiv P_{-k,t}/P_{k,t}$, we get that

$$P_{k,t}^C = P_{k,t}^{1-\sigma_k}\left(V_{-k,t}^k P_{k,t}\right)^{\sigma_k} = P_{k,t}(V_{-k,t}^k)^{\sigma_k} \tag{14}$$

and

$$\Pi^C_{k,t} = \Pi_{k,t} \left( \frac{V^k_{-k,t}}{V^k_{-k,t-1}} \right)^{\sigma_k} , \tag{15}$$

where $\Pi^C_{k,t}$ denotes consumer price inflation and $\Pi_{k,t}$ the inflation of domestic prices in country $k$. Due to our assumption of complete bond markets, we can obtain the following risk-sharing condition using equations (12) and (13):

$$U^k_{c,t} = \vartheta_k (V^k_{-k,t})^{(\sigma_k - 1)} (V^{-k}_{k,t})^{(-\sigma_{-k})} U^{-k}_{c,t} , \tag{16}$$

where $\vartheta_k \equiv U^k_{c,ss}/U^{-k}_{c,ss}$ with $U_{c,ss}$ being the zero inflation steady state value of marginal utility of consumption. This condition implies that, adjusted for relative prices, marginal utilities of consumption of the households $k$ and $-k$ co-move proportionally over time.

## 3.2 Intermediate Goods Firms

Competitive intermediate goods firms produce goods that are solely sold to domestic retail firms. At time $t$, the output of a representative intermediate goods firm $Y^k_{m,t}$ is produced with capital $K^k_{t-1,t}$ and labor $N^k_t$. The respective production function is given by

$$Y^k_{m,t} = \left( K^k_{t-1,t} \right)^{\alpha_k} \left( N^k_t \right)^{1-\alpha_k} . \tag{17}$$

Intermediate goods firm $k$ buys the capital that is productive in $t$ from the capital producing firm in $t-1$, i.e., $K^k_{t-1,t}$ is the capital stock chosen and bought at real price $Q_{k,t-1}$ in period $t-1$ and productive in $t$. At the end of period $t$, the intermediate goods firm sells the depreciated capital back to the capital producer at price $(Q_{k,t} - \delta_k)$, i.e., in $t-1$ they conclude a kind of repurchase agreement. The parameter $\delta_k$ is defined as the real depreciation rate.

So far, the setup closely resembles the modelling of intermediate goods firms by Gertler and Karadi (2011). However, with respect to the financing of their expenditures, we assume the following: at the end of period $t$, the intermediate goods firm borrows $L^k_{t,t+1} = Q_{k,t} K^k_{t,t+1}$ from bank $k$ to buy the capital stock that is productive in $t+1$. The bank credits the respective amount as deposits, $L^k_{t,t+1} = D^{L,k}_{t,t+1}$, on the intermediate goods firm's bank account, i.e., as in Kumhof and Wang (2021), loans create deposits.[13] The corresponding objective function of intermediate goods firm $k$ is given by

$$\max \Gamma^k_{m,t} = mc_{k,m,t} Y^k_{m,t} - w_{k,t} N^k_t - \left(1 + i^L_{k,t-1}\right) Q_{k,t-1} K^k_{t-1,t} + (Q_{k,t} - \delta_k) K^k_{t-1,t} \,. \quad (18)$$

Equation (18) reveals that in period $t$, the firm has to take into account four factors determining its real profits: (i) revenues defined as the product of real marginal costs and output,[14] (ii) costs of labor, (iii) interest and principal payments on the loan agreed on in period $t-1$, and (iv) the payoff from reselling depreciated capital to the capital producer. Solving (18) with respect to $K^k_{t,t+1}$ and $N^k_t$ gives the following FOCs:

$$\left(1 + i^L_{k,t}\right) Q_{k,t} = \alpha_k mc_{k,m,t+1} \frac{Y^k_{m,t+1}}{K^k_{t,t+1}} + (Q_{k,t+1} - \delta_k) \,, \quad (19)$$

$$mc_{k,m,t} = \frac{w_{k,t}}{(1-\alpha_k)\frac{Y^k_{m,t}}{N^k_t}} \,. \quad (20)$$

The LHS of equation (19) denotes the real marginal cost of capital in the form of credit and acquisition costs. The RHS describes the real marginal benefit of capital in the form of production revenues and the payoff from the repurchase agreement. Equation (20) shows that the real marginal costs of the intermediate goods firm in period $t$ solely depend on the real costs of labor (i.e., the real wage), since any additional unit of output in $t$ has to be produced using only labor input due to the lagged decision on capital input.

## 3.3 Capital Producing Firms

At the end of period $t$, the representative competitive capital producing firm $k$ buys depreciated capital from intermediate goods firms and repairs it. Then, as in Gertler and Karadi (2011), it sells the refurbished capital and the newly produced capital, to the intermediate goods firm.[15]

[13] See Section 3.5 for details.

[14] Due to perfect competition, intermediate goods firms sell their products at nominal marginal costs.

[15] The intermediate goods firm uses the loan-created deposits $D^{L,k}_{t,t+1}$ to pay for this capital. The capital producing firm sells these deposits at price 1 to the household in order to being able to invest. For the sake of simplicity, we neglect the general means of payment function of deposits (except for capital purchases) and focus on the bank deposit creation of bank loans (see Section 3.5).

Therefore, gross capital produced in period $t$, $I_t^{gr,k}$, consists of newly created capital (net investment) $I_t^k$, and the refurbishment of the bought capital $\delta_k K_{t-1,t}^k$:

$$I_t^{gr,k} = I_t^k + \delta_k K_{t-1,t}^k \ . \tag{21}$$

The law of motion for capital is thus given by

$$K_{t,t+1}^k = K_{t-1,t}^k + I_t^k \ . \tag{22}$$

As in Gertler and Karadi (2011), we assume that production costs per unit capital are 1 and consider capital adjustment costs (CAC) for newly produced capital. Then, the real period profit of a capital producing firm is given by

$$\Gamma_{c,t}^k = Q_{k,t} K_{t,t+1}^k - (Q_{k,t} - \delta_k) K_{t-1,t}^k - \delta_k K_{t-1,t}^k - I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right) \ , \tag{23}$$

with

$$f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right) = \frac{n_k}{2}\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} - 1\right)^2 \ , \tag{24}$$

where $n_k$ captures the degree of capital adjustment costs and $I_{ss}$ is steady state gross investment.[16] Equation (23) shows that the real period profit is the result of: (i) the return from selling capital, (ii) the costs of buying the depreciated old capital, (iii) the costs of repairing the old capital, (iv) the costs of producing the new capital, and (v) CAC (only for new capital). Considering equations (22), (23), and (24), the objective function of the capital producing firm becomes

$$\max \mathbb{E}_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau}^k \left((Q_{k,\tau} - 1) I_\tau^k - \frac{n_k}{2}\left(\frac{I_\tau^k + I_{ss}}{I_{\tau-1}^k + I_{ss}} - 1\right)^2 \left(I_\tau^k + I_{ss}\right)\right)\right] \ . \tag{25}$$

[16] $I_{ss}$ is included because in the zero inflation steady state net investment has to be zero since the capital stock is constant over time. This would imply a division by zero if $I_{ss}$ were excluded.

The capital producer chooses net investment $I_t^k$ to solve equation (25). The respective FOC is

$$Q_{k,t} = 1 + \frac{n_k}{2}\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} - 1\right)^2 + \frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} n_k \left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} - 1\right)$$
$$- \mathbb{E}_t \, \beta \Lambda_{t,t+1}^k \left(\frac{I_{t+1}^k + I_{ss}}{I_t^k + I_{ss}}\right)^2 n_k \left(\frac{I_{t+1}^k + I_{ss}}{I_t^k + I_{ss}} - 1\right) . \quad (26)$$

The LHS shows real marginal revenues of net investment, the RHS the corresponding real marginal costs consisting of production costs as well as current and expected CAC.

### 3.4 Retail Firms

The representative retail firm $k$ produces differentiated final output by aggregating intermediate goods. One unit of intermediate output is needed to produce one unit of final output. Consequently, the marginal costs of final goods firms correspond to the price of the intermediate good. Retail firm $k$ faces demand from households in both countries. Price setting is assumed to be staggered, following Calvo (1983). Firm $j$ chooses its price $P_{k,t}(j)$ to maximize discounted expected real profits given by

$$\max \mathbb{E}_t \left[\sum_{\tau=t}^{\infty} {\theta_k}^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left(\frac{P_{k,t}(j)}{P_{k,\tau}^C} Y_{\tau|t}^k(j) - TC(Y_{\tau|t}^k(j))\right)\right] , \quad (27)$$

subject to

$$Y_{\tau|t}^k(j) = \left(\frac{P_{k,t}(j)}{P_{k,\tau}}\right)^{-\epsilon_k} Y_\tau^k , \quad (28)$$

where $\theta_k$ is the probability of a single producer being unable to adjust the price in a certain period. Furthermore, $\beta^{\tau-t}\Lambda_{t,\tau}^k$ denotes the stochastic discount factor, $Y_{\tau|t}^k(j)$ the output in period $\tau$ for a firm that last reset its price in $t$, and $TC(\cdot)$ is the real total cost function. The respective demand function, given by equation (28), depends on the relative price of the good, the heterogeneity of the goods (captured by the elasticity of substitution $\epsilon_k$), and total aggregate demand for goods produced in country k. The FOC of the maximization problem given by equation (A.4) is

$$0 = \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} {\theta_k}^{\tau-t} \beta^{\tau-t} \Lambda^k_{t,\tau} Y^k_{\tau|t}(j) \left( \frac{P^*_{k,t}(j)}{P^C_{k,\tau}} - \frac{\epsilon_k}{\epsilon_k - 1} mc(Y^k_{\tau|t}(j)) \right) \right] , \tag{29}$$

where the real marginal cost function is given by $mc(Y^k_{\tau|t}(j)) = mc_{k,m,\tau}$, and $P^*_{k,t}(j)$ is the optimal price of firm $j$. Since all firms that are able to reset their price choose the same one, we can drop the index $j$, and get

$$\frac{P^*_{k,t}}{P_{k,t}} = \frac{\epsilon_k}{\epsilon_k - 1} \frac{x_{k,1,t}}{x_{k,2,t}} , \tag{30}$$

where

$$x_{k,1,t} \equiv U^k_{c,t} Y^k_t mc_{k,m,t} + \beta \theta_k \, \mathbb{E}_t \left[ \Pi^{\epsilon_k}_{k,t,t+1} x_{k,1,t+1} \right] ,$$

$$x_{k,2,t} \equiv U^k_{c,t} Y^k_t \left( V^k_{-k,t} \right)^{-\sigma_k} + \beta \theta_k \, \mathbb{E}_t \left[ \Pi^{\epsilon_k - 1}_{k,t,t+1} x_{k,2,t+1} \right] .$$

Obviously, if all retail firms were able to reset their price in every period ($\theta_k = 0$), they would set their optimal price as a markup over nominal marginal costs, i.e., ${P_{k,t}}^* = \epsilon_k/(\epsilon_k - 1) mc_{k,m,t} P^C_{k,t}$.

The overall domestic price level in country $k$ at time $t$ is given by

$$P^{1-\epsilon_k}_{k,t} = (1 - \theta_k)(P^*_{k,t})^{1-\epsilon_k} + \theta_k (P_{k,t-1})^{1-\epsilon_k} ,$$

i.e., a weighted average of the optimal price of the firms that can re-optimize in period $t$ and the price level of period $t - 1$.

### 3.5 Banks

Competitive bank $k$'s assets in period $t$ consist of one-period real loans granted at the end of period $t - 1$, $L^k_{t-1,t}$, and real reserves $R^k_t$, its liabilities of real deposits $D^k_t$, so that its balance sheet constraint is given by

$$L^k_{t-1,t} + R^k_t = D^k_t . \tag{31}$$

The total amount of reserves $R_t^k$ is splitted into required reserves $R_t^{RR,k}$ and excess reserves $R_t^{ER,k}$, i.e.,

$$R_t^k = R_t^{RR,k} + R_t^{ER,k} \, . \tag{32}$$

Required reserves are computed as a certain proportion $r$ of the bank's deposits $D_t^k$. The required reserve ratio $r$ is determined by the central bank. The total amount of bank $k$'s deposits is given by

$$D_t^k = D_{t-1,t}^{L,k} + \underbrace{\tilde{D}_{k,t} \cdot D_{k,t}^{QE}}_{:=D_{k,t}^{ex}} \, , \tag{33}$$

where $D_{t-1,t}^{L,k}$ represents the amount of deposits created through credit lending and $D_{k,t}^{ex} > 0 \; \forall \; t$ denotes the amount of deposits created exogenously (from the bank's point of view) through the central bank's large-scale asset purchases (QE), i.e., $D_{k,t}^{QE}$, and a potential deposit shift shock $\tilde{D}_{k,t}$. Therefore, we refer to the deposits $D_{k,t}^{ex}$ simply as exogenous deposits. In the following, we will comment on $D_{t-1,t}^{L,k}$ and $D_{k,t}^{ex}$ in more detail.

With respect to $D_{t-1,t}^{L,k}$, we assume that bank $k$ funds only one type of activity, namely the capital goods purchases of the intermediate goods firm $k$. As in Kumhof and Wang (2021), the intermediate goods firm relies on bank loans to finance its capital purchases. In period $t-1$, bank $k$ grants the respective loan to the intermediate goods firm. One unit of granted loans creates one unit of deposits *("financing through deposit creation")*, i.e., $L_{t-1,t}^k = D_{t-1,t}^{L,k}$.[17] We assume that loan-created deposits $D_{t-1,t}^{L,k}$ are credited on the intermediate goods firm $k$'s deposit account. The intermediate goods firm transfers the newly created deposits immediately to the capital producing firm to pay for the capital good. In period $t$, the intermediate goods firm repays its debt $(1+i_{k,t-1}^L)L_{t-1,t}^k$, consisting of its loans remunerated at a long-term interest rate, i.e., the bank loan rate. The respective

[17]There exist two commonly known theories that describe the technical relationship between deposits and loans. In contrast to the theory of "financing through deposit creation", bank loans in the theory of "intermediation of loanable funds" reflect the intermediation of savings (or loanable funds) between non-bank savers and non-bank borrowers: banks collect deposits from one agent and lend those savings to another agent, i.e., deposits come before loans. However, our model builds on the theory of "financing through deposit creation". Banks' key function is the provision of financing through loans for a single agent that is both borrower and, at least temporarily, depositor. Banks create new deposits when granting loans. A survey of both theories can be found, for example, in Jakab and Kumhof (2019).

deposits, that are remunerated at $i_{t-1}$, mature. The loan $L^k_{t-1,t}$ and the deposits created through bank lending $D^{L,k}_{t-1,t}$ are extinguished.

As described in detail in Section 3.6, the bank is exposed to deposits created by the central bank's QE. Therefore, $D^{QE}_{k,t}$ evolves exogenously from *the point of view of the bank*. Besides the central bank's QE, a deposit shift shock $\tilde{D}_{k,t}$ may influence the bank's exogenous deposits $D^{ex}_{k,t}$. The deposit shift shock $\tilde{D}_{k,t}$ captures a shift of QE-created deposits from country $k$ to $-k$ which can be the result of capital flight ("safe-haven-flows" or "flight-to-quality" phenomena), for instance. In particular, $\tilde{D}_{k,t}$ depicts an AR(1) shock process – which is independent of the central bank's monetary policy – given by

$$ln\left(\tilde{D}_{A,t}\right) = \rho_{\tilde{d},A} ln\left(\tilde{D}_{A,t-1}\right) + \epsilon_{\tilde{d},t} ,$$

$$ln\left(\tilde{D}_{B,t}\right) = \rho_{\tilde{d},B} ln\left(\tilde{D}_{B,t-1}\right) - \frac{D^{QE}_{A,ss}}{D^{QE}_{B,ss}} \epsilon_{\tilde{d},t} ,$$

where $\rho_{\tilde{d},k}$ depicts the shock persistence and $\epsilon_{\tilde{d},k}$ denotes a standard normally-distributed shock. This specification ensures a one-to-one shift of QE-created deposits from country B (low-liquidity country) to country A (high-liquidity country). Consider the case that, in steady state, the deposits are equally divided between both countries. In this case $\frac{D^{QE}_{A,ss}}{D^{QE}_{B,ss}} = 1$ and a 1% decrease of exogenous deposits in B leads to a 1% increase in A. However, if deposits are heterogeneously distributed between the countries, a $\frac{D^{QE}_{A,ss}}{D^{QE}_{B,ss}}$% decrease in $D^{ex}_{B,t}$ implies a 1% increase in $D^{ex}_{A,t}$.

In each period, each bank faces such a high liquidity surplus that fulfilling minimum reserve requirements is not a binding constraint when granting loans. Considering a one-to-one increase in exogenous deposits and reserves implies that bank $k$'s excess reserves are given by

$$R^{ER,k}_t = D^{ex}_{k,t} - r\left(D^{ex}_{k,t} + D^{L,k}_{t-1,t}\right) , \tag{34}$$

i.e., they correspond to the net amount of cumulated reserves created through central bank's asset purchases and/or a deposit shift shock, $D^{ex}_{k,t}$, and required minimum reserve holdings $r\left(D^{ex}_{k,t} + D^{L,k}_{t-1,t}\right)$.[18]

Bank loans are remunerated at the rate $i^L_{k,t-1}$, required reserves at the rate $i^{RR}$, and excess reserves at the rate $i^{ER}$, with $i^{RR} > i^{ER}$.[19] The rates $i^{RR}$ and $i^{ER}$ are determined by the central bank. Both bonds and bank deposits are assumed to be risk-free assets, so that they are remunerated at the same rate $i_{t-1}$. Thus, $i_{t-1}D^k_t$ constitutes the bank's interest costs on all deposits. A key feature of our model is that the bank faces increasing marginal balance sheet costs, i.e., costs increasing disproportionately in the size of its balance sheet, given in real terms by $\frac{1}{2}\upsilon_k\left(\mathbb{E}_t[D^k_{t+1}]\right)^2$. This captures the idea of existing agency and/or regulatory costs.[20]

In period $t$, bank $k$ seeks to maximize its real expected period-$(t+1)$ profit $\Gamma^k_{b,t,t+1}$. The bank's objective function is thus given by

$$\begin{aligned}\max \mathbb{E}_t[\Gamma^k_{b,t+1}] = {} & i^L_{k,t}L^k_{t,t+1} + i^{RR} r\,\mathbb{E}_t[D^k_{t+1}] + i^{ER}\,\mathbb{E}_t[R^{ER,k}_{t+1}] \\ & - i_t\,\mathbb{E}_t[D^k_{t+1}] - \frac{1}{2}\upsilon_k\left(\mathbb{E}_t[D^k_{t+1}]\right)^2 . \end{aligned} \tag{35}$$

Taking all rates as given, the bank decides on its optimal loan supply to maximize this profit. Solving this optimization problem with respect to $L^k_{t,t+1}$ yields the first order condition

$$i^L_{k,t} + r(i^{RR} - i^{ER}) = i_t + \upsilon_k\left(\mathbb{E}_t[D^{ex}_{k,t+1}] + L^k_{t,t+1}\right) . \tag{36}$$

The LHS of (36) represents the bank's real marginal revenues and the RHS its real marginal costs of granting loans. Note that granting more loans does not only imply more direct interest revenues (first term) but also more indirect interest revenues (second term). The latter is the consequence of a beneficial reserve shifting: Granting loans implies the creation of deposits. These deposits are subject to reserve requirements so that part of a

[18]A detailed explanation of the one-to-one increase in exogenous deposits and reserves is given in Sections 2 and 3.6.

[19]Note that with regard to the euro area, $i^{RR}$ corresponds to the ECB's main refinancing rate and $i^{ER}$ to the rate on the ECB's overnight deposit facility.

[20]Models explicitly considering balance sheet costs can, for example, also be found in Martin et al. (2013, 2016), Ennis (2018), Kumhof and Wang (2021), and Williamson (2019).

bank's (costly) excess reserve holdings are shifted to the higher remunerated required reserve holdings.[21] Crucially, bank costs are affected by the central bank's net asset purchases in two (opposing) ways: through interest costs $i_t$ and through balance sheet costs $\upsilon_k \, \mathbb{E}_t[D^{ex}_{k,t+1}]$.

### 3.6 Central Bank

Monetary policy is conducted at the union level. We conceptualize the conduct of monetary policy by the central bank in our model to closely follow the monetary policy operations of the ECB. Conventionally, the ECB implements monetary policy by setting its short-term interest rates.[22] However, when these short-term interest rates reach their effective lower bound, the ECB switches to unconventional monetary policy instruments, such as QE, to directly lower long-term interest rates (resulting in a flattening yield curve), i.e., the interest rates that are relevant for households' consumption and firms' investment decisions (European Central Bank, 2015).

In our model, we assume that the central bank has already encountered the effective lower bound on short-term monetary policy rates, so that QE has become its main monetary policy tool. We assume that by conducting large-scale asset purchases, the central bank is able to decrease long-term interest rates. Therefore, we do not model the asset purchases explicitly, but consider the bond rate $i_t$ as the long-term interest rate that is directly affected by the central bank. Other New Keynesian models using QE as the central bank's monetary policy tool often set $i_t = 0$ in a first step to illustrate that the central bank has reached the lower bound. However, since $i_t$ is the relevant interest rate for households' consumption and firms' investment decisions, it has rather a long-term characteristic and we assume that this rate is still above the lower bound, as it has actually been the case in the euro area.

The central bank's asset purchases do not only have an impact on the bond rate $i_t$, but, parallely, increase bank reserves and deposits (see Section 2 for institutional details).

[21] With regard to the euro area, since June 2014 excess reserves have been remunerated at a negative rate, currently (October 2021) at -.5%. Neglecting the "two-tier system", this interest rate has to be paid independently of whether the liquidity is held in the ECB's overnight deposit facility or on current accounts with the Eurosystem (European Central Bank, 2019).

[22] The ECB's short-term interest rates consist of (i) the rate on its one-week main refinancing operations with commercial banks, (ii) the rate on its overnight deposit facility, and (iii) the rate on its overnight marginal lending facility.

In the following, we describe how these two main aspects of QE are captured by our model and how the specific implementation of QE in the euro area is thus introduced into the model.

The central bank reacts to the weighted average of consumer price inflation in the union, given by $\gamma_{A,t}\pi^C_{A,t} + \gamma_{B,t}\pi^C_{B,t}$, where $\pi^C_{k,t} \equiv ln(\Pi^C_{k,t})$ and

$$\gamma_{A,t} = \frac{C^A_t}{C^A_t + C^B_t} \; ,$$

$$\gamma_{B,t} = \frac{C^B_t}{C^A_t + C^B_t} \; .$$

The country-specific levels of consumer price inflation rates are weighted by $\gamma_{k,t}$, which expresses the overall consumption level in period $t$ of the respective country in relation to the aggregate union consumption level. This reflects how consumer price inflation, which is relevant for the ECB's inflation target, is measured in the euro area.[23]

When the central bank observes a decrease in the weighted average of consumer price inflation in the union, it conducts QE, and thereby increases QE-created deposits in the banking sector. In particular, we capture the QE-induced increase in deposits $D^{QE}_{k,t}$ by a reaction function (or, a kind of Taylor rule) given by

$$D^{QE}_{k,t} = \Omega_k - \iota_k \left(1 + ln\left(\frac{1}{\beta}\right)\right) - \iota_k \phi_\pi \left(\gamma_{A,t}\pi^C_{A,t} + \gamma_{B,t}\pi^C_{B,t}\right) \; . \tag{37}$$

Again, we do not model explicitly the central bank's asset purchases, but depict them by an increase in $D^{QE}_{k,t}$. Therefore, we use increasing QE-created deposits as a synonym for central bank asset purchases. The parameter $\phi_\pi$ represents the standard reaction coefficient of the central bank to inflation in Taylor rules. $\Omega_k$ is simply a country-specific calibrated parameter to match the share of QE-created deposits in the length of the bank's balance sheet.[24] Importantly, note that the extent of the increase in $D^{QE}_{k,t}$ is captured by the country-specific, calibrated parameter $\iota_k$. This parameter allows us to depict the heterogeneous distribution of excess reserves across euro area countries described in Section 2.[25] Furthermore, considering a main institutional feature described in Section

[23]See European Central Bank (2021b) for detailed information.

[24]For more detailed information with regard to the calibrated parameter $\Omega_k$, see Section 4.1.

[25]For more detailed information with regard to the calibrated parameter $\iota_k$, see Section 4.1.

2, we assume that the central bank's asset purchases are conducted with counterparties residing outside the monetary union that have their deposit account with a bank inside the monetary union. Consequently, the asset purchases lead to a one-to-one increase in deposits and reserves of the bank in that country, where the respective counterparties have their deposit accounts with, i.e.,

$$\mathrm{d}R_t^k = \mathrm{d}D_{k,t}^{QE} \,. \tag{38}$$

Large-scale central bank asset purchases induce decreasing yields of the respective assets. We capture this effect formally by modelling a negative relationship between $i_t$ and $D_{k,t}^{QE}$ given by

$$1 + i_t = \frac{\Omega_k - D_{k,t}^{QE}}{\iota_k} \,. \tag{39}$$

Therefore, our model considers the simultaneous QE-induced decrease in the bond rate $i_t$ and the increase in bank deposits. Note that this relationship is a technical depiction to simplify matters. The increase in $D_{k,t}^{QE}$ and the decrease in $i_t$ are both consequences of the implementation of QE, but, in reality, they occur independently of each other.

We assume that, as a result of past central bank asset purchases, all banks have a high stock of excess reserves and thus of QE-created deposits in steady state. This allows us to also consider contractionary monetary policy. The central bank conducts monetary policy via its *net* asset purchases. If the central bank buys more assets than mature, i.e., if its net asset purchases are positive, it will conduct expansionary monetary policy. If the central bank's net asset purchases are negative, monetary policy will be contractionary (quantitative tightening).

Besides conducting QE, the central bank sets the nominal interest rates on commercial banks' required and excess reserves holdings $r^{RR}$ and $r^{ER}$, respectively, and determines the ratio for banks' required reserve holdings $r$.

### 3.7 Equilibrium

In order to close the model, we continue by stating the market clearing conditions. Bond market clearing implies

$$B_t^k = -B_t^{-k} \; , \tag{40}$$

i.e., bonds are in zero net supply. Final goods are consumed by households in the union and used to adjust capital:[26]

$$Y_t^k = C_{k,t}^k + C_{k,t}^{-k} + I_t^{gr,k} + \frac{n_k}{2}\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} - 1\right)^2 \left(I_t^k + I_{ss}\right) \; . \tag{41}$$

Furthermore, all goods sold by retail firms have to be produced by intermediate goods firms, i.e.,

$$Y_{m,t}^k = Y_t^k \; . \tag{42}$$

Note that the standard condition for labor market clearing with sticky prices given by

$$\left(\frac{Y_t^k}{{K_{t-1,t}^k}^{\alpha_k}}\right)^{\frac{1}{1-\alpha_k}} \Delta_t^k = N_t^k \; , \tag{43}$$

where $\Delta_t^k \equiv \int_0^1 \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\frac{\epsilon_k}{1-\alpha_k}} dj$, holds. Moreover, the market for loans clears

$$L_{t,t+1}^k = Q_{k,t} K_{t,t+1}^k \; . \tag{44}$$

Lastly, the real interest rate is defined in terms of the (log-linearized) union-wide bond rate and consumer price inflation of country $k$ (Fisher equation):

$$i_{k,t}^{real} = i_t - \mathbb{E}_t\left[\pi_{k,t+1}^C\right] \; . \tag{45}$$

[26]Note that for simplicity, as in Kumhof and Wang (2021), we assume that balance sheet costs as well as interest costs for QE-created deposits represent lump-sum transfers to the household instead of resource costs. However, our results are not affected by these assumptions.

# 4 Model Analysis

In this section, we discuss the macroeconomic consequences of a preference shock at the household level and a deposit shift shock at the bank level. Before analyzing the model responses to these shocks, we state the calibration strategy.

## 4.1 Calibration

The calibration of our model is depicted in Table 1. As discussed in Section 2, QE asset purchases are to a large extent conducted with counterparties residing outside the euro area, implying a heterogeneous increase in excess reserves and deposits across euro area countries. Accordingly, we calibrate the model to represent Germany (as the high-liquidity country) and Italy (as the low-liquidity country) in steady state. The euro area bank balance sheet statistics refer to these deposits of non-euro area residents held on accounts with euro area commercial banks officially as "liabilities of euro area monetary financial institutions (excluding the Eurosystem) towards non-euro area residents". In our model, these deposits are captured by the variable $D_k^{QE}$. In relation to the length of banks' balance sheets in the respective banking sector, $D_k^{QE}$ adds up to 9% in Germany and 2% in Italy.[27] We calibrate the parameter $\Omega_k$ accordingly.

In order to realistically capture the (mechanical) relationship between QE-created deposits and the bond rate $i_t$ ($\iota_k$ in our model), we draw from the work of Urbschat and Watzka (2020), who use an event study approach to estimate the effect of QE-related press releases on bond yields. On average, German bond yields fell by 5.91 basis points (bp), while Italian bond yields dropped by 69.67 bp after APP press releases between 2014 and 2016. Naturally, these decreases can only serve as an approximation of yield changes since they only capture the impact of the announcement of QE measures while leaving out the actual purchases. However, this approach ensures that we capture the isolated effect of QE on bond yields. Alternatives, for example using actual drops in bond yields, are more likely to be prone to influences independent of the asset purchases of the ECB.

[27] The respective data can be found at Deutsche Bundesbank (2021) and Banca d'Italia (2021).

| | Description | Value A Germany | Value B Italy | Target/Source |
|---|---|---|---|---|
| | | Households | | |
| $\beta$ | Time Preference | 0.9983 | 0.9983 | Albonico et al. (2019) |
| $\Psi_k$ | Habit Parameter | 0.73 | 0.81 | Albonico et al. (2019) |
| $\chi_k$ | Labor Disutility Parameter | 2.62 | 5.98 | Internally Calibrated |
| $\varphi_k$ | Inverse Frisch Elasticity of Labor Supply | 2.98 | 2.07 | Albonico et al. (2019) |
| $\sigma_k$ | Share of Foreign Goods in Consumption | 0.2612 | 0.205 | Albonico et al. (2019) |
| $\epsilon_k$ | Price Elasticity of Demand | 9 | 9 | Galí (2015) |
| $\rho_{z,k}$ | Preference Shock Persistence | 0.9 | 0.9 | |
| | | Firms | | |
| $\delta_K$ | Capital Depreciation Rate | 0.0143 | 0.0136 | Albonico et al. (2019) |
| $n_k$ | Capital Adjustment Cost Parameter | 31 | 19 | Albonico et al. (2019) |
| $\alpha_k$ | Partial Factor Elasticity of Capital | 0.35 | 0.35 | Albonico et al. (2019) |
| $\theta_k$ | Price Stickiness Parameter | 0.75 | 0.75 | Galí (2015) |
| | | Banks and Central Bank | | |
| $\Omega_k$ | QE-Created Deposits in Bank Balance Sheet | 106.51 | 2.41 | Share Germany: 9%, Share Italy: 2%, Internally Calibrated |
| $\iota_k$ | Interdependence Parameter of QE and Bond Rate | 100.41 | 1.42 | Drop German Bond Yields: 5.91 bp, Drop Italian Bond Yields: 69.67 bp, Internally Calibrated |
| $\rho_{\tilde{d},k}$ | Deposit Shift Shock Persistence | 0.9 | 0.9 | |
| $r$ | Required Reserve Ratio | 0.01 | 0.01 | ECB: Minimum Reserve Ratio |
| $i^{RR}$ | Required Reserve Interest Rate | 0 | 0 | ECB: Main Refinancing Rate |
| $i^{ER}$ | Excess Reserve Interest Rate | $-\frac{0.005}{4}$ | $-\frac{0.005}{4}$ | ECB: Deposit Rate |
| $\upsilon_k$ | Balance Sheet Costs | 0.000021 | 0.000037 | Interest Rate Germany: $\frac{0.0122}{4}$, Interest Rate Italy: $\frac{0.0140}{4}$, Internally Calibrated |
| $\phi_\pi$ | Inflation Response Taylor Rule | 1.5 | 1.5 | Galí (2015) |

Table 1: Calibration.

Regarding the structural parameters of the household and the firm sector, we draw from the work by Albonico et al. (2019), who build a multi-country model including Germany and Italy. They estimate certain structural parameters based on the respective economies, some of which are also used in our model specification.

The interest rates as well as the required reserve ratio set by the central bank are chosen to represent the respective values of the ECB. Note that the annual rates of the ECB have to be converted into quarterly rates due to the timing of the model.

With respect to bank costs, we calibrate balance sheet costs in a way that, given the respective ECB interest rates and the required reserve ratio, the loan interest rate matches data for average (annual) interest rates of newly granted loans to non-financial corporations in Germany and Italy provided by the European Central Bank (2021d,e). Obviously, when firms take out a loan from a bank, they do not only have to pay interest, but often additional fees. Consequently, the banks' marginal revenues (LHS of (36)) consist of more than interest payments which in turn implies higher marginal costs due to perfect competition of banks. However, as we consider only interest payments when calibrating the banks' balance sheet costs (second term on the RHS of (36)), the corresponding calibrated value of this cost factor serves as a lower bound, implying that all effects resulting from balance sheet costs also constitute a lower bound.

We now turn to a comparison of the steady state, generated by this particular calibration, with data. Table 2 shows several data points and the corresponding steady state values of our model. The steady state replicates the relative capital stock of Germany to Italy (1.24 in the data, 1.24 in the model). Furthermore, in steady state, the model fits the data for average (annual) interest rates of newly granted loans to non-financial corporations in Germany (1.22% to 1.22%) and Italy (1.40% to 1.40%). This implies that the choice of the level of balance sheet costs is reasonable. Note that, considering that our model does not capture government spending, the share of investment and consumption in GDP is slightly higher in the model than in the data, as expected.

| Description | Value Data | Data Source | Value Model |
|---|---|---|---|
| Relative GDP/Capita: Germany (A) to Italy (B) | 1.27 | OECD (2021b) | 1.26 |
| Relative Average (Annual) Salary: Germany (A) to Italy (B) | 1.32 | OECD (2021a) | 1.26 |
| Consumption Share Germany (A) in Overall Consumption (Germany (A) + Italy (B)), Taylor Rule Parameter | 0.63 | The World Bank (2021) | 0.65 |
| Relative Capital Stock: Germany (A) to Italy (B) | 1.24 | University of Groningen and University of California (2021a,b) | 1.24 |
| Investment Share in GDP: Germany (A) | 0.225 | CEIC (2021a) | 0.256 |
| Investment Share in GDP: Italy (B) | 0.170 | CEIC (2021c) | 0.247 |
| Consumption Share in GDP: Germany (A) | 0.506 | CEIC (2021b) | 0.744 |
| Consumption Share in GDP: Italy (B) | 0.608 | CEIC (2021d) | 0.753 |
| Average (Annual) Interest Rate of New Loans to Corporations: Germany (A) 2017 – 2020 | 1.22% | European Central Bank (2021d) | 1.22% |
| Average (Annual) Interest Rate of New Loans to Corporations: Italy (B) 2017 – 2020 | 1.40% | European Central Bank (2021e) | 1.40% |
| Share of Liabilities of Euro Area Monetary Financial Institutions (Excluding the Eurosystem) Towards Non-Euro Area Residents on Banks' Balance Sheets: Germany (A) | 9% | Deutsche Bundesbank (2021) | 9% |
| Share of Liabilities of Euro Area Monetary Financial Institutions (Excluding the Eurosystem) Towards Non-Euro Area Residents on Banks' Balance Sheets: Italy (B) | 2% | Banca d'Italia (2021) | 2% |

Table 2: Steady state in comparison to data.

Moreover, while the model slightly understates labor income inequality between Germany and Italy (1.32 to 1.26), it closely replicates relative GDP per capita of Germany to Italy (1.27 to 1.26). In addition, the parameter relevant for weighting consumer price inflation in country $A$ and $B$ in the Taylor rule, $\gamma_{k,t}$, is very close to the data-equivalent in steady state (0.63 to 0.65). Lastly, as already mentioned, we calibrate the model to exactly replicate the share of liabilities of euro area monetary financial institutions (excluding the Eurosystem) towards non-euro area residents on banks' balance sheets in Germany (9%) and Italy (2%).

## 4.2 Dynamic Analysis

We continue by examining the model responses to a preference shock and a deposit shift shock. All results are deviations from the zero inflation steady state.

### 4.2.1 Preference Shock

Figure 2 depicts the impulse responses of the monetary union to a symmetric negative 1% preference shock in countries A and B. An example for this shock could be the COVID-19 pandemic. The responses are qualitatively similar in both countries but differ quantitatively. The preference shock implies a decrease in the households' appreciation of consumption, formally captured by a decrease in their marginal utility for each level of consumption. Thus, consumption decreases, proportionally in domestic and foreign terms. Note that the low-liquidity country B reaches its lowest consumption slightly later due to its higher habit parameter. Furthermore, the households' marginal benefit from labor, and thus their labor supply, decreases and real wages go up initially. The demand for goods decreases, implying falling output and prices. The latter implies an expansionary monetary policy reaction. The central bank increases its net asset purchases (QE), leading to a decrease in the long-term interest rate $i_t$, i.e., the bond rate, and an increase in QE-created bank deposits (equation (37)). Note that, motivated by the mechanical peculiarities of QE in the euro area presented in Section 2, QE-created bank deposits increase more in the high-liquidity country A than in the low-liquidity country B.

As a consequence of this expansionary monetary policy action, there are two effects on bank costs. On the one hand, banks face lower interest costs (interest rate channel of QE), on the other hand, they have to cope with higher balance sheet costs due to the increase in deposits (reverse bank lending channel of QE). As we calibrate balance sheet costs to be rather low (see Section 4.1), ensuring that our results with respect to the negative impact of balance sheet costs on the efficacy of QE constitute a lower bound, the decrease in costs due to the lower interest rate outweighs the increase implied by higher balance sheet costs.

Consequently, bank loan supply increases, implying a decrease in the bank loan rate and higher bank lending (interest rate channel but weakened by the reverse bank lending channel). Investment and thus (one period lagged) capital increase. The increasing capital stock implies higher labor productivity. Real wages rise, leading to increasing labor and consumption.

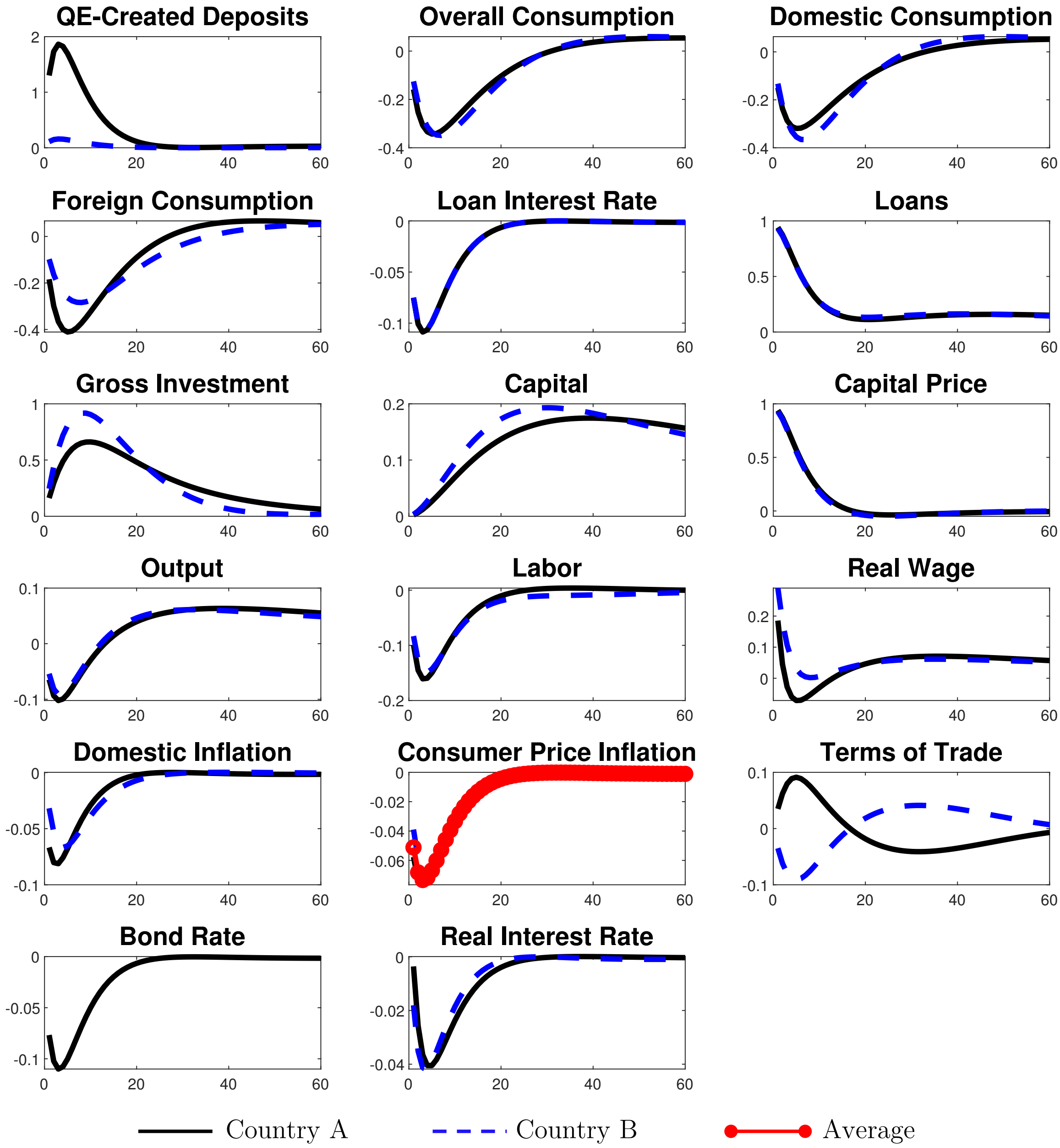


Figure 2: Impulse responses to a symmetric, negative 1% preference shock.

Inflation starts to increase but rather slowly, due to the price rigidities, implying that monetary policy remains expansionary, leading to further increases in the capital stock. Therefore, there are two positive effects on consumption over time: first, the shock reduction, and second, the rise in real wages due to the increase in the capital stock and thus higher labor productivity. The price rigidities imply a still expansionary monetary policy and, therefore, a further buildup of the capital stock, even when the shock itself is already completely reduced. This leads to a temporary "overshooting" (levels temporarily exceed their steady state) of real wages, consumption, and output.[28]

The rigidities in the form of the CAC imply, on the one hand, that the buildup of the capital stock is impeded. Consequently, coming from negative consumption deviations, the steady state of consumption is reached later and the overshooting is dampened. However, on the other hand, the CAC also imply that the overshooting lasts longer as the reduction of the capital stock is also impeded. Note that higher CAC in the high-liquidity country A imply a lower increase in investment and capital in A than in B as well as a longer lasting overshooting.

Consequently, QE in our model works as expected of an expansionary monetary policy impulse: it triggers investment and therefore increases the capital stock, supporting output, consumption, and ultimately the consumer price level to reach steady state levels. However, the effect would be stronger if it were not for the QE-induced increase in balance sheet costs resulting from higher QE-created deposits. Balance sheet costs imply a reverse bank lending channel. The traditional bank lending channel describes a positive relationship between bank deposits and credit lending. For instance, a contractionary monetary policy impulse leads to decreasing deposits and hence to a decline in lending (Bernanke and Gertler, 1995; Kashyap and Stein, 1995). Accordingly, expansionary monetary policy, for instance QE, should increase bank deposits and credit lending. However, in our model, increasing deposits imply larger (balance sheet) costs for banks. Therefore, there is a reverse bank lending channel weakening the interest rate channel of QE. The specific implementation of QE implies a higher increase in excess reserves and QE-created deposits, and thereby also in bank balance sheet costs, in country A than in country B. Thus, the dampening effects are stronger in the high-liquidity country A, i.e., in our model, monetary policy is less effective in that country.

[28]This overshooting is slightly reinforced by the one-period lag between the firms' investment decision and the use of the capital in the production process.

#### 4.2.2 Deposit Shift Shock

Figure 3 depicts the impulse responses of the monetary union to a deposit shift shock. We simulate an approximately 12% withdrawal of QE-created deposits from low-liquidity country B. These deposits are then moved to the high-liquidity country A, increasing deposits by 2%. This shock can be interpreted as capital flight ("safe-haven-flows" or "flight-to-quality" phenomena). As described in Section 2, such a shift in deposits could be primarily observed during the financial and sovereign debt crisis. In current times, an additional deposit shift would strengthen the already existing asymmetric distribution of deposits.

The consequences of such a deposit shift shock in country A are as follows. Bank A's deposits, and thus its balance sheet costs, increase which leads to a decrease in its loan supply. The bank loan rate increases and bank lending in country A decreases. Consequently, investment and thus the capital stock decrease, implying a lower output. The influence of the CAC are analogous to the described effects in Section (4.2.1). Labor productivity, and therefore labor demand, decrease. Real wages and labor input fall. First, the resulting lower labor costs imply decreasing prices. However, over time higher loan and capital costs dominate and firms adjust prices upwards.

In country B, the consequences of the deposit shift are reversed. Lower bank costs imply more investment, and thus a higher capital stock and labor input, which leads to more output and initially increasing prices. As a consequence of higher prices, domestic consumption initially decreases in country B. Nevertheless, output increases due to higher investment, causing higher labor demand and wages. Over time, lower capital costs lead to a decrease in the price level, implying higher consumption of domestic goods, lower consumption of foreign goods, and an increase in the terms of trade between country B and country A over time.

Note that the monetary policy reaction is rather weak as it reacts to the average consumer price inflation rate in the monetary union. As the shock becomes less relevant, so too does the decrease (increase) in country A's (B's) capital stock, until the process returns and the capital stock converges to its steady state.

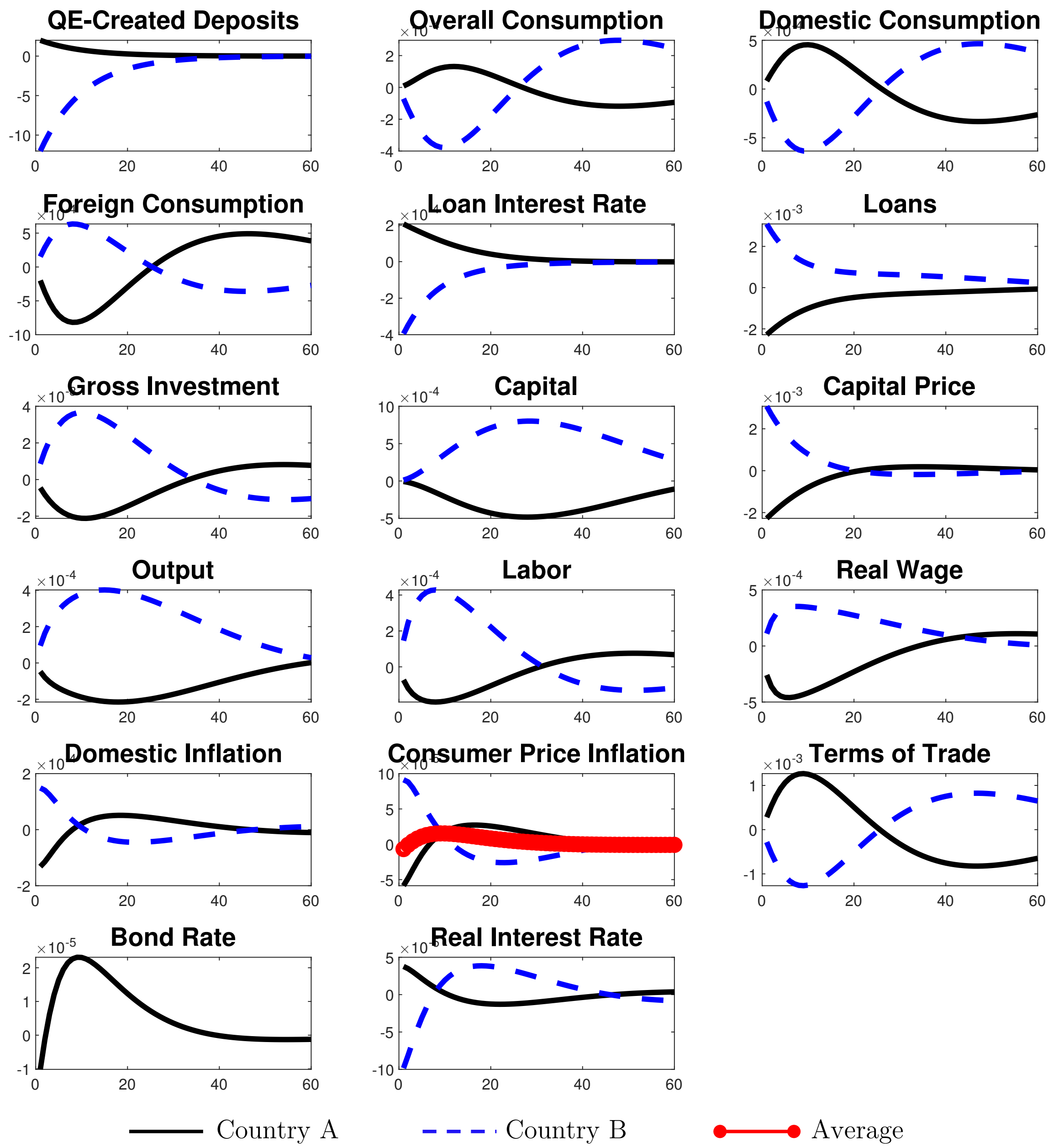


Figure 3: Impulse responses to a deposit shift shock from country B to A.

Thus, in our model that focusses on excess reserves and does not consider potential underlying reasons for this shift, the deposit shift from country B to A negatively affects the economy of country A due to higher bank costs, implying lower investment and thus a lower capital stock, and therefore a decrease in output and consumption. Analogously, the country B economy benefits from this shock.

## 5 Conclusion

Since the start of the Eurosystem's QE program in March 2015, excess reserves in the euro area banking sector have persistently increased. The large quantity of excess reserves as well as its asymmetric distribution across euro area countries resulting from the specific implementation of QE has triggered a great amount of concern and debate. However, there is little analysis of whether and to what extent large quantities of excess reserves affect macroeconomic variables in different countries of a monetary union. For instance, with regard to the impact on bank lending, only little research has been conducted on whether there is a *bank lending channel* in the sense that QE-induced increases in bank reserves and deposits have a positive impact on bank lending.

Against this background, our paper develops a two-country New Keynesian model to analyze the macroeconomic effects of QE, explicitly considering the QE-induced heterogeneous increases in excess reserves and deposits in a monetary union. The model is calibrated for Germany and Italy to represent a high- and a low-liquidity euro area country. Hereby, we capture the consequences of the specific implementation of QE in the euro area, i.e., the resulting large amount of excess reserves in the banking sector, as well as its heterogeneous distribution across euro area countries. These consequences have important implications for our model as banks are exposed to balance sheet costs, i.e., costs related to the size of their balance sheet (for instance, in the form of agency or regulatory costs). We introduce QE as the central bank's monetary policy tool. Applying QE decreases long-term interest rates, but, in addition, also implies an increase in banks' excess reserve and deposit holdings.

Analyzing the model responses to a negative preference shock in both countries (due to the COVID-19 pandemic, for instance), we find that QE, as an expansionary monetary policy tool, works as expected: the QE-induced decrease in long-term interest rates implies an increase in consumption and bank loan-financed investment. As a consequence, output, employment, and prices rise (*interest rate channel* of QE). However, the effects of this expansionary monetary policy reaction to the shock are weakened by QE-induced increases in excess reserves and deposits, implying increasing (balance sheet) costs for banks and, therefore, a smaller decrease in the bank loan rate and thus a lower increase in bank loan-financed investment. Consequently, the interest rate channel is dampened by a *reverse bank lending channel*. The dampening effects are more pronounced in the high-liquidity country.

With respect to the ECB's reaction to the COVID-19 pandemic, one can conclude the following from our model. One measure of the ECB in response to the pandemic was the introduction of the Pandemic Emergency Purchase Programme (PEPP). While the PEPP has a dual objective, i.e., creating financial conditions (low interest rates) to stabilize the economy and mitigating the pandemic-induced malfunctioning of financial markets (Schnabel, 2020), its implementation is similar to the implementation of the APP introduced in 2015. Therefore, the stabilizing effects on the economy of the PEPP through an interest rate channel are also weakened by a reverse bank lending channel.

Our model suggests that central banks should consider that QE-induced increases in excess reserves and deposits may dampen the stimulating and stabilizing effects of this monetary policy measure on the economy. In particular, it should be taken into consideration that these dampening effects may differ across countries due to the asymmetric distribution of excess reserves and bank deposits as a consequence of the specific technical implementation of QE in the euro area. Moreover, optimal monetary policy within the given institutional framework may differ when these effects are taken into account.

# A Appendix

## A.1 Households

*Expenditure Minimization – Composition of Domestic and Foreign Composite Consumption Good.* The household minimizes its expenditures for any given level of domestic consumption:

$$\min_{C^k_{k,t}(j)} \int_0^1 P_{k,t}(j) C^k_{k,t}(j) dj$$

subject to

$$\left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1}} = \bar{C}^k_k \; .$$

This is equivalent to maximizing the following Lagrange function with respect to the consumption of a representative good $i$:

$$\max_{C^k_{k,t}(i)} L = - \int_0^1 P_{k,t}(j) C^k_{k,t}(j) dj + \lambda_{k,t} \left[ \left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1}} - \bar{C}^k_k \right] \; .$$

The first order conditions are given by

$$\frac{\partial L}{\partial C^k_{k,t}(i)} = -P_{k,t}(i) + \lambda_{k,t} \left[ \left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1} - 1} C^k_{k,t}(i)^{\frac{\epsilon_k - 1}{\epsilon_k} - 1} \right] = 0 \; ,$$

$$\frac{\partial L}{\partial \lambda_{k,t}} = 0 \; .$$

Rearranging yields

$$0 = -P_{k,t}(i) + \lambda_{k,t} \left[ \left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} di \right)^{\frac{1}{\epsilon_k - 1}} C^k_{k,t}(i)^{-\frac{1}{\epsilon_k}} \right] \; ,$$

$$C^k_{k,t}(i) = \left( \frac{P_{k,t}(i)}{\lambda_{k,t}} \right)^{-\epsilon_k} C^k_{k,t} \; .$$

In order to obtain the expression for optimal consumption, it is necessary to solve for the lagrange multiplier $\lambda_{k,t}$ by using the constraint:

$$\left( \int_0^1 C^k_{k,t}(j)^{\frac{\epsilon_k - 1}{\epsilon_k}} dj \right)^{\frac{\epsilon_k}{\epsilon_k - 1}} = \bar{C}^k_k \; ,$$

$$\left(\int_0^1 \left[\left(\frac{P_{k,t}(j)}{\lambda_{k,t}}\right)^{-\epsilon_k} \bar{C}_k^k\right]^{\frac{\epsilon_k-1}{\epsilon_k}} dj\right)^{\frac{\epsilon_k}{\epsilon_k-1}} = \bar{C}_k^k \ ,$$

$$\int_0^1 \left(\frac{P_{k,t}(j)}{\lambda_{k,t}}\right)^{1-\epsilon_k} dj = 1 \ .$$

Thus, the solution for $\lambda_{k,t}$ is

$$\lambda_{k,t} = \left(\int_0^1 P_{k,t}(j)^{1-\epsilon_k} dj\right)^{\frac{1}{1-\epsilon_k}} = P_{k,t} \ .$$

Plugging this solution into the optimal consumption decision for any domestic good $j$ yields

$$C_{k,t}^k(j) = \left(\frac{P_{k,t}(j)}{P_{k,t}}\right)^{-\epsilon_k} C_{k,t}^k \ .$$

Symmetrically, the optimal consumption for any foreign good $j$ is

$$C_{-k,t}^k(j) = \left(\frac{P_{-k,t}(j)}{P_{-k,t}}\right)^{-\epsilon_k} C_{-k,t}^k \ .$$

*Expenditure Minimization – Allocation between Domestic and Foreign Goods.* The household minimizes its expenditures for any level of overall consumption:

$$\min_{C_{k,t}^k, C_{-k,t}^k} \ P_{k,t} C_{k,t}^k + P_{-k,t} C_{-k,t}^k$$

subject to

$$\frac{\left(C_{k,t}^k\right)^{1-\sigma_k} \left(C_{-k,t}^k\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k} (\sigma_k)^{\sigma_k}} = \bar{C}^k \ .$$

This is equivalent to maximizing the following Lagrange function with respect to the domestic and foreign consumption level:

$$L = -P_{k,t} C_{k,t}^k - P_{-k,t} C_{-k,t}^k + \lambda_{k,t} \left(\frac{\left(C_{k,t}^k\right)^{1-\sigma_k} \left(C_{-k,t}^k\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k} (\sigma_k)^{\sigma_k}} - \bar{C}^k\right) \ .$$

The first order conditions are:

$$\frac{\partial L}{\partial C^k_{k,t}} = -P_{k,t} + \lambda_{k,t}\left(\frac{(1-\sigma_k)\left(C^k_{k,t}\right)^{-\sigma_k}\left(C^k_{-k,t}\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k}(\sigma_k)^{\sigma_k}}\right) = 0 \ ,$$

$$\frac{\partial L}{\partial C^k_{-k,t}} = -P_{-k,t} + \lambda_{k,t}\left(\frac{\left(C^k_{k,t}\right)^{1-\sigma_k}\sigma_k\left(C^k_{-k,t}\right)^{\sigma_k-1}}{(1-\sigma_k)^{1-\sigma_k}(\sigma_k)^{\sigma_k}}\right) = 0 \ ,$$

$$\frac{\partial L}{\partial \lambda_{k,t}} = 0 \ .$$

Rearranging yields

$$P_{k,t} = \lambda_{k,t}(1-\sigma_k)\left(\frac{\left(C^k_{k,t}\right)^{-\sigma_k}\left(C^k_{-k,t}\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k}(\sigma_k)^{\sigma_k}}\frac{C^k_{k,t}}{C^k_{k,t}}\right) ,$$

$$P_{-k,t} = \lambda_{k,t}\sigma_k\left(\frac{\left(C^k_{k,t}\right)^{1-\sigma_k}\left(C^k_{-k,t}\right)^{\sigma_k-1}}{(1-\sigma_k)^{1-\sigma_k}(\sigma_k)^{\sigma_k}}\frac{C^k_{-k,t}}{C^k_{-k,t}}\right) ,$$

which can be rewritten as

$$C^k_{k,t} = (1-\sigma_k)\left(\frac{P_{k,t}}{\lambda_{k,t}}\right)^{-1} C^k_t \ ,$$

$$C^k_{-k,t} = \sigma_k\left(\frac{P_{-k,t}}{\lambda_{k,t}}\right)^{-1} C^k_t \ .$$

Plugging into the constraint gives

$$\frac{\left((1-\sigma_k)\left(\frac{P_{k,t}}{\lambda_{k,t}}\right)^{-1}\bar{C}^k\right)^{1-\sigma_k}\left(\sigma_k\left(\frac{P_{-k,t}}{\lambda_{k,t}}\right)^{-1}\bar{C}^k\right)^{\sigma_k}}{(1-\sigma_k)^{1-\sigma_k}(\sigma_k)^{\sigma_k}} = \bar{C}^k \ .$$

Clearly,

$$\lambda_{k,t} = P^{1-\sigma_k}_{k,t}P^{\sigma_k}_{-k,t} \equiv P^C_{k,t} \ ,$$

and the optimal allocation of consumption expenditures between domestic and foreign consumption is given by

$$C^k_{k,t} = (1-\sigma_k)\left(\frac{P_{k,t}}{P^C_{k,t}}\right)^{-1} C^k_t \ ,$$

$$C^k_{-k,t} = \sigma_k\left(\frac{P_{-k,t}}{P^C_{k,t}}\right)^{-1} C^k_t \ .$$

*Utility Maximization.* The household seeks to maximize expected lifetime utility:

$$\max_{C^k_t, N^k_t, B^k_t} \mathbb{E}_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[Z_\tau ln\left(C^k_\tau - \Psi_k C^k_{\tau-1}\right) - \frac{\chi_k}{1+\varphi_k}(N^k_\tau)^{1+\varphi_k}\right]\right]$$

subject to

$$P^C_{k,t} C^k_t + B^k_t = (1+i_{t-1}) B^k_{t-1} + W_{k,t} N^k_t + \Upsilon^k_t \ .$$

The Lagrange function is

$$L = \mathbb{E}_t \left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[Z_\tau ln\left(C^k_\tau - \Psi_k C^k_{\tau-1}\right) - \frac{\chi_k}{1+\varphi_k}(N^k_\tau)^{1+\varphi_k} - \lambda_{k,\tau}\left(P^C_{k,\tau} C^k_\tau + B^k_\tau - (1+i_{\tau-1}) B^k_{\tau-1} - W_{k,\tau} N^k_\tau - \Upsilon^k_\tau\right)\right]\right] .$$

The first order conditions are given by

$$\frac{\partial L}{\partial C^k_t} = U^k_{c,t} - \lambda_{k,t} P^C_{k,t} = 0 \ , \qquad (A1)$$

$$\frac{\partial L}{\partial N^k_t} = \chi_k (N^k_t)^{\varphi_k} + \lambda_{k,t} W_{k,t} = 0 \ , \qquad (A2)$$

$$\frac{\partial L}{\partial B^k_t} = -\lambda_{k,t} + \beta(1+i_t)\, \mathbb{E}_t\left[\lambda_{k,t+1}\right] = 0 \ , \qquad (A3)$$

$$\frac{\partial L}{\partial \lambda_{k,t}} = 0 \ , \qquad (A4)$$

with

$$U^k_{c,t} \equiv \left(\frac{Z_t}{C^k_t - \Psi_k C^k_{t-1}} - \frac{\mathbb{E}_t\left[Z_{t+1}\right] \Psi_k \beta}{\mathbb{E}_t\left[C^k_{t+1}\right] - \Psi_k C^k_t}\right) .$$

Plugging (A1) into (A2) and (A3) gives

$$\chi_k (N^k_t)^{\varphi_k} = U^k_{c,t} \frac{W_{k,t}}{P^C_{k,t}} \ ,$$

$$\beta(1+i_t)\,\mathbb{E}_t\left[\frac{P^C_{k,t}}{P^C_{k,t+1}}\right]\Lambda^k_{t,t+1} = 1\ ,$$

with

$$\Lambda^k_{t,t+1} \equiv \mathbb{E}_t\left[\frac{U^k_{c,t+1}}{U^k_{c,t}}\right]\ .$$

*Risk-Sharing.* The Euler equation holds in both countries at all times. Thus,

$$\frac{P^C_{k,t}}{P^C_{k,t+1}}\frac{U^k_{c,t+1}}{U^k_{c,t}} = \frac{P^C_{-k,t}}{P^C_{-k,t+1}}\frac{U^{-k}_{c,t+1}}{U^{-k}_{c,t}}\ ,$$

or, using the definition of the terms of trade,

$$\frac{P_{k,t}\left(V^k_{-k,t}\right)^{\sigma_k}}{P_{k,t+1}\left(V^k_{-k,t+1}\right)^{\sigma_k}}\frac{U^k_{c,t+1}}{U^k_{c,t}} = \frac{P_{-k,t}\left(V^{-k}_{k,t}\right)^{\sigma_{-k}}}{P_{-k,t+1}\left(V^{-k}_{k,t+1}\right)^{\sigma_{-k}}}\frac{U^{-k}_{c,t+1}}{U^{-k}_{c,t}}\ .$$

This relation holds in all periods, i.e.,

$$\frac{P_{k,t-1}\left(V^k_{-k,t-1}\right)^{\sigma_k}}{P_{k,t}\left(V^k_{-k,t}\right)^{\sigma_k}}\frac{U^k_{c,t}}{U^k_{c,t-1}} = \frac{P_{-k,t-1}\left(V^{-k}_{k,t-1}\right)^{\sigma_{-k}}}{P_{-k,t}\left(V^{-k}_{k,t}\right)^{\sigma_{-k}}}\frac{U^{-k}_{c,t}}{U^{-k}_{c,t-1}}\ .$$

This condition can be rearranged in the following way:

$$\frac{U^k_{c,t}}{U^{-k}_{c,t}} = \frac{P_{k,t}}{P_{-k,t}}\frac{P_{-k,t-1}}{P_{k,t-1}}\frac{\left(V^{-k}_{k,t-1}\right)^{\sigma_{-k}}}{\left(V^k_{-k,t-1}\right)^{\sigma_k}}\frac{\left(V^k_{-k,t}\right)^{\sigma_k}}{\left(V^{-k}_{k,t}\right)^{\sigma_{-k}}}\frac{U^k_{c,t-1}}{U^{-k}_{c,t-1}}\ ,$$

$$\frac{U^k_{c,t}}{U^{-k}_{c,t}} = \left(V^k_{-k,t}\right)^{-1}V^k_{-k,t-1}\frac{\left(V^{-k}_{k,t-1}\right)^{\sigma_{-k}}}{\left(V^k_{-k,t-1}\right)^{\sigma_k}}\frac{\left(V^k_{-k,t}\right)^{\sigma_k}}{\left(V^{-k}_{k,t}\right)^{\sigma_{-k}}}\frac{U^k_{c,t-1}}{U^{-k}_{c,t-1}}\ ,$$

$$\frac{U^k_{c,t}}{U^{-k}_{c,t}} = \left(V^k_{-k,t}\right)^{\sigma_k-1}\left(V^k_{-k,t-1}\right)^{1-\sigma_k}\left(V^{-k}_{k,t}\right)^{-\sigma_{-k}}\left(V^{-k}_{k,t-1}\right)^{\sigma_{-k}}\frac{U^k_{c,t-1}}{U^{-k}_{c,t-1}}\ .$$

In the previous period:

$$\frac{U^k_{c,t-1}}{U^{-k}_{c,t-1}} = \left(V^k_{-k,t-1}\right)^{\sigma_k-1}\left(V^k_{-k,t-2}\right)^{1-\sigma_k}\left(V^{-k}_{k,t-1}\right)^{-\sigma_{-k}}\left(V^{-k}_{k,t-2}\right)^{\sigma_{-k}}\frac{U^k_{c,t-2}}{U^{-k}_{c,t-2}}\ .$$

Recursively,

$$\frac{U_{c,t}^{k}}{U_{c,t}^{-k}} = \left(V_{-k,t}^{k}\right)^{\sigma_k - 1} \left(V_{-k,t-2}^{k}\right)^{1-\sigma_k} \left(V_{k,t}^{-k}\right)^{-\sigma_{-k}} \left(V_{k,t-2}^{-k}\right)^{\sigma_{-k}} \frac{U_{c,t-2}^{k}}{U_{c,t-2}^{-k}} \ .$$

Continuing this procedure to the initial period, i.e., the steady state, we get

$$\frac{U_{c,t}^{k}}{U_{c,t}^{-k}} = \left(V_{-k,t}^{k}\right)^{\sigma_k - 1} \left(V_{-k,ss}^{k}\right)^{1-\sigma_k} \left(V_{k,t}^{-k}\right)^{-\sigma_{-k}} \left(V_{k,ss}^{-k}\right)^{\sigma_{-k}} \frac{U_{c,ss}^{k}}{U_{c,ss}^{-k}} \ ,$$

with $V_{-k,ss}^{k} = V_{k,ss}^{-k} = 1$. Rearranging yields:

$$U_{c,t}^{k} = \vartheta_k (V_{-k,t}^{k})^{(\sigma_k - 1)} (V_{k,t}^{-k})^{(-\sigma_{-k})} U_{c,t}^{-k} \ .$$

## A.2 Intermediate Goods Firms

The competitive intermediate goods firm maximizes its period profit:

$$\max_{N_t^k, K_{t,t+1}^k} \Gamma_{m,t}^{k} = mc_{k,m,t} Y_{m,t}^{k} - w_{k,t} N_t^k - \left(1 + i_{k,t-1}^{L}\right) Q_{k,t-1} K_{t-1,t}^{k} + (Q_{k,t} - \delta_k) K_{t-1,t}^{k} \ ,$$

with

$$Y_{m,t}^{k} = \left(K_{t-1,t}^{k}\right)^{\alpha_k} \left(N_t^k\right)^{1-\alpha_k} \ .$$

The first order conditions are given by

$$\frac{\partial \Gamma_{m,t}^{k}}{\partial N_t^k} = mc_{k,m,t}(1-\alpha_k)\frac{Y_{m,t}^{k}}{N_t^k} - w_{k,t} = 0 \ ,$$

$$\frac{\partial \Gamma_{m,t+1}^{k}}{\partial K_{t,t+1}^{k}} = mc_{k,m,t+1}\alpha_k \frac{Y_{m,t+1}^{k}}{K_{t,t+1}^{k}} - \left(1 + i_{k,t}^{L}\right) Q_{k,t} + Q_{k,t+1} - \delta_k = 0 \ .$$

Rearranging yields:

$$mc_{k,m,t} = \frac{w_{k,t}}{(1-\alpha_k)\frac{Y_{m,t}^{k}}{N_t^k}} \ ,$$

$$\left(1 + i_{k,t}^{L}\right) Q_{k,t} = \alpha_k mc_{k,m,t+1} \frac{Y_{m,t+1}^{k}}{K_{t,t+1}^{k}} + Q_{k,t+1} - \delta_k \ .$$

## A.3 Capital Producing Firms

Gross capital produced in period $t$, $I_t^{gr,k}$, consists of newly created capital (net investment) $I_t^k$, and the refurbishment of the bought capital $\delta_k K_{t-1,t}^k$:

$$I_t^{gr,k} = I_t^k + \delta_k K_{t-1,t}^k \ .$$

The law of motion for capital is thus given by

$$K_{t,t+1}^k = K_{t-1,t}^k + I_t^k \ .$$

The real period profit of a capital producing firm is then:

$$\Gamma_{c,t}^k = Q_{k,t} K_{t,t+1}^k - (Q_{k,t} - \delta_k) K_{t-1,t}^k - \delta_k K_{t-1,t}^k - I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right)$$

$$\Leftrightarrow \Gamma_{c,t}^k = Q_{k,t} K_{t,t+1}^k - Q_{k,t} K_{t-1,t}^k + \delta_k K_{t-1,t}^k - \delta_k K_{t-1,t}^k - I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right)$$

$$\Leftrightarrow \Gamma_{c,t}^k = Q_{k,t}(K_{t,t+1}^k - K_{t-1,t}^k) - I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right)$$

$$\Leftrightarrow \Gamma_{c,t}^k = Q_{k,t} I_t^k - I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right)$$

$$\Leftrightarrow \Gamma_{c,t}^k = (Q_{k,t} - 1) I_t^k - f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right)\left(I_t^k + I_{ss}\right) \ ,$$

with capital adjustment costs (CAC) given by:

$$f\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}}\right) = \frac{n_k}{2}\left(\frac{I_t^k + I_{ss}}{I_{t-1}^k + I_{ss}} - 1\right)^2 \ .$$

The objective function of the capital producing firm thus becomes

$$\max \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( (Q_{k,\tau} - 1) I_\tau^k - \frac{n_k}{2}\left(\frac{I_\tau^k + I_{ss}}{I_{\tau-1}^k + I_{ss}} - 1\right)^2 \left(I_\tau^k + I_{ss}\right)\right) \ .$$

Capital producers choose net investment $I_t^k$ to maximize their discounted expected profits. The respective first order condition is given by

$$Q_{k,t}-1-\frac{n_k}{2}\left(\frac{I_t^k+I_{ss}}{I_{t-1}^k+I_{ss}}-1\right)^2+2\frac{n_k}{2}\frac{1}{I_{t-1}^k+I_{ss}}\left(\frac{I_t^k+I_{ss}}{I_{t-1}^k+I_{ss}}-1\right)\left(I_t^k+I_{ss}\right)-\mathbb{E}_t\,\beta\Lambda_{t,t+1}^k\left(\frac{I_{t+1}^k+I_{ss}}{I_t^k+I_{ss}}\right)^2 n_k\left(\frac{I_{t+1}^k+I_{ss}}{I_t^k+I_{ss}}-1\right)\stackrel{!}{=}0$$

$$\Leftrightarrow Q_{k,t}=1+\frac{n_k}{2}\left(\frac{I_t^k+I_{ss}}{I_{t-1}^k+I_{ss}}-1\right)^2+\frac{I_t^k+I_{ss}}{I_{t-1}^k+I_{ss}}n_k\left(\frac{I_t^k+I_{ss}}{I_{t-1}^k+I_{ss}}-1\right)-\mathbb{E}_t\,\beta\Lambda_{t,t+1}^k\left(\frac{I_{t+1}^k+I_{ss}}{I_t^k+I_{ss}}\right)^2 n_k\left(\frac{I_{t+1}^k+I_{ss}}{I_t^k+I_{ss}}-1\right)\ ,$$

where marginal revenues (LHS) equal marginal costs (RHS).

## A.4 Retail Firms

Firm $j$ chooses its price $P_{k,t}(j)$ to maximize discounted expected real profits given by

$$\max\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}{\theta_k}^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left(\frac{P_{k,t}(j)}{P_{k,\tau}^C}Y_{k,\tau|t}(j)-TC(Y_{k,\tau|t}(j))\right)\right]\ ,$$

subject to

$$\begin{aligned}Y_{k,\tau|t}(j)&=\left(\frac{P_{k,t}(j)}{P_{k,\tau}}\right)^{-\epsilon_k}\left(C_{k,\tau|t}^k+C_{k,\tau|t}^{-k}\right)\\&=\left(\frac{P_{k,t}(j)}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\ .\end{aligned}$$

$$\Rightarrow\max_{P_{k,t}(j)}\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}{\theta_k}^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left(P_{k,t}(j)\frac{1}{P_{k,\tau}^C}\left(P_{k,t}(j)\right)^{-\epsilon_k}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}-TC\left(\left(\frac{P_{k,t}(j)}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\right)\right)\right]$$

$$\Rightarrow\max_{P_{k,t}(j)}\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}{\theta_k}^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left(\frac{1}{P_{k,\tau}^C}\left(P_{k,t}(j)\right)^{1-\epsilon_k}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}-TC\left(\left(\frac{P_{k,t}(j)}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\right)\right)\right]\ .$$

The first oder condition is given by

$$\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}\theta_k^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left((1-\epsilon_k)\frac{1}{P_{k,\tau}^C}\left(P_{k,t}^*(j)\right)^{-\epsilon_k}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}-(-\epsilon_k)\left(P_{k,t}^*(j)\right)^{-\epsilon_k-1}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\cdot mc(Y_{k,\tau|t}(j))\right)\right]\stackrel{!}{=}0$$

$$\Leftrightarrow\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}\theta_k^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left((1-\epsilon_k)\frac{1}{P_{k,\tau}^C}\left(\frac{P_{k,t}^*(j)}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}-(-\epsilon_k)\left(P_{k,t}^*(j)\right)^{-\epsilon_k-1}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\cdot mc(Y_{k,\tau|t}(j))\right)\right]\stackrel{!}{=}0$$

$$\Leftrightarrow\mathbb{E}_t\left[\sum_{\tau=t}^{\infty}\theta_k^{\tau-t}\beta^{\tau-t}\Lambda_{t,\tau}^k\left((1-\epsilon_k)\frac{1}{P_{k,\tau}^C}Y_{k,\tau|t}(j)-(-\epsilon_k)\left(P_{k,t}^*(j)\right)^{-\epsilon_k}\left(P_{k,t}^*(j)\right)^{-1}\left(\frac{1}{P_{k,\tau}}\right)^{-\epsilon_k}Y_{k,\tau}\cdot mc(Y_{k,\tau|t}(j))\right)\right]\stackrel{!}{=}0$$

$$\Leftrightarrow \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( (1-\epsilon_k) \frac{Y_{k,\tau|t}(j)}{P_{k,\tau}^C} + \epsilon_k \left(P_{k,t}^*(j)\right)^{-1} Y_{k,\tau|t}(j) \cdot mc(Y_{k,\tau|t}(j)) \right) \right] \stackrel{!}{=} 0$$

$$\Leftrightarrow \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k Y_{k,\tau|t}(j) \left( (1-\epsilon_k) \frac{1}{P_{k,\tau}^C} + \epsilon_k \frac{1}{P_{k,t}^*(j)} \cdot mc(Y_{k,\tau|t}(j)) \right) \right] \stackrel{!}{=} 0$$

$$\Leftrightarrow \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k Y_{k,\tau|t}(j) \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}^C} - \frac{\epsilon_k}{\epsilon_k - 1} \cdot mc(Y_{k,\tau|t}(j)) \right) \right] \stackrel{!}{=} 0 ,$$

with the real marginal costs of the retail firm equaling the price they are paying for each unit of intermediate goods, i.e., the real marginal cost function is given by

$$mc(Y_{k,\tau|t}(j)) = mc_{k,m,\tau} = P_{k,m,\tau} .$$

Derive optimal price $P_{k,t}^*(j)$ of firm $j$ as following:[29]

$$\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k Y_{k,\tau|t}(j) \frac{P_{k,t}^*(j)}{P_{k,\tau}^C} \right] = \frac{\epsilon_k}{\epsilon_k - 1} \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k Y_{k,\tau|t}(j) \cdot mc_{k,m,\tau} \right] ,$$

with $Y_{k,\tau|t}(j) = \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}^C} \right)^{-\epsilon_k} Y_{k,\tau}$ :

$$\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}} \right)^{-\epsilon_k} Y_{k,\tau} \frac{P_{k,t}^*(j)}{P_{k,\tau}^C} \right] = \frac{\epsilon_k}{\epsilon_k - 1} \mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}} \right)^{-\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right] .$$

Solving for $P_{k,t}^*(j)$ yields:

$$1 = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}} \right)^{-\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( \frac{P_{k,t}^*(j)}{P_{k,\tau}} \right)^{-\epsilon_k} Y_{k,\tau} \frac{P_{k,t}^*(j)}{P_{k,\tau}^C} \right]}$$

[29] Note that index $j$ is dropped since all firms being able to adopt their prices will set the same price.

$$\Leftrightarrow 1 = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( P_{k,t}^*(j) \right)^{-\epsilon_k} (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k \left( P_{k,t}^*(j) \right)^{1-\epsilon_k} (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \left( P_{k,\tau}^C \right)^{-1} \right]}$$

$$\Leftrightarrow 1 = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k P_{k,t}^*(j) (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \left( P_{k,\tau}^C \right)^{-1} \right]}$$

$$\Leftrightarrow P_{k,t}^*(j) = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \left( P_{k,\tau}^C \right)^{-1} \right]} ,$$

with $P_{k,\tau}^C(j) = P_{k,\tau} \cdot \left( V_{-k,\tau}^k \right)^{\sigma}$ :

$$\Leftrightarrow P_{k,t}^*(j) = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} (P_{k,\tau})^{-1} \left( V_{-k,\tau}^k \right)^{-\sigma} \right]}$$

$$\Leftrightarrow P_{k,t}^*(j) = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (P_{k,\tau})^{\epsilon_k - 1} Y_{k,\tau} \left( V_{-k,\tau}^k \right)^{-\sigma} \right]}$$

$$\Leftrightarrow \frac{P_{k,t}^*(j)}{P_{k,t}} = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (\Pi_{k,\tau})^{\epsilon_k} Y_{k,\tau} \cdot mc_{k,m,\tau} \right]}{\mathbb{E}_t \left[ \sum_{\tau=t}^{\infty} \theta_k^{\tau-t} \beta^{\tau-t} \Lambda_{t,\tau}^k (\Pi_{k,\tau})^{\epsilon_k - 1} Y_{k,\tau} \left( V_{-k,\tau}^k \right)^{-\sigma} \right]} .$$

Re-write expression as

$$\frac{P_{k,t}^*(j)}{P_{k,t}} = \frac{\epsilon_k}{\epsilon_k - 1} \cdot \frac{x_{k,1,t}}{x_{k,2,t}} ,$$

where

$$x_{k,1,t} \equiv \left[ \frac{Z_t}{C_t^k - \Psi_k C_{t-1}^k} - \frac{\mathbb{E}_t[Z_{t+1}] \Psi_k \beta}{\mathbb{E}_t[C_{t+1}^k] - \Psi_k C_t^k} \right] Y_{k,t}\, mc_{k,m,t} + \beta \theta_k\, \mathbb{E}_t \left[ (\Pi_{k,t,t+1})^{\epsilon_k} x_{k,1,t+1} \right] ,$$

$$x_{k,2,t} \equiv \left[ \frac{Z_t}{C_t^k - \Psi_k C_{t-1}^k} - \frac{\mathbb{E}_t[Z_{t+1}] \Psi_k \beta}{\mathbb{E}_t[C_{t+1}^k] - \Psi_k C_t^k} \right] Y_{k,t} \left( V_{-k,t}^k \right)^{-\sigma_k} + \beta \theta_k\, \mathbb{E}_t \left[ (\Pi_{k,t,t+1})^{\epsilon_k - 1} x_{k,2,t+1} \right] .$$

$$\Leftrightarrow x_{k,1,t} \equiv U^k_{c,t} Y_{k,t} mc_{k,m,t} + \beta\theta_k \, \mathbb{E}_t \left[ (\Pi_{k,t,t+1})^{\epsilon_k} x_{k,1,t+1} \right] \ ,$$

$$\Leftrightarrow x_{k,2,t} \equiv U^k_{c,t} Y_{k,t} \left( V^k_{-k,t} \right)^{-\sigma_k} + \beta\theta_k \, \mathbb{E}_t \left[ (\Pi_{k,t,t+1})^{\epsilon_k - 1} x_{k,2,t+1} \right] \ .$$

## A.5 Banks

In period $t$, bank $k$ seeks to maximize its real period profit $\Gamma^k_{b,t,t+1}$ for period $t+1$. The bank's objective function is given by:

$$\max \mathbb{E}_t[\Gamma^k_{b,t+1}] = i^L_{k,t} L^k_{t,t+1} + i^{RR} r \, \mathbb{E}_t[D^k_{t+1}] + i^{ER} \, \mathbb{E}_t[R^{ER,k}_{t+1}] - i_t \, \mathbb{E}_t[D^k_{t+1}] - \frac{1}{2} \upsilon_k \left( \mathbb{E}_t[D^k_{t+1}] \right)^2 \ .$$

Inserting $D^k_{t+1} = D^{ex}_{k,t+1} + D^{L,k}_{t,t+1}$ , $D^{L,k}_{t,t+1} = L^k_{t,t+1}$ and $R^{ER,k}_{t+1} = D^{ex}_{k,t+1} - r \left( D^{ex}_{k,t+1} + D^{L,k}_{t,t+1} \right)$ yields:

$$\max \mathbb{E}_t[\Gamma^k_{b,t+1}] = i^L_{k,t} L^k_{t,t+1} + i^{RR} r \, \mathbb{E}_t[D^{ex}_{k,t+1} + L^k_{t,t+1}] + i^{ER} \, \mathbb{E}_t[D^{ex}_{k,t+1} - r \left( D^{ex}_{k,t+1} + L^k_{t,t+1} \right)]$$
$$- i_t \, \mathbb{E}_t[D^{ex}_{k,t+1} + L^k_{t,t+1}] - \frac{1}{2} \upsilon_k \left( \mathbb{E}_t[D^{ex}_{k,t+1} + L^k_{t,t+1}] \right)^2 \ .$$

Bank $k$ decides on its optimal loan supply to maximize this profit. Solving this optimization problem with respect to $L^k_{t,t+1}$ yields the first order condition:

$$\frac{\delta \, \mathbb{E}_t[\Gamma^k_{b,t+1}]}{\delta L^k_{t,t+1}} = i^L_{k,t} + i^{RR} r - i^{ER} r - i_t - \upsilon_k \left( \mathbb{E}_t[D^{ex}_{k,t+1}] + L^k_{t,t+1} \right) \stackrel{!}{=} 0$$

$$\Leftrightarrow \ i^L_{k,t} + r(i^{RR} - i^{ER}) = i_t + \upsilon_k \left( \mathbb{E}_t[D^{ex}_{k,t+1}] + L^k_{t,t+1} \right) \ ,$$

where the LHS represents the bank's real marginal revenues of granting loans and the RHS its real marginal costs of granting loans.

# Bibliography

Albonico, A., L. Calés, R. Cardani, O. Croitorov, F. Di Dio, F. Ferroni, M. Giovannini, S. Hohberger, B. Pataracchia, F. Pericoli, P. Pfeiffer, R. Raciborski, M. Ratto, W. Roeger, and L. Vogel (2019). The global multi-country model (GM): An estimated DSGE model for euro area countries. *European Commission, European Economy Discussion Paper 102, July 2019*.

Alvarez, I., F. Casavecchia, M. De Luca, A. Duering, F. Eser, C. Helmus, C. Hemous, N. Herrala, J. Jakovicka, M. Lo Russo, F. Pasqualone, M. Rubens, R. Soares, and F. Zennaro (2017). The use of the Eurosystem's monetary policy instruments and operational framework since 2012. *ECB Occasional Paper 188, May 2017*.

Baldo, L., B. Hallinger, C. Helmus, N. Herrala, D. Martins, F. Mohing, F. Petroulakis, M. Resinek, O. Vergote, B. Usciati, and Y. Wang (2017). The distribution of excess liquidity in the euro area. *ECB Occasional Paper 200, November 2017*.

Banca d'Italia (2021). Statistical Database. Bank of Italy balance sheet: Liabilities - liabilities on non-euro-area residents, in euro and foreign currency. `https://infostat.bancaditalia.it/inquiry/home?spyglass/taxo:CUBESET=/PUBBL_00/PUBBL_00_02_01_04/PUBBL_00_02_01_04_03/SPBI0200&ITEMSELEZ=BAM_SPBI.M.1000.2520120.9.101.WRDBI2.S0.1000.1101026|true&OPEN=false/&ep:LC=EN&COMM=BANKITALIA&ENV=LIVE&CTX=DIFF&IDX=2&/view:CUBEIDS=BAM_SPBI.M.1000.53002073.9.101.WRDBI3.S2BI74.1000.1101026;BAM_SPBI.M.1000.2520120.9.101.WRDBI2.S0.1000.1101026/&timestamp=1584721708328`. [Online; accessed 30-September-2021].

Beetsma, R. M. and H. Jensen (2005). Monetary and fiscal interactions in a micro-founded model of a monetary union. *Journal of International Economics 67*(2), 320–352.

Bekaert, G., S. Cho, and A. Moreno (2010). New Keynesian macroeconomics and the term structure. *Journal of Money, Credit and Banking 42*(1), 33–62.

Benigno, P. (2004). Optimal monetary policy in a currency area. *Journal of International Economics 63*(2), 293–320.

Bernanke, B. S. and M. Gertler (1995). Inside the black box: The credit channel of monetary policy transmission. *Journal of Economic Perspectives 9*(4), 27–48.

Bhattarai, S., J. W. Lee, and W. Y. Park (2015). Optimal monetary policy in a currency union with interest rate spreads. *Journal of International Economics 96*(2), 375–397.

Brunnermeier, M. K. and Y. Koby (2018). The reversal interest rate. *NBER Working Paper Series 25406*.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics 12*(3), 383–398.

CEIC (2021a). Global Database. Germany investment: Percent of GDP. `https://www.ceicdata.com/en/indicator/germany/investment--nominal-gdp`. [Online; accessed 30-September-2021].

CEIC (2021b). Global Database. Germany private consumption: Percent of GDP. https://www.ceicdata.com/en/indicator/germany/private-consumption--of-nominal-gdp. [Online; accessed 30-September-2021].

CEIC (2021c). Global Database. Italy investment: Percent of GDP. https://www.ceicdata.com/en/indicator/italy/investment--nominal-gdp. [Online; accessed 30-September-2021].

CEIC (2021d). Global Database. Italy private consumption: Percent of GDP. https://www.ceicdata.com/en/indicator/italy/private-consumption--of-nominal-gdp. [Online; accessed 30-September-2021].

Chen, H., V. Cúrdia, and A. Ferrero (2012). The macroeconomic effects of large-scale asset purchase programmes. *The Economic Journal 122*(564), 289–315.

Cúrdia, V. and M. Woodford (2011). The central-bank balance sheet as an instrument of monetary policy. *Journal of Monetary Economics 58*(1), 54–79.

Dennis, R. (2005). Specifying and estimating New Keynesian models with instrument rules and optimal monetary policies. *Federal Reserve Bank of San Francisco Working Paper Series*.

Deutsche Bundesbank (2021). Time Series Database. Assets and liabilities of monetary financial institutions (excluding the Bundesbank) in Germany. https://www.bundesbank.de/dynamic/action/en/statistics/time-series-databases/time-series-databases/759784/759784?listId=www_s101_b2023_2. [Online; accessed 30-September-2021].

Ennis, H. M. (2018). A simple general equilibrium model of large excess reserves. *Journal of Monetary Economics 98*, 50–65.

European Central Bank (2015). ECB announces Expanded Asset Purchase Programme. *Press release, 22 January 2015*.

European Central Bank (2019). ECB introduces two-tier system for remunerating excess liquidity holdings. *Press release, 19 September 2019*.

European Central Bank (2021a). Asset purchase programmes. https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html. [Online; accessed 30-September-2021].

European Central Bank (2021b). Measuring inflation  the harmonised index of consumer prices (HICP). https://www.ecb.europa.eu/stats/macroeconomic_and_sectoral/hicp/html/index.en.html. [Online; accessed 30-September-2021].

European Central Bank (2021c). Pandemic emergency purchase programme (PEPP). https://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html. [Online; accessed 30-September-2021].

European Central Bank (2021d). Statistical Data Warehouse. Bank interest rates - loans to corporations (pure new loans) - Germany. https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=124.MIR.M.DE.B.A2A.A.R.A.2240.EUR.P. [Online; accessed 30-September-2021].

European Central Bank (2021e). Statistical Data Warehouse. Bank interest rates - loans to corporations (pure new loans) - Italy. `https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=124.MIR.M.IT.B.A2A.A.R.A.2240.EUR.P`. [Online; accessed 30-September-2021].

European Central Bank (2021f). What is TARGET2? `https://www.ecb.europa.eu/paym/target/target2/html/index.en.html`. [Online; accessed 30-September-2021].

Ferrero, A. (2009). Fiscal and monetary rules for a currency union. *Journal of International Economics 77*(1), 1–10.

Galí, J. (2015). *Monetary Policy, Inflation, and the Business Cycle* (2 ed.). Princeton University Press.

Galí, J. and T. Monacelli (2005). Monetary policy and exchange rate volatility in a small open economy. *Review of Economic Studies 72*(3), 707–734.

Galí, J. and T. Monacelli (2008). Optimal monetary and fiscal policy in a currency union. *Journal of International Economics 76*(1), 116–132.

Gerali, A., S. Nero, L. Sessa, and F. Signoretti (2010). Credit and banking in a DSGE model of the euro area. *Journal of Money, Credit and Banking 42*, 107–141.

Gertler, M. and P. Karadi (2011). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34.

Gertler, M. and P. Karadi (2013). QE 1 vs. 2 vs. 3...: A framework for analyzing large-scale asset purchases as a monetary policy tool. *International Journal of Central Banking 9*(1), 5–53.

Horst, M. and U. Neyer (2019). The impact of quantitative easing on bank loan supply and monetary policy implementation in the euro area. *Review of Economics 70*(3), 229–265.

Ireland, P. N. (2004). Technology shocks in the New Keynesian model. *The Review of Economics and Statistics 86*(4), 923–936.

Jakab, Z. and M. Kumhof (2019). Banks are not intermediaries of loanable funds – facts, theory and evidence. *Bank of England Staff Working Paper No. 761*.

Kashyap, A. K. and J. C. Stein (1995). The impact of monetary policy on bank balance sheets. *Carnegie-Rochester Conference Series on Public Policy 42*, 151–195.

Keister, T. and J. McAndrews (2009). Why are banks holding so many excess reserves? *Current Issues in Economics and Finance 15*(8).

Kumhof, M. and X. Wang (2021). Banks, money and the zero lower bound on deposit rates. *Journal of Economic Dynamics and Control*, 104–208.

Martin, A., J. McAndrews, A. Palida, and D. Skeie (2013). Federal Reserve tools for managing rates and reserves. *Federal Reserve Bank of New York, Staff Report No. 642*.

Martin, A., J. McAndrews, and D. Skeie (2016). Bank lending in times of large bank reserves. *International Journal of Central Banking 12*(4), 193–222.

Mendizábal, H. R. (2020). Narrow banking with modern depository institutions: Is there a reason to panic? *International Journal of Central Banking 16*(4), 145–197.

OECD (2021a). OECD Database. Average wages. `https://data.oecd.org/earnwage/average-wages.htm`. [Online; accessed 30-September-2021].

OECD (2021b). OECD Database. Gross domestic product. `https://data.oecd.org/gdp/gross-domestic-product-gdp.htm`. [Online; accessed 30-September-2021].

Saraceno, F. and R. Tamborini (2020). Quantitative easing in a monetary union. *Oxford Economic Papers 72*(1), 124–148.

Schnabel, I. (2020). The ECB's policy in the COVID-19 crisis - a medium-term perspective. `https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200610~a16c903e5c.en.html`. [Online; accessed 30-September-2021].

The World Bank (2021). World Bank National Accounts Data, and OECD National Accounts Data Files. Final consumption expenditure - Germany, Italy. `https://data.worldbank.org/indicator/NE.CON.TOTL.CD?locations=DE-IT`. [Online; accessed 30-September-2021].

University of Groningen and University of California (2021a). Federal Reserve Bank of St. Louis Economic Data. Capital stock at constant prices for Germany. `https://fred.stlouisfed.org/series/RKNANPDEA666NRUG`. [Online; accessed 30-September-2021].

University of Groningen and University of California (2021b). Federal Reserve Bank of St. Louis Economic Data. Capital stock at constant prices for Italy. `https://fred.stlouisfed.org/series/RKNANPITA666NRUG`. [Online; accessed 30-September-2021].

Urbschat, F. and S. Watzka (2020). Quantitative easing in the euro area - an event study approach. *The Quarterly Review of Economics and Finance 77*, 14–36.

Williamson, S. D. (2019). Interest on reserves, interbank lending, and monetary policy. *Journal of Monetary Economics 101*, 14–30.

Wu, J. C. and J. Zhang (2019a). Global effective lower bound and unconventional monetary policy. *Journal of International Economics 118*, 200–216.

Wu, J. C. and J. Zhang (2019b). A shadow rate New Keynesian model. *Journal of Economic Dynamics & Control 107*.

# Paper III:

## Asymmetries in TARGET2 Balances in the Euro Area*

Maximilian Horst Ulrike Neyer

**Abstract**

Large increases in TARGET2 balances in the euro area since 2008 have led to concern and debate about the appropriate interpretation and policy reaction – in particular in TARGET2 creditor countries such as Germany. Against this background, we examine the main drivers of the increases and asymmetries in TARGET2 balances that have emerged in the context of the financial and sovereign debt crises as well as in the context of the Eurosystem's implementation of quantitative easing (QE) and the COVID-19 pandemic. Moreover, this paper analyzes the potential risks for euro area member states in the case of (i) the unchanged continuity of the monetary union, (ii) the withdrawal of a member state with (large) TARGET2 liabilities, and (iii) the break-up of the whole monetary union. Depending on the outcome of exit negotiations and the operational handling, there can be direct risks in the form of default losses of TARGET2 balances and indirect risks in the form of threat potentials if TARGET2 debtor countries pretend to plan to leave the euro area. Based on this, we discuss adaption options for the TARGET2 payment system and consider an exit from the ECB's accommodative monetary policy in order to scale back the high amount of excess liquidity in the euro area banking sector which is the prerequisite for the emergence of TARGET2 balances.

*JEL classification:* E42, E52, E58, F45.

*Keywords:* TARGET2 balances, payment system, euro area, central bank balance sheet, monetary policy, quantitative easing (QE), excess liquidity, exit strategies.

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# 1 Introduction

TARGET2 balances are claims and liabilities of euro area national central banks vis-à-vis the European Central Bank (ECB).[1] They emerge as a result of cross-border payments in central bank money (reserves) between euro area national central banks.[2]

Until the peak of the euro area financial crisis in 2008 after the Lehman bankruptcy, TARGET2 (T2) balances fluctuated at around zero. In the aftermath of the financial crisis and during the subsequent sovereign debt crisis from 2010 onwards, they increased for the first time. Since the beginning of the Eurosystem's large-scale asset purchase program (APP) – commonly referred to as quantitative easing (QE) – in March 2015 and over the course of the COVID-19 pandemic, T2 balances have again started to increase continuously (see Figure 2). Moreover, their development is very heterogeneous across euro area countries. In July 2020, for instance, the Bundesbank's T2 claim on the ECB exceeded 1 trillion euros for the first time, while the T2 liability of the Banca d'Italia towards the ECB exceeded 500 billion euros (data source: Eurosystem). Large and asymmetric T2 balances have provoked a great amount of concern and intense debate, in particular in T2 creditor countries such as Germany.

Against this background, the first aim of this paper is to provide some detailed insights on the functioning of the T2 system and especially on the emergence and the interpretation of (large) T2 balances as well as on their relation to euro area monetary policy implementation. The second aim of this paper involves examining potential risks of high T2 balances for euro area member states and discussing potential adaption options to the T2 system.

With respect to the first aim, we show that the reasons for the observed increases in T2 balances change over time and depend on different scenarios: The emergence of T2 balances during the financial and sovereign debt crises was a symptom of increased levels of distrust and risk perception which implied tension in the money market and funding stress in the euro area banking sector. In contrast, the increase during the QE period and the COVID-19 pandemic is mainly a result of specific technical particularities with regard

[1] The acronym TARGET stands for Trans-European Automated Real-time Gross Settlement Express Transfer System.

[2] To simplify matters, we assume that all payments are settled by credit transfers. Therefore, the terms *payment* and *credit transfer* are used synonymously in this paper.

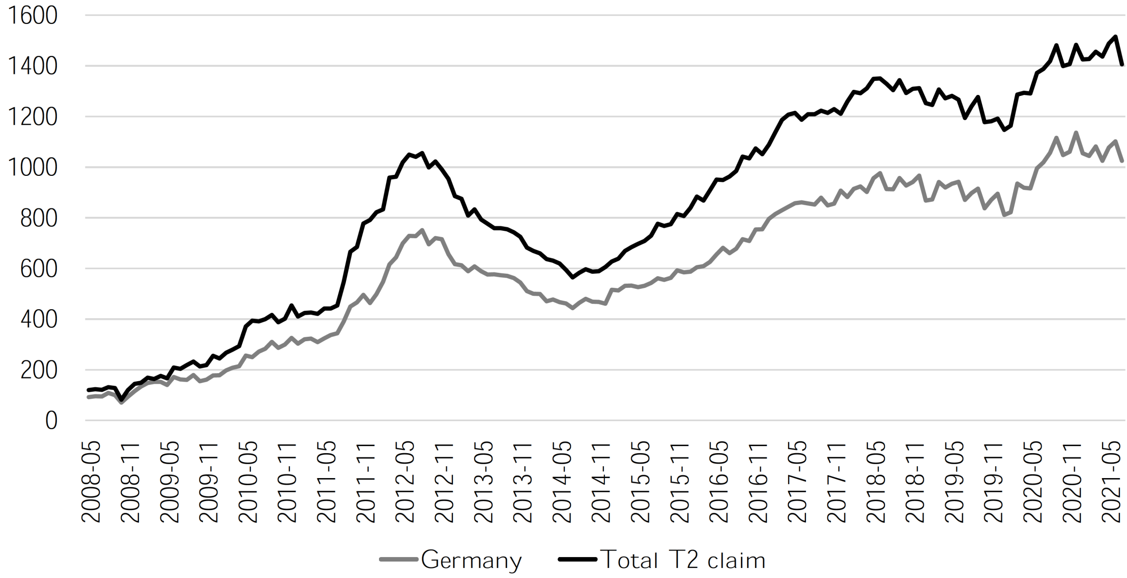


Figure 1: The Bundesbank's T2 claim on the ECB as a share of total T2 claims in the euro area (in billion euros, end of month position). Data source: Eurosystem.

to the implementation of the Eurosystem's large-scale asset purchases. Asset purchases are primarily conducted with counterparties residing outside the purchasing country or even outside the euro area, resulting in cross-border payments and hence increasing T2 balances. Thus, T2 balances are not necessarily always a sign of crises but rather a symptom of the decentralized implementation of monetary policy by the respective euro area national central banks. In both cases, the creation and provision of excess liquidity through the Eurosystem is the common prerequisite for the emergence of T2 balances. It can be expected that as long as the Eurosystem continues its large-scale asset purchases and thus continues to create further excess liquidity, T2 balances will also continuously increase.

With respect to the second aim of our paper, we argue that the risks of large T2 imbalances for the euro area member states are scenario dependent. In case of (i) the unchanged continuity of the euro area, large T2 balances do not constitute direct risks in the form of default risks. However, they may bear indirect risks in the form of a threat potential if countries exposed to large T2 liabilities try to take advantage of this circumstance by blackmailing the other member states. In case of (ii) the withdrawal of a euro area member state that is exposed to a large T2 liability, the legal effects are by all means ambiguous and the potential risk in the form of a default of the T2 liability of the exiting country would depend on the results of exit negotiations and the operational handling. If a (residual) T2 liability were irrecoverable, the ECB would be exposed to a loss. This could also reduce the national central banks' equity capital. If a national central bank then needed to be recapitalized by its government, the loss might have to be absorbed by the taxpayers. In case of (iii) the break-up of the monetary union, the creditor countries' T2 claims might be at risk. Every single creditor national central bank would hold a claim on a system that would no longer exist. A total loss of corresponding T2 claims on the ECB would therefore be possible, including the consequences and potential losses for the member states and their taxpayers. Against the background that large T2 balances bear direct and indirect risks, we discuss potential adaption options to the existing T2 payment system in order to limit the level of T2 balances and be able to settle T2 balances when necessary. We find that proposals directly and exclusively considering the T2 payment system such as introducing progressively rising penalty interest payments for T2 liabilities, a mandatory cap limiting the T2 balances, an annual gold settlement, or a collateralization of T2 balances are less suitable than proposals affecting the ECB's monetary policy. The existence of excess liquidity is the prerequisite for the emergence of T2 balances. Therefore, the ECB may consider scaling back its large-scale asset purchases or restricting its main refinancing operations with full allotment at zero interest costs, for example. As soon as the amount of excess liquidity decreases, T2 balances are expected to drop again.

The remainder of the paper is organized as follows: Section 2 describes the technical framework of the T2 payment system. As a basis for understanding the emergence of T2 balances and any subsequent analysis of their significance, it is explained in detail how cross-border payments are technically settled in the euro area. Section 3 examines the development of T2 balances during different periods. In order to interpret the drivers of the emergence of T2 balances, the technical relation between T2 balances and the concept of the balance of payments (BoP) is depicted. Section 4 analyzes the potential risks of (large) T2 imbalances with regard to three different scenarios and discusses potential adaption options to the T2 system. Section 5 summarizes the paper.

# 2 A Technical Note on the TARGET2 Payment System and the Emergence of TARGET2 Balances

## 2.1 Institutional Aspects of TARGET and TARGET2

As specified in Article 127(2) of the Treaty on the Functioning of the European Union (TFEU) and Article 3 of the Statutes of the European System of Central Banks (ESCB) and of the European Central Bank, the Eurosystem is assigned the task of providing, ensuring and supervising the operation of payment and settlement systems in the euro area. An efficient and well-functioning payment system is key for maintaining the stability of the financial system, helpful to preserve the confidence in the common currency, and a crucial condition for the smooth implementation of the common union-wide monetary policy (Bank for International Settlements, 2003; Bindseil and König, 2012). The first generation of the Eurosystem's own payment system known as TARGET was put into operation on 4 January 1999 with three main objectives, namely (i) to serve the needs of the Eurosystem's monetary policy, (ii) to increase the efficiency of intra-European cross-border payments, and (iii) to supply a reliable and safe mechanism for the settlement of cross-border payments (European Central Bank, 2001). Initially, TARGET was a decentralized payment system that linked the real-time gross settlement (RTGS) funds transfer systems of national central banks and the ECB's payment mechanism. While TARGET facilitated the integration of money markets within the euro area, its decentralized nature had several shortcomings, in particular with respect to cost efficiency and technical maintenance. Therefore, it was replaced in May 2008 by its successor system TARGET2 (T2) to overcome these shortcomings.[3]

T2 is a payment system based on a single shared platform (SSP) that is owned and operated by the Eurosystem. Its purpose is to facilitate and accelerate the final settlement of both national and cross-border payments in central bank money (reserves). T2 payments are settled in real time and used exclusively by central banks and commercial banks. Therefore, both central banks and commercial banks have accounts in T2. In 2020, an average of around 345,000 payments amounting to about 1.8 trillion euros was processed

[3]For more detailed information about the TARGET and T2 payment systems, see, for example, European Central Bank (2001).

through T2 every working day. Over the whole year, about 88 million payments with a value of about 465 trillion euros were settled through T2 (European Central Bank, 2021).[4] These payment transactions can be a result of payments for goods deliveries, purchases or sales of securities, the granting or repayment of a loan or the depositing of funds at a bank, for instance. While payments within a country, e.g., current account transactions between customers of different commercial banks, are settled by the respective national central bank alone, cross-border payments require the involvement of the relevant foreign national central bank (Deutsche Bundesbank, 2020b).

## 2.2 TARGET2 Balances

T2 balances emerge as a result of cross-border payments between commercial banks and central banks in different countries. The net amount of cross-border payments between two countries (i.e., the total payment orders received and executed minus the total payment orders sent) is recorded on the balance sheets of the national central banks of the two countries involved. This happens regardless of whether the credit transfer was initiated by a commercial bank or the central bank. The accumulation of these payments over time are T2 balances. The ECB also sends and receives cross-border payment orders for the implementation of its monetary policy and therefore also has its own T2 balance.

To avoid each euro area national central bank having a separate balance with all of the other euro area national central banks and the ECB,[5] at the end of each business day, all intraday bilateral balances are automatically cleared in a settlement system which means that they are simplified to one single balance – the T2 balance – with the ECB (netting procedure via novation). If banks in one country sent – in sum – more payment orders through T2 than they received, the central bank of that country would have a negative balance, i.e., a T2 liability towards the ECB. If the opposite was the case, i.e., banks received more payment orders than they sent, the central bank would have a positive

[4] In 2020, the Bundesbank alone processed around 76 million transactions with a total value of about 174 trillion euros using T2. This is the equivalent of more than fifty times the total German economic output in one year (data source: Bundesbank).

[5] Since the size of bilateral imbalances (claims and liabilities) between national euro area central banks built up quite rapidly after the launch of the TARGET system in 1999, the ECB's Governing Council decided just a few months later that the TARGET balances should be netted out daily at the end of each business day by "novation". This implied that all national central banks' obligations were substituted by ECB obligations, leaving each national central bank with one single net position (if positive, a TARGET claim and, if negative, a TARGET liability) vis-à-vis the ECB (European Central Bank, 2012, Article 6).

balance, i.e., a T2 claim on the ECB.[6] The sum of all T2 claims and liabilities within the whole system has to be zero, since a T2 claim (liability) of one national central bank automatically corresponds to a T2 liability (claim) of another national central bank.

To understand the emergence of T2 balances, it is essential to clarify how cross-border payments are technically settled. In the following, we describe a stylized closed system of financial accounts of the financial sector of an economy. The framework allows an illustration of the mechanics and development of intra-system claims and liabilities. We use it as a basis for understanding the nature of T2 balances and the subsequent analyses of their significance. We consider two countries (country A and country B) within a monetary union. Each country is endowed with a commercial bank and a national central bank. Moreover, there is a common union-wide central bank (see Table 1). The starting point is a firm in country B that buys a good from a firm in country A.[7] Thus, both commercial banks are involved in a cross-border payment transaction which is the prerequisite for the emergence of T2 balances. Bank B arranges the credit transfer by debiting the respective purchase amount from firm B's account. The result is a decrease in firm B's deposits (D) held on its current account. In a scenario without sufficiently large amounts of excess reserves in country B's banking sector and without private capital transfers between both countries (e.g., from commercial bank A to B via a functioning interbank money market), bank B needs to take part in the central banks' refinancing operations (RO) to balance the loss in deposits. This transaction appears on bank B's balance sheet as an accounting exchange on the liability side, i.e., the length of bank B's balance sheet remains the same. Central bank B now has a claim on bank B and transmits the credit transfer to central bank A. The offsetting liability item on central bank B's balance sheet is a liability towards central bank A. Central bank A executes the credit transfer by crediting, on behalf of

[6]For example, the Bundesbank's (net) T2 claim on the ECB is indicated on the asset side of the Bundesbank's balance sheet under the item "9. Intra-Eurosystem claims"/"9.4 Other claims within the Eurosystem (net)". At the end of December 2020, the (net) T2 claim amounted to 1,136.002 billion euros which corresponded to a share of almost 50% of the length of the balance sheet (2,526.56 billion euros). Alternatively, the value of the (net) T2 claim is published in the statistics on the "External Position" of the Bundesbank and there under the item "External assets"/"Other investment"/"Currency, deposits and loans"/"Clearing accounts within the ESCB". At the end of September 2021, the Bundesbank's net external position (total external assets minus total external liabilities) stood at 686 billion euros. The (net) T2 claim on the ECB amounted to 1,115.13 billion euros accounting for around 78% of total external assets (data source: Bundesbank).

[7]Considered in isolation, this standard good transfer between the two firms leads to a surplus in country A's balance of trade and a deficit in country B's balance of trade.

central bank B, the purchase amount in the form of reserves (R) to bank A's account. Hence central bank A faces a liability towards bank A. However, its balance sheet no longer balances. Central bank A needs to add a balancing item to reflect that there are now more reserves on its balance sheet than it originally created. The offsetting asset item on central bank A's balance sheet is a claim on central bank B. Bank A credits the respective amount in the form of deposits (D) to firm A's current account. Firm A can then use these funds. From the point of view of bank A's balance sheet, this transaction results in an extension of the length of its balance sheet. In sum, money (reserves and deposits) has increased (decreased) in country A's (B's) banking sector and the good has moved from country A to B.

Since all intraday bilateral claims and liabilities are transferred to the common union-wide central bank at the end of the business day, based on this example, central bank A has a T2 claim on the union-wide central bank while central bank B has a T2 liability towards the union-wide central bank. From an accounting perspective, one side effect of this example is an extension of all central bank balance sheets.[8]

**Commercial Bank (A)**

| Assets | Liabilities |
|---|---|
| R ↑ | D ↑ |

**Commercial Bank (B)**

| Assets | Liabilities |
|---|---|
| | D ↓ |
| | RO ↑ |

**National Central Bank (A)**

| Assets | Liabilities |
|---|---|
| T2 (CB) ↑ | R ↑ |

**National Central Bank (B)**

| Assets | Liabilities |
|---|---|
| RO ↑ | T2 (CB) ↑ |

**Union-wide Central Bank**

| Assets | Liabilities |
|---|---|
| T2 (B) ↑ | T2 (A) ↑ |

Table 1: Creation of T2 balances in a scenario without excess reserves in country B's banking sector and without private capital transfers from country A to B.

[8]Note that exactly the same T2 balances emerge when there is capital flight, e.g., "safe-haven-flows" or "flight-to-quality" phenomena, from country B to A.

Since October 2015, the euro area banking sector has been exposed to a structural liquidity surplus.[9] Due to the liquidity created through the Eurosystem's large-scale asset purchases (QE), banks hold large amounts of excess reserves. Therefore, we consider a second scenario in which bank B faces sufficiently large amounts of excess reserves to compensate for the loss in deposits without taking part in the central bank's refinancing operations. In this scenario, bank B's holdings of excess reserves with central bank B decrease and the subbalances in our example emerge as represented by Table 2.[10]

**Commercial Bank (A)**

| Assets | Liabilities |
|---|---|
| R ↑ | D ↑ |

**Commercial Bank (B)**

| Assets | Liabilities |
|---|---|
| R ↓ | D ↓ |

**National Central Bank (A)**

| Assets | Liabilities |
|---|---|
| T2 (CB) ↑ | R ↑ |

**National Central Bank (B)**

| Assets | Liabilities |
|---|---|
| | R ↓ |
| | T2 (CB) ↑ |

**Union-wide Central Bank**

| Assets | Liabilities |
|---|---|
| T2 (B) ↑ | T2 (A) ↑ |

Table 2: Creation of T2 balances in a scenario with sufficiently large amounts of excess reserves in country B's banking sector.

## 2.3 TARGET2 Balances as Actual Claims and Liabilities

T2 balances represent actual claims (liabilities) of national central banks on (towards) the ECB. If they were not settled in the case of a dissolution of the euro area or the withdrawal of a member state, the T2 system would be used as a transfer system, instead of a payment system. To clarify this, we return to the example of a cross-border payment between two countries described in Section 2.2. Country B imports goods from country A, i.e., assets are transferred from country A to country B. As a consequence, T2 balances emerge to offset the transfer of assets in the respective national central banks' balance

[9]See, for example Horst and Neyer (2019), for further information regarding the characteristics and distinction between a structural liquidity *deficit* and a structural liquidity *surplus* in the banking sector.

[10]The emergence of T2 balances as a result of a cross-border payment for a security, e.g., in the context of the Eurosystem's QE program, is described in detail in Section 3.4.

sheets.[11] If they were not settled, the cross-border payment would imply an asset transfer from country A to country B *financed* through the T2 system. However, since the T2 system is designed as a payment system and not as a transfer system, in the case of a dissolution of the monetary union or the withdrawal of a member state, T2 balances have to be settled (see Section 4). Therefore, T2 balances indeed represent actual claims and liabilities.[12]

## 3 Development and Interpretation of TARGET2 Balances

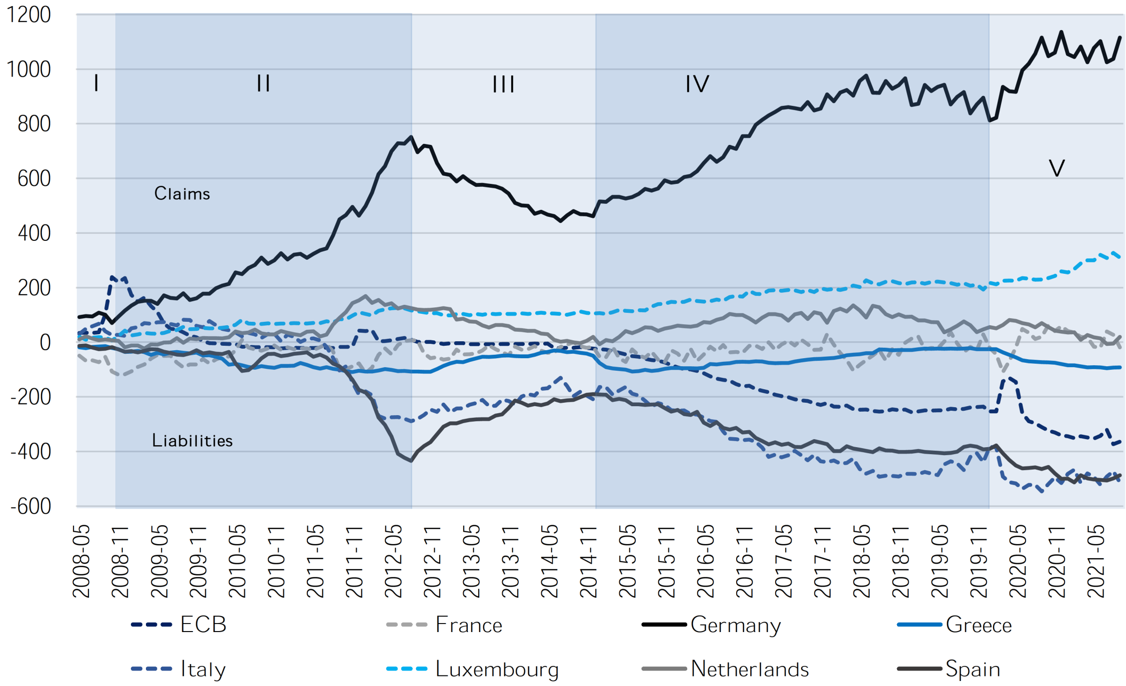


Figure 2: T2 balances of the ECB and selected euro area national central banks (in billion euros, end of month position). Data source: Eurosystem.

Figure 2 depicts the development of T2 balances of selected euro area countries. In the following, we distinguish between five different periods of events, i.e., (i) the period before the outbreak of the financial crisis, (ii) the period of the financial and sovereign debt crises, (iii) the period after the announcement of the Outright Monetary Transactions (OMT)

[11]The same applies to a cross-border payment for a security, e.g., under the Eurosystem's QE program (see Section 3.4).

[12]For a more in-depth discussion on whether or not T2 balances represent claims or liabilities, see, e.g., Homburg (2019); Spahn (2019); van Suntum (2019); Hellwig (2018); Hellwig and Schnabel (2019a); Sinn (2019a, 2020).

program by the former ECB president Mario Draghi ("whatever it takes" speech), (iv) the period of the Eurosystem's QE program, and (v) the period of the COVID-19 pandemic.

Before examining the respective drivers of the increases and asymmetries in T2 balances in the euro area, we briefly describe the relationship between the emergence of T2 balances and changes in the balance of payments.

### 3.1 TARGET2 Balances and the Balance of Payments

The emergence of T2 balances is technically related to adjustments in the balance of payments (BoP). Therefore, we briefly describe the concept of the BoP to deepen the understanding of the emergence of T2 balances. The BoP of an economy documents all economic transactions within a given period of time between residents and non-residents of the economy. It thus shows the country's complex economic links with the rest of the world. The BoP primarily consists of the current account and the financial account (FA).[13] For simplification reasons, the current account is here reduced to the balance of trade (BoT) where the value of exports and imports of goods is reflected.[14] The FA records all financial transactions of domestic residents with foreign residents and can be broken down into the "private" FA and into the "official" FA.[15] The private FA documents the value of private capital exports and imports. The official FA comprises "other investment" of the national central bank ($OI\_NCB$) and the government.[16] Formally, changes in the national central bank's T2 balance are reported at a monthly frequency as part of other investments in the official FA under the item "Other Investment - Central Bank". Since the BoP must always be statistically balanced ($BoP = 0$), either (i) the respective subbalances, i.e., the BoT and the FA, must be balanced, or (ii) a surplus in the BoT ($BoT > 0$) must be offset by a deficit of the same amount in the private or official FA ($FA > 0$), and vice versa. The $BoP$, $BoT$ and $FA$ are defined – in a simplified form – as follows:

[13] To simplify matters, the terms "Capital Account" and "Balancing Items (Errors and Omissions)" are ignored. For more information regarding the individual components of the BoP, see e.g., Deutsche Bundesbank (2020a); European Central Bank (2020b).

[14] Hence we use both terms interchangeably in the following.

[15] Domestic residents include banks and other financial institutions, non-financial institutions, households as well as the official sector.

[16] Note that this stylized representation of the FA excludes the foreign exchange account and thus the central bank's change in foreign currency reserves ("Reserve Assets"), since there is only one common currency in the monetary union.

$$BoP = BoT - FA = 0\,,$$

with

$$BoT = Exports - Imports$$

and

$$FA \;=\; \underbrace{Capital\ Exports - Capital\ Imports}_{\text{private FA}} + \underbrace{OI\_NCB}_{\substack{\text{official FA}\\ \text{(T2 balance)}}}\ .$$

Simplifying further, we can rewrite the change in T2 balances as an imbalance between the BoT and the private FA. Thus, the technical prerequisite for the emergence of T2 balances is an imbalance between the BoT and the private FA:

$$T2\,balance = BoT - FA\ (private)\,.$$

According to this last equation, a BoT surplus and/or private net capital imports are, at least in part, offset by rising T2 claims of the national central bank. Accordingly, a BoT deficit and/or private net capital exports are offset by rising T2 liabilities. Note that changes in T2 balances are automatically mirrored in other components of the BoP, while changes in specific components of the BoP are not necessarily reflected by a change in T2 balances. To summarize, it can be stated that the increase in T2 balances is a direct measure of net cross-border payments. T2 liabilities (claims) measure (i) the proportion of a BoT deficit (surplus) which is not counterbalanced by sufficiently large private net capital imports (exports) implying a surplus (deficit) in the private FA, or, equivalently, (ii) the sum of the BoT deficit (surplus) and net capital exports (imports). Indirectly, they also measure a national central bank's stock of reserves created and credited to commercial banks beyond what was initially needed for domestic circulation.

### 3.2 TARGET2 Balances in "Normal Times"

Before the outbreak of the financial crisis, T2 balances in the euro area were stable and more or less close to zero (see Figure 2, first period). For illustration purposes we distinguish between core and periphery euro area countries. We consider Germany, France, Luxembourg and the Netherlands as core countries. Accordingly, Greece, Italy and Spain are periphery countries. On the one hand, core countries (and especially Germany) usually realized a surplus in their BoT as a result of (large) net exports of goods. On the other hand, however, core countries were exposed to private net capital exports (outflows) at approximately the same level. These private net capital exports have primarily been the result (i) of credit lending operations of core-country banks to periphery-country banks via the interbank money market and (ii) of investments in periphery countries carried out by core-country private sector financial market participants (firms and individuals). Hence, the surplus in the BoT was compensated by a deficit in the private FA. In sum, the BoP was practically leveled and net T2 balances were close to zero.[17]

### 3.3 TARGET2 Balances in the Financial and Sovereign Debt Crises

During the financial crisis, which peaked in September 2008 after the bankruptcy of Lehman Brothers, and the subsequent outbreak of the sovereign debt crisis in 2010, T2 balances in the euro area started to increase continuously (see Figure 2, second period). Core countries still faced a surplus in their BoT. However their so far offsetting deficit in their private FA diminished or even turned into a surplus. Instead, the BoP was balanced by a deficit in their official FA, reflected by a net T2 claim on the ECB. Periphery countries still faced a deficit in their BoT. Additionally, they were exposed to private capital outflows, resulting in a deficit in their private FA. The offsetting item in their BoP was a surplus in their official FA, represented by a net T2 liability towards the ECB.

The reasons are as follows: Increased levels of distrust and risk perception as well as increased information asymmetries led to tension in the money market and funding stress in the euro area banking sector. Especially private capital outflows in the form of capital flight ("safe-haven-flows" and "flight-to-quality" phenomena) from banks in periphery countries to banks in core countries implied funding stress in the banking sectors of periphery countries on the one hand and additional private capital inflows to banks in core countries on the other hand. However, banks in core countries were less willing, or in some cases unable, to lend funds to foreign banks via the interbank money market (confidence

[17]Exactly the opposite was the case for periphery countries. Typically, they faced a deficit in their BoT that was compensated by a surplus in the private FA due to private foreign capital inflows, so that net T2 balances in sum were also close to zero.

crisis). Instead, they preferred to deposit their excess reserves at their national central bank. Moreover, firms and individuals refused to invest funds abroad due to increased levels of risk and distrust. As a result, banks in periphery countries were concerned by difficulties in financing themselves. The associated increase in T2 balances was supported by the fact that banks in periphery countries were forced to participate more significantly in the Eurosystem's refinancing operations in order to substitute for the loss in market-based funding and thus to close the funding gap in their balance sheets, while banks in core countries decreased their borrowing in the refinancing operations.[18] However, this liquidity provided through the Eurosystem's refinancing operations was again, to a large extent, transferred via cross-border transactions from periphery countries to "safe havens", i.e., to core countries. In sum, with regard to core countries, private capital inflows increased, implying a surplus in their private FA. Their BoP was offset by a respective deficit in their official FA, represented by a T2 claim on the ECB. With regard to periphery countries, private capital outflows increased implying a deficit in their private FA. The balancing item in their BoP was a surplus in their official FA, expressed by a T2 liability towards the ECB. The overall increase in T2 balances during the financial and sovereign debt crises is commonly interpreted as a consequence of a balance of payments crisis (Deutsche Bundesbank, 2011).

Following the announcement of the Eurosystem's outright purchases of securities, the Outright Monetary Transactions (OMT)-program, by the former ECB president Mario Draghi and his significant commitment to be willing to do "whatever it takes" to ensure the continued existence of the euro area and to preserve the euro, the high levels of distrust and risk perception started to return to normality. Imbalances in the BoT were predominantly again offset by the according adjustment processes in the private FA. As a result, T2 balances started to decline gradually towards their pre-crisis levels (see Figure 2, third period).

[18]When providing commercial banks with central bank money, the respective national central banks de facto issue a liability towards the Eurosystem. Participating in the central banks' refinancing operations might go in line with a T2 liability towards the ECB, if (a part of) this liquidity is subsequently used for cross-border payments to another country via T2. The asymmetries in T2 balances in the euro area during this period are, to a certain degree, also a result of commercial banks' uneven recourse to the Eurosystem's refinancing operations implying a changed distribution in refinancing operations with central banks in the euro area. The asymmetries have been strengthened by the ample supply of liquidity by the Eurosystem: In October 2008, the ECB introduced a fixed-rate tender procedure with full allotment of all bids in the refinancing operations in order to counteract the dislocations in the money market.

### 3.4 TARGET2 Balances and the Eurosystem's Asset Purchase Program (APP)

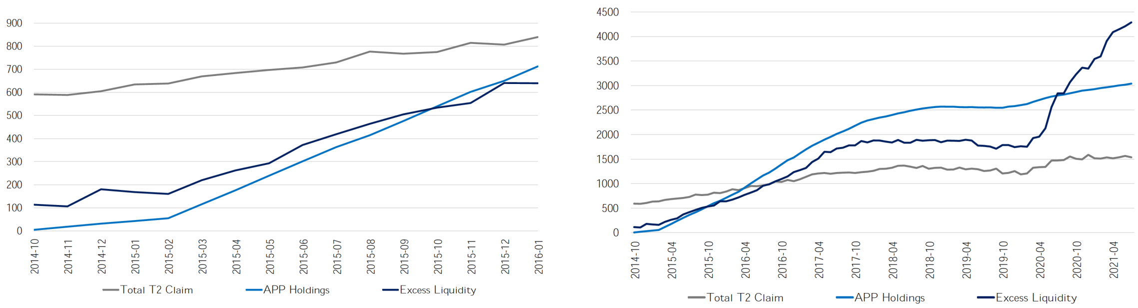


Figure 3: Excess liquidity in the euro area banking sector, cumulated APP purchases and sum of all positive T2 balances (in billion euros, end of month position). Data source: Eurosystem.

Since the beginning of the Eurosystem's large-scale asset purchases (APP, commonly referred to as QE) in March 2015, T2 balances once again started to increase continuously, reaching unprecedented levels (see Figure 2, fourth period). However, the main reasons for the increase are different compared with the period of the financial and sovereign debt crises: Large T2 balances during this period are predominantly no longer a sign of crises but instead a technical consequence of the decentralized implementation of QE in the euro area.[19] Figure 3 shows that T2 balances have increased synchronously during this period with the Eurosystem's holdings under the APP and the associated amount of excess liquidity.[20] In particular, the large-scale purchases of euro area government bonds under the Public Sector Purchase Programme (PSPP) since March 2015 and the creation of excess liquidity thereby induced coincide with the renewed surge in T2 balances.[21] As the majority of APP securities are purchased from counterparties residing outside the country of the purchasing national central bank,[22] the implementation of the APP involves

[19]In this context, decentralized monetary policy implementation refers to the fact that each national central bank purchases its own domestic government bonds on behalf of the Eurosystem in accordance with its share in the ECB's capital key.

[20]Excess liquidity is defined here as the sum of (i) commercial banks' reserve holdings on their current accounts with their national central bank in excess of minimum reserve requirements and (ii) their recourse to the ECB's overnight deposit facility.

[21]The APP involves four programs under which both private and public sector securities are purchased. Covering a share of more than 80% of all assets bought under the APP (until October 2021), the PSPP represents by far the most important component of the APP.

[22]Around 80% of overall APP purchases by volume occurred with 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 located outside the euro area, most of them being resident in the UK (Cœuré, 2017; Baldo et al., 2017).

cross-border payments via T2. Non-euro area counterparties need a current account with a euro area commercial bank in order to access the T2 payment system via the respective euro area national central bank. This is a prerequisite for participating in those payment transactions. Since most of the non-euro area counterparties have their current accounts predominantly with commercial banks in only a few selected countries such as Germany, France, the Netherlands, Luxembourg, and Finland (which serve as so-called financial centers or gateways), the QE-induced creation of excess liquidity takes place in these countries.[23] Accordingly, these countries are exactly the ones with the largest T2 claims on the ECB and their T2 claims rise continuously with the APP purchases of other national central banks (see Figure 2).

For illustrative purposes consider the following example (see Table 3): the Italian central bank purchases Italian government bonds from a counterparty resident outside the euro area. In order to participate in this cross-border transaction, the counterparty needs access to the T2 payment system. As an example, we consider a UK-based counterparty, e.g., a commercial bank, that uses a correspondent German commercial bank as an access point for T2.[24] In this case, the security purchase of the Italian central bank implies that both the Italian and the German central bank are involved in a cross-border payment resulting in a T2 claim (liability) of the German (Italian) central bank on (towards) the ECB. The settlement of the payment is described in detail as follows. The UK-APP counterparty transfers the respective amount of government bonds to the Italian central bank while the corresponding purchase amount is credited to the UK-APP counterparty's current account in the form of newly created deposits. Hence 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 German central bank's balance sheet, increase. Note again that, as described in Section 2, by executing the payment order, the German central bank credits the reserves to the German commercial bank's account on behalf of the Italian central bank. The offsetting asset item of

[23]For further information with regard to the QE-induced creation of excess liquidity and its heterogeneous distribution across euro area countries, see also Horst and Neyer (2019) and Horst et al. (2020).

[24]Around 50% of the overall purchase volume is conducted with UK-based banks that access T2 via the German central bank (Cœuré, 2017; Alvarez et al., 2017).

the German central bank's balance sheet is a T2 claim on the ECB. The Italian central bank, on the other hand, has a T2 liability towards the ECB. Moreover, the deposits in the German banking sector increase, since the German commercial bank credits the respective amount in the form of freshly created deposits to the UK-APP counterparty's current account.[25] The increase in the German central bank's positive T2 balance (and the increase in excess reserves in the German banking sector) are thus a consequence of the bond purchases by the Italian central bank from non-euro area counterparties which have their deposit account with a German commercial bank. The consolidated balance sheet of the Eurosystem demonstrates that its government bond holdings and (excess) reserves have increased.

**APP-Counterparty (UK)**

| Assets | Liabilities |
|---|---|
| Bonds ↓<br>D ↑ | |

**Commercial Bank (Germany)**

| Assets | Liabilities |
|---|---|
| R ↑ | D ↑ |

**National Central Bank (Germany)**

| Assets | Liabilities |
|---|---|
| T2 (ECB) ↑ | R ↑ |

**National Central Bank (Italy)**

| Assets | Liabilities |
|---|---|
| Bonds ↑ | T2 (ECB) ↑ |

**European Central Bank**

| Assets | Liabilities |
|---|---|
| T2 (Italy) ↑ | T2 (Germany) ↑ |

**Eurosystem**

| Assets | Liabilities |
|---|---|
| Bonds ↑ | R ↑ |

Table 3: Emerging T2 balances when APP security is purchased from a counterparty residing outside the euro area.

Thus, the residence of the purchasing national central banks' counterparties strongly influences the impact of the APP implementation on the development and distribution of T2 balances. Euro area commercial banks participate in T2 via their local national central bank. Banks located outside the euro area participate in T2 via a branch or subsidiary in the euro area or via a correspondent bank. Regardless of whether they are situated

[25] Note that the ECB statistics ("Monetary Financial Institutions Balance Sheet Statistics Including the Eurosystem") distinguish between bank deposits of euro area and non-euro area residents. Therefore, it refers to these deposits of non-euro area residents held on accounts with euro area commercial banks as "liabilities of euro area monetary financial institutions (excluding the Eurosystem) towards non-euro area residents" in the consolidated balance sheet of the monetary financial institutions (see also Horst and Neyer (2019)).

in another euro area country or outside the euro area, central bank asset purchases from non-domestic counterparties result in cross-border payments and hence imply an increase in T2 balances. Consequently, compared with the mainly demand-driven surge in T2 balances during the euro area financial and sovereign debt crisis, the drivers and the interpretation of the increase in T2 balances in the context of the APP differ notably since it is a supply-driven phenomenon (Eisenschmidt et al., 2017).

Additionally, to some extent during this period, the rise in T2 liabilities of at least Spain and Italy might also be reinforced by private capital outflows ("capital flight") of domestic investors due to increased levels of political and economic uncertainty.

When the ECB stopped its net APP purchases temporarily between January 2019 and November 2019, T2 balances started to decline slightly (see Figure 2, fourth period).[26] Additionally, in September 2019 the ECB's Governing Council introduced a two-tier system for the remuneration of excess reserve holdings. This enabled commercial banks to hold a certain amount of excess reserves on their account with their respective national central bank without being obliged to pay a negative interest rate on it.[27] Instead, the exemption allowance is remunerated at the ECB's main refinancing rate and is calculated as a six times multiple of the individual commercial bank's minimum reserve requirements (European Central Bank, 2019; Deutsche Bundesbank, 2021b). This new system temporarily increased interbank market activities and thereby induced cross-border flows of reserves from banks in euro area countries with large amounts of excess reserves who already used their exemption allowances in full (e.g., Germany, France, Netherlands) to banks in countries with relatively low amounts of excess reserves whose exemption allowance was not used up yet (e.g., Italy, Spain, and Greece).[28] This redistribution/shift of excess reserves between euro area countries also temporarily implied slightly decreasing T2 balances.[29] However, T2 balances were rapidly again dominated by cross-border transactions evolving from large-scale asset purchases by the Eurosystem.

[26]For more information with regard to the respective average monthly purchase pace since the APP beginning in 2015, see European Central Bank (2020a).

[27]Neglecting the two-tier system, excess reserve holdings are generally remunerated at the rate on the ECB's overnight deposit facility which amounts to -0.5% (October 2021).

[28]Within the first few days of the introduction of the two-tier system, banks with unused exemption allowances borrowed about 16 billion euros via euro area money markets, meaning that cross-border transactions within the euro area as a percentage of the total volume increased by roughly two percentage points to 20% (Deutsche Bundesbank, 2021b).

[29]On 30 October 2019, total T2 claims/liabilities decreased by 32 billion euros (data source: ECB).

### 3.5 TARGET2 Balances in the COVID-19 Pandemic

T2 balances have again been rising significantly since March 2020 (see Figure 2, fifth period). The renewed rise in overall T2 balances during this period can mainly be viewed as a consequence of the expansion of the Eurosystem's asset purchases (APP) in response to the COVID-19 pandemic.[30] Moreover, the ECB launched a new non-standard monetary policy tool, the Pandemic Emergency Purchase Programme (PEPP), which involves temporary additional asset purchases of private and public sector securities.[31] These measures are the reason why the volumes of the Eurosystem's monthly monetary policy net purchases as well as the overall amount of excess liquidity in the euro area banking sector are higher than ever before (see also Figure 3). Both the expansion of the APP and the additional asset purchases under the PEPP reinforce the mechanics of the emergence and distribution of T2 balances described in Section 3.4. Thus, there are more cross-border payments, resulting in an ongoing asymmetric rise in T2 balances in the euro area.

Additionally, the ECB introduced (i) a third series of ten Targeted Longer-Term Refinancing Operations (TLTROs III), each with a maturity of three years, starting in September 2019 at a quarterly frequency and (ii) a new series of seven so-called Pandemic Emergency Longer-Term Refinancing Operations (PELTROs) starting in May 2020, allotted on a near monthly basis and maturing in the third quarter of 2021. In December 2020, the ECB announced that it would offer four additional PELTROs in 2021 allotted on a quarterly basis and three additional TLTROs III in June, September and December 2021.[32] The implementation of both instruments, the TLTROs III and the PELTROs, creates additional excess liquidity in the system. This might also induce an additional increase in T2 balances if (a part of) this liquidity is subsequently used for cross-border payments via T2 between countries that participated in the TLTROs III/PELTROs with their respective national central bank and other countries (Deutsche Bundesbank, 2021a).

[30]On 12 March 2020, the ECB's Governing Council decided to add "a temporary envelope of additional net asset purchases of 120 billion euros" until the end of 2020 (European Central Bank, 2020a).

[31]The ECB's Governing Council decided to increase the initial 750 billion euros envelope for the PEPP by 600 billion euros on 4 June 2020 and by 500 billion euros on 10 December, for a new total of 1,850 billion euros. All asset categories eligible under the existing asset purchase programme (APP) are also eligible under the PEPP. The PEPP is implemented in the same way as the PSPP. Net asset purchases under the PEPP will be terminated once it judges that the COVID-19 pandemic phase is over, but in any case not before the end of March 2022 (European Central Bank, 2020d).

[32]For more detailed information, see also European Central Bank (2020c).

It is likely that T2 balances in the euro area will remain high as long as the Eurosystem continues to purchase assets on a large scale and thus continues to create further excess liquidity. As soon as the Eurosystem scales back its unconventional monetary policy measures and the amount of excess liquidity created by those measures decreases automatically, the cross-border interbank money market is expected to regain its significance with regard to commercial banks' liquidity management (see Section 3.2) and T2 balances are expected to drop again.

# 4 Potential Risks of Large TARGET2 Imbalances - Three Scenarios

Large and asymmetric T2 balances in the euro area have sparked substantial controversy. Section 3 has shown that reasons for increasing T2 balances across euro area countries can be various and that high T2 balances are not necessarily a sign of crises. However, they reflect imbalances between the individual components of a country's BoP. The emergence of T2 balances is associated with an uneven supply of reserves by national central banks across euro area countries. This section investigates whether or not and to what extent large and asymmetric T2 balances might include risks for an individual country but also for the whole monetary union. We examine the potential risks for euro area member states and in particular for countries facing (large) T2 claims on the ECB with respect to three potential scenarios: (i) an unchanged continuity of the monetary union, (ii) a withdrawal of a euro area member state facing a large T2 liability towards the ECB, and (iii) a dissolution of the euro area. Considering the potential risks of large T2 imbalances, we discuss adaption options to the existing T2 payment system in order to limit the level of T2 balances and be able to settle T2 balances when necessary.

## 4.1 Unchanged Continuity of the Monetary Union

In the case of an unchanged continuity of the euro area, (large) T2 imbalances do not represent sources of direct risks in the form of default risks. Nevertheless, one main point of criticism with respect to the current design of the T2 payment system is the absence of a regular netting procedure for T2 balances (see, e.g., Sinn and Wollmershäuser (2012)).

For instance, the US-equivalent "Interdistrict Settlement Acccount" (ISA) balances are netted regularly once a year via a transfer of gold certificates between the Federal Reserve Banks (Federal Reserve System, 2021). However, even though T2 are not netted out in the euro area, they may also decrease in the future without any intervention or adaptation of legal foundations being necessary (an example would be the aftermath of the sovereign debt crisis between 2012 and 2015, Figure 2). T2 balances reflect asymmetries, in particular with regard to an uneven creation of central bank money by euro area national central banks, as explained in Sections 2 and 3. Technically, they represent a claim (or a liability) that can never be called due. However, they have built up in exchange for goods and assets. This might provoke some indirect risks. Some economists play down their importance by arguing that they represent just a value or a technical, statistical balancing item in the central banks' balance sheets without further relevant economic significance (Deutsche Bundesbank, 2011). Others describe them as an opportunity for blackmail, or as a threat potential, for (over-indebted) countries facing large T2 liabilities towards the ECB which may pretend to plan to leave the euro area (mainly a political component). For instance, those countries might request (further) fiscal transfers, debt mutualization, monetary support (e.g., the continuation of a negative interest rate policy), or other privileges within the monetary union.

Especially the counterbalancing characteristic of T2 balances in the central banks' balance sheets is criticized (Fuest and Sinn, 2018a,b). In contrast to gold or foreign reserve assets, for instance, T2 claims do not represent counterparts that can be transferred into other assets or sold. For illustration purposes, the T2 system and the associated adjustment processes are briefly compared with those under the gold standard system, the Bretton-Woods system of fixed exchange rates and a flexible exchange rate regime.

Under the (pure) gold standard system, payment transactions are settled with gold.[33] For instance, if a country faces larger exports than imports of goods, its stock of gold increases.[34] The increasing gold stock will imply an increasing money stock and thus increasing price levels in the economy. Consequently, the country's competitiveness com-

[33]Under the classic gold standard system (approx. 1880–1914 and 1925–1931) both the circulating money stock of an economy and its currency were bound to gold.

[34]Either transactions are directly paid with gold or the fact that the currency is subjected to appreciation pressure as a result of the country's BoT surplus implies an import of gold due to arbitrage processes. Both result in an increase in the country's stock of gold.

pared with foreign countries decreases. Exports of domestic goods decrease and imports of foreign goods increase until the BoT, and thus also the BoP, are balanced again. Therefore, compared with the T2 payment system, national central banks which receive more payment orders than they send accumulate gold on the asset side of their balance sheet that compensates for the increase in reserves on the liability side, and vice versa. In this system, the offsetting asset item is physical in nature. In contrast to a T2 claim, it can normally be converted into other assets or sold at any time.

Under the Bretton-Woods system (1944–1973), all national currencies had a fixed exchange rate with the dollar, and the dollar (reserve currency) in turn had a fixed exchange rate with gold, which was guaranteed by the US Federal Reserve Bank. For instance, the national central bank of a country facing a BoT surplus needed to supply domestic currency and to buy foreign currency in order to prevent an appreciation of its own currency. Thus, the balancing item in the central bank's balance sheet was an increase in foreign reserve assets. As well as gold, foreign reserve assets can be converted into other assets or sold at any time. Note that with regard to T2 deficit countries, if a central bank's stock of gold or foreign reserve assets is exhausted, there is a natural limit for further imports of goods (BoT deficits). This country is then unable to send any further payment orders to other countries. So there is a natural upper limit for its BoT deficit.

In the euro area, the exchange rates are, by definition, fixed. There is only one common union-wide currency and it is impossible to determine whether a euro coin or banknote originates from Italy or Germany, for example. In this regard, T2 balances technically can be compared with the stock of foreign reserve assets as a result of central banks' interventions on foreign exchange markets in a system of fixed exchange rates (Smeets, 2018; van Suntum, 2019).[35]

In a system with (totally) flexible exchange rates, the adjustment of foreign reserve assets equals zero. An imbalance in the BoT is instead offset by an adjustment of the exchange rate. There is no impact on the central bank balance sheet. However, as pointed out, since there is only one common currency in the euro area, this balancing mechanism does not work.

[35] During the era of the Bretton-Woods system until 1973, the Bundesbank accumulated about 400 tons of gold. Currently (October 2021), the Bundesbank's T2 claim would correspond to 30,000 tons of gold, which is more than all central banks in the world own together.

It is commonly criticized that, under the T2 system, there is no such (physical) compensation. Instead central banks accumulate T2 claims (liabilities) which technically level the central banks' balance sheets, but whose value cannot be called due. Accordingly, with regard to the current design of the T2 payment system, there is neither a floor nor a ceiling for T2 balances as long as there is enough excess liquidity in the banking sector.[36]

In contrast, some economists understate the issue of large T2 imbalances between euro area countries by stressing that they are interest bearing so that there is compensation for countries facing large T2 claims. Indeed, T2 claims and liabilities are remunerated at the ECB's main refinancing rate. However, there are no interest payments from countries facing T2 liabilities to countries facing T2 claims. Instead, national central banks report their interest claims (obligations) resulting from T2 claims (liabilities) on their individual monetary income statement as revenues (costs). These interest claims (obligations) therefore increase (reduce) national central banks' monetary income. However, the overall monetary income of the Eurosystem is distributed between national central banks according to their share in the ECB's capital key. Since each T2 claim (liability) of a national central bank on (towards) the ECB stands vis-à-vis a T2 liability (claim) of the ECB towards (on) that national central bank, the sum of overall interest claims and obligations balances out to zero. Therefore, the remuneration of T2 balances has no impact on the Eurosystem's monetary income and its distribution between national central banks (European Central Bank, 2004; Hellwig and Schnabel, 2019a,b).

In sum, in the case of an unchanged continuity of the monetary union, (large) T2 imbalances represent in particular indirect risks. (Over-indebted) countries that are subject to large T2 liabilities might have an incentive to try to take advantage of this circumstance by blackmailing the other euro area member states. This risks destabilizing the monetary union. Apart from this threat potential, although there are no direct risks originating from T2 imbalances as long as their value is continuously and legally validly reported on the national central banks' balance sheets, in any case, T2 imbalances express asymmetries with regard to the creation of reserves by national central banks and its distribution across euro area countries. However, this is more a symptom of the decentralized implementa-

[36]See also Horst and Neyer (2019).

tion of monetary policy in the euro area by the respective national central banks than an inadequacy with regard to the design of the payment system.

## 4.2 Withdrawal of a Euro Area Member State

Whether country-specific risks may occur in the case of a withdrawal of a euro area member state that faces a T2 liability towards the ECB primarily depends on the operational handling of the ECB, the European Commission and the remaining euro area member states. The withdrawal of a member state from the euro area is not intended and has not been included in the Treaty on the Functioning of the European Union, or in the Statutes of the European System of Central Banks (ESCB) and of the European Central Bank. Thus, no solutions have been designed accordingly. Therefore, the legal effects are ambiguous. It is to be expected that, in the context of the exit negotiations, the ECB and the European Commission would insist that the T2 liability of the withdrawing country persists in the same amount and has to be treated as a debt. The withdrawing country would possibly claim that the T2 liability does not reflect any debt and thus any obligation. We described in Section 2 that T2 balances serve as an item in the central banks' balance sheets to neutralize a shift in net assets between central banks occurring from cross-border transactions. Consequently, they represent a claim or a liability and need to be balanced – through a respective transfer of financial assets, for instance – in the case of a withdrawal or the dissolution of the monetary union. In this context, in January 2017, the former ECB president Mario Draghi released an extraordinary letter which he had written to two Italian members of the European Parliament stressing that "if a country were to leave the Eurosystem, its national central bank's claims on or liabilities to the ECB would need to be settled in full" (Draghi, 2017).[37] However, he neither mentioned how they would have to be settled, nor on which legal foundation his statement was based. The withdrawing country would possibly stress that the T2 liability does not reflect any debt or obligation, but only a statistical balancing item in the central bank's balance sheet. Thus, in particular due to the missing legal basis, it is unlikely that a consensual agreement would be reached.

[37] Mario Draghi's letter was a response to a request of two Italian European Parliament members who asked officially in December 2016 whether and how T2 balances of a net debtor member state would be settled technically if the country decided to quit the monetary union.

If we assume that the concerns that the ECB may lose its T2 claim on a member state opting to leave the euro area are justified, the consequences for the remaining member states might be as follows: If, for instance, Italy chose to leave the euro area, its T2 liability amounting to around 500 billion euros (September 2021) would need to be settled.[38] However, neglecting the political controversy, it is unlikely that Italy would financially be able to repay its debt. After the exit, Italy would introduce its own currency, i.e., the lira, for example. The lira would immediately depreciate against the euro. The claims on private and public debtors on the asset side of the Italian central bank's balance sheet would be denominated in lira while the T2 liability would still be denominated in euro. Technically, the Italian central bank would de facto go bankrupt (Sinn, 2018). Thus, the concerns that the T2 liability might be irrecoverable could be appropriate. However, so far this does not necessarily imply that losses for taxpayers will accrue.

If the leaving member state were unable or refused to repay its T2 liability, the ECB would (i) try to exploit the deposited collateral at the Italian central bank. However, the collateral deposited at the Italian national central bank is a result of its refinancing operations conducted with domestic commercial banks, for instance. Thus, the ECB would have no recourse to this collateral (Deutsche Bundesbank, 2012, p. 25). Moreover, it is likely that the liquidation of this collateral may be insufficient to balance the T2 liability.[39] Then, (ii) if the T2 liability of the leaving member state were irrecoverable, the ECB would have the possibility – according to Article 33.2 of the ESCB Statutes – to take the missing amount out of its general reserve fund. The reserve fund is part of the ECB's accruals for financial risks and cannot exceed the sum of the capital shares paid up by the euro area national central banks at the ECB which roughly amounts to 7.5 billion euros in total (data source: ECB). Thus, compared with the T2 liability of the Italian central bank amounting to around 500 billion euros, this seems to be an insufficient solution. (iii) Also according to Article 33.2 in connection with Article 32.5 of the ESCB

[38]The withdrawal of Italy from the monetary union is still unlikely, but not impossible. The Lega party and its federal secretary Matteo Salvini have frequently stressed during their government participation in 2018–2019 that Italy should consider to withdraw from the euro area. In May 2019, they convinced the Italian parliament to prepare a resolution for the introduction of a new parallel currency (Mini-BOTs). This has been considered as a credible exit threat by the other euro area member states.

[39]Note that this circumstance may also be supported by the fact that the (quality) requirements for collateral have been lowered significantly in the context of the financial and sovereign debt crisis and once again in April 2020 in the context of the COVID-19 pandemic.

Statutes, and following the decision of the ECB's Governing Council, the ECB could offset the shortfall against the overall monetary income of the relevant financial year.[40] In 2020, the ECB's monetary income amounted to 1.6 billion euros which also might be insufficient to balance the Italian T2 liability. (iv) Another possibility for the ECB would be to create an adjustment item for the "default of T2 claims" on its balance sheet.[41]

So far, we did not consider any form of loss sharing between the remaining national central banks, since loss sharing is neither included in the Treaty on the Functioning of the European Union, nor in the ESCB Statutes.[42] However, if the ECB stated that a residual claim were irrecoverable, the ECB would have to write-off the residual claim as a bad debt and thus would be exposed to a loss in its balance sheet through a reduction in its equity (Deutsche Bundesbank, 2012, p. 25). This loss could be divided between the remaining member states. The prerequisite for this is that the national central banks vote – in their capacity as shareholders in the ECB's Governing Council – for a sharing of the loss by qualified majority measured in terms of their respective capital shares (according to Article 10.3 of the ESCB Statutes). The national central banks would then participate in the loss according to their share in the newly adjusted ECB's capital key (German Council of Economic Experts, 2018, p. 186). For instance, if Italy left the euro area, Germany's share in the ECB's capital key would increase from 26% to 31%. Thus, the Bundesbank's share of loss would de facto reduce its T2 claim on the ECB by around 155 billion euros (corresponding to 4.7% of the German GDP). Consequently, the Bundesbank's equity would decrease. National central banks are owned by the respective member state. If they earn a profit, this profit is distributed to the respective finance ministry. A central bank can also generate losses and even operate with negative equity. However, in this context, the German Federal Constitutional Court ("Bundesverfassungsgericht") stated that the German government would, depending on the respective amount, need to recapitalize the Bundesbank to (i) ensure the Bundesbank's proper business activities, (ii) ensure its

[40] According to Article 32.5 of the ESCB Statutes, the overall monetary income is shared between the national central banks in accordance with their share in the ECB's capital.

[41] We abstain here from additional potential losses for the Eurosystem occurring from the circulating amount of cash denominated in euro in the country that has withdrawn from the euro area. The country could still use this cash after the exit to settle payments in euro, if the Eurosystem would not try to devalue the cash holdings before (Sinn, 2019b). Since this is not directly related to the country's T2 balance, we neglect this aspect in our analysis.

[42] See also Siekmann (2017).

financial independence, and (iii) also avoid a loss in the Bundesbank's credibility (Bundesverfassungsgericht (2016, Rn217), Bundesverfassungsgericht (2017, Rn126)).[43] Then, the irrecoverable amount could be passed on to the taxpayers. For example, the German government could carry out the recapitalization by refunding the missing equity capital through the emission and transfer of new government bonds to the Bundesbank. This would increase the government debt accordingly. Alternatively, the Bundesbank could also add an adjustment item to its balance sheet to balance the loss, like it already did in 1973 at the end of the Bretton-Woods era when the Bundesbank's foreign reserve assets (dollars) suddenly depreciated (Siekmann, 2017).

In sum, this should show that the risk that (a portion of) the irrecoverable amount could be passed on to the taxpayers cannot be ruled out but is nevertheless rather low and depends on many other factors. Whether this risk materializes, mainly depends on the amount of the T2 liability as well as on the exit negotiations and the operational handling. Since a withdrawal is not intended and thus not included in legal agreements, one can only speculate about the possible consequences. In this context, it also has to be mentioned that there could be a risk of imitations by other member states depending on the outcome of the exit negotiations and the compromises granted. This could trigger a downward trend and destabilize the whole monetary union. Therefore, the ECB, the European Commission and the remaining member states would have an incentive to create a precedent by making as few concessions as possible.

Following an exit and the settlement of the T2 balance a direct consequence with regard to the ECB's and the remaining national central banks' future income would be as follows: The monetary income of the national central bank of the withdrawing country would no longer exist for disposal with regard to the sharing of profits between all national central banks of the monetary union. Equally, the central bank of the withdrawing country would lose its claim on a part of the Eurosystem's monetary income and the ECB's profit. If the central bank's claim on the Eurosystem's monetary income and on the ECB's profit were superior to its contribution to the Eurosystem's income, the exit would be beneficial for the remaining national central banks from a business perspective, and vice versa. So

[43] This assessment was also shared by the European Central Bank (2016) and the Deutsche Bundesbank (2012, p. 29) which even pronounced that losses realized within the Eurosystem would have to be absorbed by the taxpayers of the euro area member states.

depending on the withdrawing country's share in the ECB's capital and its contribution to the overall monetary income, the withdrawal can, from a business perspective, either be advantageous or disadvantageous for both the withdrawing country as well as the remaining national central banks in the Eurosystem (Hellwig and Schnabel, 2019a).

Note that the amounts of T2 claims and liabilities of the remaining national central banks play no role in this scenario. For instance, with respect to the Bundesbank, its T2 claim officially exists on the ECB and not on a single member state. Hence, even in the case of the withdrawal of Italy, it would continue to exist unchanged as long as the monetary union continues to exist.

## 4.3 Dissolution of the Monetary Union

In its assessment of the risks of large T2 balances, the Deutsche Bundesbank (2018, p. 17) stressed that the amount of its T2 claim on the ECB is irrelevant in the event of a withdrawal of a (single) member state from the euro area. However, in the case of a break-up of the whole euro area, the surplus countries' T2 claims are at risk. They hold a claim on a system that no longer exists. A legal basis for T2 claims does not exist for this case. Neither the ESCB Statutes nor the EU treaties contain any proposals for how such a scenario could be handled. A total loss of corresponding T2 claims on the ECB would therefore be possible including the potential consequences for the member states and their taxpayers (see Section 4.2).

Probably the simplest solution would be if T2 liabilities were repaid by T2 debtor countries by selling goods and securities with an equivalent value to T2 creditor countries or by realizing private net capital outflows from creditor to debtor countries. However, there is no possibility to enforce this behavior (Deutsche Bundesbank, 2019). For instance, even if T2 debtor countries were able and willing to sell the according amount of goods and securities, it is questionable whether T2 creditor countries would be willing to buy them.

However, it has to be considered, that in the event of a dissolution of the monetary union, the initial member states would be exposed to many other serious risks in addition to the default of T2 balances. T2 claims only represent one single aspect in the overall consideration of intra-Eurosystem claims and liabilities that would need to be settled.

### 4.4 Solution Approaches

(Large) T2 balances reflect asymmetries with regard to the creation of reserves between euro area national central banks. They bear direct and indirect risks. T2 balances serve as an offsetting item in the central banks' balance sheets to neutralize a realized transfer of assets between the countries involved. Because the T2 system is designed as a payment system instead of a transfer system, T2 balances represent actual claims and liabilities. Thus, there should be a possibility to call them due and to redeem them when necessary. However, compared with other counterbalancing assets in the central banks' balance sheets such as gold or foreign reserve assets, there is neither a chance of transferring them into other assets, nor to sell them.

Against this background, in order to limit the level of T2 balances and to establish the settlement of T2 balances, several adaption options for the existing T2 payment system or solution approaches are frequently discussed in the literature. One proposal for limiting the amount of T2 balances involves introducing progressively rising penalty interest payments for T2 liabilities. It is questionable whether this proposal would be feasible since it primarily concerns the debtor countries which would probably vote by majority against this proposal. Alternatively, an annual gold settlement for the T2 balances that would follow the rules prevailed with the US Federal Reserve districts until 1975, or a settlement of T2 balances like in the US ISA system could be implemented. This would allow T2 balances to be settled annually. However, this would again require a unanimous decision by the ECB's Governing Council, which is unrealistic due to the current high level of heterogeneity between the euro area member states. In this context, a mandatory cap limiting the T2 balances has also been proposed. However, this would restrict the free movement of capital within the monetary union, thereby delaying the process of integrated financial markets and supporting a segmentation of money markets. A collateralization of T2 balances is scarcely conceivable in light of the current level of T2 balances. In this context, the selection of acceptable eligible collateral may prove complicated. Moreover, depending on its communication, the ECB would risk a loss of credibility if it declared that the T2 balances previously considered "safe" would suddenly need to be collateralized. This could cause additional distrust towards the ECB.

We have shown that large T2 imbalances are not a reason but a symptom of asymmetries, or even crises, within the euro area. Consequently, solutions or adaption options that do not address the T2 payment system directly and exclusively, but rather concern the ECB's general monetary policy, for instance, are potentially more appropriate. As soon as the Eurosystem scales back its unconventional expansionary monetary policy measures and the amount of excess liquidity created by those measures decreases, the cross-border interbank money market is expected to regain its significance with regard to commercial banks' liquidity management and the reallocation of central bank money. T2 balances are then expected to drop again. In this scenario, for example, potential imbalances in a country's balance of trade must be offset by the appropriate adjustments in the private financial account as was the case before the outbreak of the financial and sovereign debt crises when T2 balances fluctuated close to zero. Against this background, the ECB could also try to scale back its refinancing operations with full allotment at zero interest costs. Requirements for eligible collateral could also be tightened. The ECB would then be tasked with setting the correct framework which would mainly involve (i) reestablishing a scarcity of central bank money and thus a reduction in overall excess liquidity and (ii) a functioning interbank money market.[44] Of course, the appropriate exit from an unconventional monetary policy is subject to a complex benefit-risk assessment and has to be evaluated sensitively in consideration of many more macroeconomic aspects. Nevertheless, the existence of (large amounts) of excess liquidity, and thus of a structural liquidity surplus in the euro area banking sector, is the prerequisite for the emergence of T2 balances. As long as the Eurosystem eases its monetary policy, continues its large-scale asset purchases and thus continues to create further excess liquidity, it is likely that T2 balances in the euro area will increase further. Consequently the reduction of overall excess liquidity and the return to a structural liquidity deficit in the euro area banking

[44]If necessary, the ECB could also try to support the reactivation of the interbank money market in a first step by collateralizing the credit operations to increase the level of trust between commercial banks.

sector, as it was actually the case until October 2015,[45] should be the appropriate way to reduce T2 balances and thus the potential risks involved.

## 5 Summary

T2 balances are claims and liabilities of euro area national central banks vis-à-vis the ECB. They emerge as a result of cross-border payments between national central banks. A positive (negative) T2 balance indicates that the amount of payment orders a national central bank received has exceeded (fallen below) the amount of payment orders it has sent to other national central banks. Large and asymmetric T2 balances in the euro area have sparked substantial controversy. Against this background, the first part of this paper deals with the functioning of the T2 system and the causes of the observed large increases in T2 balances. The second part of this paper analyzes potential risks of large T2 balances for euro area member states and discusses adaption options to the T2 system.

The drivers and causes of large and asymmetric T2 balances change over time and depend on different scenarios. Following the outbreak of the financial crisis and during the subsequent sovereign debt crisis, T2 balances started to increase for the first time in the euro area. T2 balances during this period are a symptom of increased levels of distrust and risk perception as well as increased information asymmetries which implied tension in the money market and funding stress in the euro area banking sector. Thus, in this context, they can be interpreted as a sign of crises. However, the second period of increasing T2 balances from the beginning of the QE period in 2015 and over the course of the COVID-19 pandemic until today is mainly a consequence of the technical particularities with regard to the implementation of the Eurosystem's large-scale asset purchases. Thus, T2 imbalances during this period are predominantly no longer a sign of crises. In particular, they are a symptom of the decentralized implementation of monetary policy by the respective euro area national central banks. In both scenarios, the provision of (large amounts of) excess liquidity by the Eurosystem is a prerequisite for the emergence of T2 balances.

[45] For detailed information with regard to the distinction between a structural liquidity deficit and a structural liquidity surplus as well as their significance for monetary policy implementation, see, e.g., Horst and Neyer (2019).

Potential risks arising from large T2 balances are scenario dependent. In the scenario of (i) an unchanged continuity of the euro area, large T2 balances do not constitute direct risks. However, they may bear indirect risks in the form of a threat potential if countries exposed to (large) T2 liabilities were to try to take advantage of this circumstance by blackmailing the other member states. In the event of (ii) a withdrawal of a euro area member state facing a (large) T2 liability, direct risks exist in the form of losses for the remaining national central banks as well as for the remaining member states and their taxpayers. Their extent primarily depends on the outcome of exit negotiations and the subsequent operational handling. Depending on these negotiations, an additional potential risk could arise in the form of imitations if other member states exposed to (large) T2 liabilities opted to leave the euro area as well. This could bear the risk of destabilizing the monetary union. In the event of (iii) a dissolution of the whole monetary union, the creditor countries' T2 claims may be at risk. They would hold claims on a system that no longer exists. A total loss of corresponding T2 claims on the ECB would be possible.

Against the background that large T2 balances bear direct and indirect risks, we discuss potential adaption options to the T2 system. We find that proposals directly and exclusively considering the T2 payment system such as introducing progressively rising penalty interest rates for T2 liabilities, a mandatory cap limiting the T2 balances, or a collateralization of T2 balances are less suitable than proposals affecting the ECB's monetary policy such as scaling back its large-scale asset purchases or restricting its main refinancing operations with full allotment at zero interest costs, for example.

Last but not least, from the ECB's point of view, it may be advantageous to expand its communication with regard to the relevance of large T2 imbalances in the future. A willingness to deal with criticisms as they arise could help to avoid increasing levels of concern and distrust with regard to the T2 payment system. A detailed and successful central bank communication has become more and more important in the past few years. In particular with regard to this sensitive topic, the ECB's objective should be to provide a high level of information in order to decrease the level of uncertainty and to reach a high level of credibility to ensure the basis for a successful monetary policy.

# Bibliography


Alvarez, I., F. Casavecchia, M. De Luca, A. Duering, F. Eser, C. Helmus, C. Hemous, N. Herrala, J. Jakovicka, M. Lo Russo, F. Pasqualone, M. Rubens, R. Soares, and F. Zennaro (2017). The use of the Eurosystem's monetary policy instruments and operational framework since 2012. *ECB Occasional Paper 188, May 2017*.

Baldo, L., B. Hallinger, C. Helmus, N. Herrala, D. Martins, F. Mohing, F. Petroulakis, M. Resinek, O. Vergote, B. Usciati, and Y. Wang (2017). The distribution of excess liquidity in the euro area. *ECB Occasional Paper 200, November 2017*.

Bank for International Settlements (2003). Payment systems in the euro area. `https://www.bis.org/cpmi/paysys/ecbcomp.pdf`. [Online; accessed 07-October-2021].

Bindseil, U. and P. J. König (2012). TARGET2 and the European sovereign debt crisis. *Credit and Capital Markets 45*(2), 135–174.

Bundesverfassungsgericht (2016). Urteil des Zweiten Senats vom 21. Juni 2016, 2 BvE 13/13, Randnr. 99-102, 109. `https://www.bundesverfassungsgericht.de/SharedDocs/Entscheidungen/DE/2016/06/rs20160621_2bvr272813.html`. [Online; accessed 07-October-2021].

Bundesverfassungsgericht (2017). Beschluss des Zweiten Senats vom 18. Juli 2017, 2 BvR 859/15, Randnr. 1-137. `https://www.bundesverfassungsgericht.de/SharedDocs/Entscheidungen/DE/2017/07/rs20170718_2bvr085915.html`. [Online; accessed 07-October-2021].

Cœuré, B. (2017). The international dimension of the ECB's asset purchase programme. `https://www.ecb.europa.eu/press/key/date/2017/html/ecb.sp170711.en.html`. Speech at the meeting of the Foreign Exchange Contact Group, 11 July 2017. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2011). The German balance of payments in 2010. *Deutsche Bundesbank Monthly Report, March 2011*, 34–35.

Deutsche Bundesbank (2012). Stellungnahme vom 21.12.2012 im OMT-Verfahren vor dem Bundesverfassungsgericht, 2 BvR 1390. `https://www.bundesbank.de/resource/blob/799684/14bcbdeda81af076aa78e40891f0997a/mL/2012-12-%20%20%20%20%20%20%20%20%2021-omt-data.pdf`. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2018). Annual report 2018. `https://www.bundesbank.de/resource/blob/779146/28a66617341a428a89608ca281971f3f/mL/2018-annual-report-data.pdf`. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2019). Stellungnahme der Deutschen Bundesbank anlässlich der öffentlichen Anhörung des Finanzausschusses des Deutschen Bundestags am 05.07.2019. `https://www.bundesbank.de/de/presse/stellungnahmen/stellungnahme-der-deutschen-bundesbank-anlaesslich-der-oeffentlichen-anhoerung-des-finanzausschusses-des-deutschen-bundestags-am-5-juni-2019-798206`. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2020a). Balance of payments. https://www.bundesbank.de/en/statistics/external-sector/balance-of-payments/balance-of-payments-776588. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2020b). TARGET2 - balance. https://www.bundesbank.de/en/tasks/payment-systems/target2/target2-balance/target2-balance-626782. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2021a). Coronavirus crisis pushes TARGET2 balance above one trillion euros. https://www.bundesbank.de/en/tasks/topics/coronavirus-crisis-pushes-target2-balance-above-1-trillion-840812. [Online; accessed 07-October-2021].

Deutsche Bundesbank (2021b). The two-tier system for reserve remuneration and its impact on banks and financial markets. *Deutsche Bundesbank Monthly Report, January 2021*, 59–79.

Draghi, M. (2017). Letter to Mr Marco Valli and Mr Marco Zanni – members of the European Parliament, Frankfurt a.M., 18 January 2017. https://www.ecb.europa.eu/pub/pdf/other/170120letter_valli_zanni_1.en.pdf. [Online; accessed 07-October-2021].

Eisenschmidt, J., D. Kedan, M. Schmitz, R. Adalid, and P. Papsdorf (2017). The Eurosystem's asset purchase programme and TARGET balances. *ECB Occasional Paper Series 196, September 2017*.

European Central Bank (2001). TARGET annual report. *European Central Bank, Frankfurt a.M., May 2001*.

European Central Bank (2004). Statute of the ESCB and of the ECB – rules of procedure. *European Central Bank, Frankfurt a.M., 2004*.

European Central Bank (2012). Guideline of the European Central Bank of 5 December 2012 on a Trans-European Automated Real-time Gross settlement Express Transfer system (TARGET2). *Official Journal of the European Union*.

European Central Bank (2016). Convergence report, June 2016. https://www.ecb.europa.eu/pub/pdf/conrep/cr201606.de.pdf. [Online; accessed 07-October-2021].

European Central Bank (2019). ECB introduces two-tier system for remunerating excess liquidity holdings. *Press release, 12 September 2019*.

European Central Bank (2020a). Asset purchase programmes. https://www.ecb.europa.eu/mopo/implement/omt/html/index.en.html. [Online; accessed 07-October-2021].

European Central Bank (2020b). Balance of payments and international investment position. https://www.ecb.europa.eu/stats/balance_of_payments_and_external/balance_of_payments/html/index.en.html. [Online; accessed 07-October-2021].

European Central Bank (2020c). Monetary policy decisions. *Press release, 10 December 2020*.

European Central Bank (2020d). Pandemic emergency purchase programme (PEPP). https://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html. [Online; accessed 07-October-2021].

European Central Bank (2021). TARGET annual report. *European Central Bank, Frankfurt a.M., May 2021*.

Federal Reserve System (2021). Financial accounting manual for Federal Reserve Banks. *Board of Governors of the Federal Reserve System, July 2021*.

Fuest, C. and H.-W. Sinn (2018a). Target-Risiken ohne Austritte. *ifo Schnelldienst 71*(24), 15–25.

Fuest, C. and H.-W. Sinn (2018b). Target risks without euro exits. *CESifo Forum 19*(4), 36–45.

German Council of Economic Experts (2018). Annual report 2018/19 – setting the right course for economic policy. `https://www.sachverstaendigenrat-wirtschaft.de/fileadmin/dateiablage/gutachten/jg201819/Chapter_4.pdf`. [Online; accessed 07-October-2021].

Hellwig, M. (2018). Target-Falle oder Empörungsfalle? Zur deutschen Diskussion über die Europäische Währungsunion. *Perspektiven der Wirtschaftspolitik 19*(4), 345–382.

Hellwig, M. and I. Schnabel (2019a). Do Target balances create risks for taxpayers? *Wirtschaftsdienst 99*(8), 553–561.

Hellwig, M. and I. Schnabel (2019b). Target balances, current account balances, money creation, banks and capital markets. *Wirtschaftsdienst 99*(9), 632–640.

Homburg, S. (2019). Targetsalden sind nicht empörend, sondern gefährlich. *Perspektiven der Wirtschaftspolitik 20*(2), 98–102.

Horst, M. and U. Neyer (2019). The impact of quantitative easing on bank loan supply and monetary policy implementation in the euro area. *Review of Economics 70*(3), 229–265.

Horst, M., U. Neyer, and D. Stempel (2020). Asymmetric macroeconomic effects of QE-induced increases in excess reserves in a monetary union. *DICE Discussion Paper No. 346*.

Siekmann, H. (2017). Die Einstandspflicht der Bundesrepublik Deutschland für die Deutsche Bundesbank und die Europäische Zentralbank. *Institute for Monetary and Financial Stability, Goethe University Frankfurt, Working Paper Series* (120).

Sinn, H.-W. (2018). Fast 1 000 Milliarden Target-Forderungen der Bundesbank: Was steckt dahinter? *ifo Schnelldienst 71*(14), 26–37.

Sinn, H.-W. (2019a). Der Streit um die Targetsalden. *Perspektiven der Wirtschaftspolitik 20*(3), 170–217.

Sinn, H.-W. (2019b). Der Streit um die Targetsalden – Kommentar zu Martin Hellwigs Artikel "Target-Falle oder Empörungsfalle?". *ifo Working Papers* (316), 1–100.

Sinn, H.-W. (2020). The economics of target balances – from Lehman to Corona. *Springer Nature*.

Sinn, H.-W. and T. Wollmershäuser (2012). Target loans, current account balances and capital flows: the ECB's rescue facility. *International Tax and Public Finance 19*(4), 468–508.

Smeets, H.-D. (2018). Die deutschen TARGET Forderungen – ein hausgemachtes (Schein-)Problem?, Wirtschaftliche Freiheit – Das ordnungspolitische Journal. `http://wirtschaftlichefreiheit.de/wordpress/?p=23463#more-23463`. [Online; accessed 07-October-2021].

Spahn, P. (2019). Targetsalden und die Vollendung der Währungsunion. *Perspektiven der Wirtschaftspolitik 20*(2), 103–106.

van Suntum, U. (2019). Targetsalden und andere Risiken in der Europäischen Währungsunion. *Perspektiven der Wirtschaftspolitik 20*(2), 107–114.

## Eidesstattliche Erklärung

Ich, Maximilian Julius Horst, versichere an Eides statt, dass die vorliegende Dissertation von mir selbstständig und ohne unzulässige fremde Hilfe unter Beachtung der „Grundsätze zur Sicherung guter wissenschaftlicher Praxis an der Heinrich-Heine-Universität Düsseldorf“ erstellt worden ist.

Düsseldorf, den 27. Oktober 2021

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