Essays on the European financial market structure and the monetary union

DISSERTATION
of the University of St.Gallen,
School of Management,
Economics, Law, Social Sciences,
International Affairs and Computer Science,
to obtain the title of
Doctor of Philosophy in Economics and Finance

submitted by

Hannah Lucy Winterberg

from

Germany

Approved on the application of

Prof. Dr. Christian Keuschnigg

and

Prof. Dr. Şebnem Kalemli-Özcan

Dissertation no. 5263

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The University of St.Gallen, School of Management, Economics, Law, Social Sciences, International Affairs and Computer Science, hereby consents to the printing of the present dissertation, without hereby expressing any opinion on the views herein expressed.

St.Gallen, June 13, 2022

The President:

Prof. Dr. Bernhard Ehrenzeller

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Cologne, July 2022 Hannah Winterberg

Contents

Summary

The adaption of a single currency in the Euro area is a unique experiment in recent history. Its introduction has united a group of economies with diverse economic traditions under one single monetary framework. This dissertation is a collection of three research essays on the structure of the financial markets in that single currency union.

The closest comparison to the Euro area's currency union can be drawn from the United States. While the single states forming the United States historically had - and in parts still have - separate government budgets and local economic conditions they are now a "well-integrated monetary union of continental dimension"[1]. In the first chapter (*How would European firms fund themselves in the United States?*), I analyze the composition of corporate debt by comparing European and American firms. I find that the higher prevalence of bank over bond funding in Europe is partially driven by different financial market settings and partially by different firm characteristics, particularly firm size and collateral availability. To illustrate the impact of these differences, I introduce a theoretical model and provide a counterfactual analysis. The analysis suggests that if all European firms would relocate to the United States, their aggregate bond funding share would still be only half of the share in the native U.S. economy.

The currency union has seen its first monetary challenges starting with the financial crisis in 2007/2008. These challenges created the need for novel monetary policy actions. In the second chapter (*Monetary Policy Disconnect*), which is joint work with B. Ballensiefen and A. Ranaldo, we analyze the implications of the monetary policy framework on the effectiveness and transmission of monetary policy. We find that two crucial aspects of the central bank framework can disconnect the transmission of monetary policy: access to central bank deposits and Quantitative Easing. We show how both aspects hinder the monetary policy transmission through the main secured short-term funding market, the repurchase agreement market.

The different countries of the Euro area entered into the monetary union with varying fundamental economic conditions. The sovereign debt crisis has brought these differences into the center of the public discussion. In the third chapter (*Italy in the Eurozone*), which is joint work with C. Keuschnigg, L. Kirschner, and M. Kogler, we consider the implications of membership in the monetary union at the example of Italy. We investigate two scenarios for the future of the Italian economy, one focusing on sustained reforms within the Euro area and one considering the return to monetary autonomy. We conclude that the prospect of a depreciating Lira benefits Italy's recovery but that this may come at the cost of severe financial market distress.

[1]Gaspar, V. (2015). The making of a continental financial system: lessons for Europe from early American history. Journal of European Integration, 37(7), 847-859. Page 3.

Zusammenfassung

Die Einführung einer Gemeinschaftswährung im Euroraum ist ein einzigartiges Experiment in der jüngeren Geschichte, welches eine Gruppe von Volkswirtschaften mit unterschiedlichen Wirtschaftstraditionen unter einem einzigen monetären Rahmen vereint hat. Diese Dissertation ist eine Sammlung von drei Forschungsaufsätzen zur europäischen Währungsunion und der Struktur ihrer Finanzmärkte.

Für einen Vergleich zum Euroraum eignen sich insbesondere die USA. Obwohl die einzelnen Bundesstaaten historisch gesehen getrennte Staatshaushalte und lokale Wirtschaftsräume hatten und teilweise auch noch haben, stellen sie heute eine gut integrierte Währungsunion dar. Im ersten Kapitel (*Wie würden sich europäische Firmen in den Vereinigten Staaten finanzieren?*) analysiere ich die unterschiedliche Zusammensetzung des Fremdkapitals europäischer und amerikanischer Firmen. Die Beliebtheit von Bankkrediten im Vergleich zu Unternehmensanleihen in Europa ist teilweise auf Unterschiede in den Finanzmärkten und teilweise auf verschiedene Unternehmensmerkmale zurückzuführen. Ich berechne, wie sich die europäischen Firmen finanzieren würden, wenn sie Zugriff auf den amerikanischen Finanzmarkt hätten. Ich komme dabei zum Ergebnis, dass europäische Firmen trotzdem einen deutlich geringeren Anteil des Fremdkapitals in Form von Unternehmensanleihen ausgeben würden, da sie sich in ihren Eigenschaften von amerikanischen Firmen unterscheiden, zum Beispiel im Durchschnitt kleiner sind.

Die Währungsunion hat seit der Finanzkrise 2007/2008 mehrere geldpolitische Herausforderungen erlebt, welche die Einführung neuer Instrumente erfordert haben. Im zweiten Kapitel (*Geldpolitische Entkopplung*), welches in Zusammenarbeit mit B. Ballensiefen und A. Ranaldo entstanden ist, analysieren wir die Auswirkungen des geldpolitischen Rahmenwerks auf die Wirksamkeit und Transmission der Geldpolitik. Wir stellen fest, dass insbesondere zwei Aspekte die Transmission der Geldpolitik in den grössten Markt für kurzfristiges Fremdkapital, den Markt für Rückkaufvereinbarungen, entkoppeln können: der Zugang zu Zentralbankeinlagen und die Bedingungen für den Ankauf von Staatsanleihen.

Die Staatsschuldenkrise hat die unterschiedlichen Voraussetzungen, mit denen die Länder des Euroraums der Währungsunion beigetreten sind, in den Mittelpunkt der öffentlichen Diskussion gerückt. Im dritten Kapitel (*Italien in der Eurozone*), das in gemeinsamer Arbeit mit C. Keuschnigg, L. Kirschner und M. Kogler entstanden ist, betrachten wir die Implikationen einer Währungsunion am Beispiel Italiens. Wir untersuchen zwei Zukunftsszenarien für die italienischen Wirtschaft. Das Erste betrachtet kontinuierliche Reformen innerhalb der Eurozone und das Zweite simuliert die Rückkehr zur Währungsautonomie. In diesem Fall kommt die Abwertung der Lira der Erholung Italiens zwar zugute, sie birgt jedoch auch ein Risiko für schwere Finanzkrisen.

Chapter 1

How would European firms fund themselves in the United States?

Hannah Winterberg[1]

I analyze firms' funding choice between bonds and bank loans in the Eurozone and compare it to the United States. The higher prevalence of bank over bond funding in Europe is partially driven by different financial market settings and partially driven by different firm characteristics. I show that the extent to which a firm uses bonds instead of bank loans depends foremost on its size and collateral availability. I introduce a theoretical model and provide a counterfactual analysis of funding choice, which suggests that if all European firms were to be relocated to the United States, their aggregate bond funding share would still be 18.5 percentage points (about one third) lower than the share in the native U.S. economy due to different firm characteristics.

JEL classification: E4, E5, F3, G0, G1, P1.

[1] I thank Sebnem Kalemli-Özcan, Christian Keuschnigg, Michael Kogler, Daniel Rabetti (discussant), S. Ghon Rhee (discussant), as well as conference participants at the RCEA conference on recent developments in Economics, Econometrics and Finance (2022), the 29th Finance Forum (2022) and the FMA conference (2022) for their valuable comments and suggestions. This work is supported by the Swiss National Science Foundation (grant number P1SGP1_188111).

European firms' debt funding is dominated by bank loans, whereas firms in the United States choose to issue more bonds. Why do European firms seem to reach such different conclusions regarding their best debt choice? If European firms were facing a financial market akin to the U.S. market, would the aggregate debt funding choice be the same?

I analyze the cross-sectional dimensions of firm debt choice in the Eurozone in comparison to the United States. For this, I compile a unique, extensive data set and show that firm size and collateral availability are significant predictors of a firm's debt choice. I introduce a theoretical model to estimate the extent to which the aggregate debt choice is driven by similar firms using different funding sources in the two areas, as opposed to being driven by fundamentally different firms operating in those regions. Based on these estimates, I present counterfactual scenarios for the aggregate funding choice of European firms if they were relocated to the United States. I find that the use of bond funding among them would remain significantly lower due to different firm fundamentals.

Nonfinancial corporations' debt funding is split between bank loans and corporate bonds; in Europe, those shares are around 85%/15% in the aggregate[2], while in the United States, there is a greater balance, tilting towards corporate bonds with shares of 45%/55%, respectively[3].

The distribution of funding choices across firms of different characteristics follows similar patterns in both regions. First, large firms, which are frequently public entities, carry a higher share of market debt (bond debt) on their balance sheets. In the United States, the bond debt share in this group is almost 70% (Caglio et al., 2021). In the Euroarea, larger firms also employ more bond debt, but the bond funding share remains below 50% even for the largest quartile of public firms (largest in terms of total assets, Darmouni and Papoutsi, 2020). Second, firms at the bottom of the firm size distribution almost exclusively use bank loans to fund themselves. Among small and mid-size enterprises (SMEs) in the United States, bank loans make up more than 90% of all debt, implying a share of market debt below 10% (Caglio et al., 2021).[4]

[2] Statistical Data Warehouse, time series "Debt Securities And Loans" and "Total Debt Securities".

[3] Federal Reserve Economic Data, time series NCBLL and NCBDBIQ027S.

[4] In the United States, 'SMEs' are defined as firms with less than 500 employees, Caglio et al. (2021) employ the OECD definition under which 'SMEs' are firms with less than 250

Larger European firms not only issue fewer bonds than their American counterparts, but they also make up a smaller share of the total economy since the distribution of firm sizes differs between the two regions. While in the United States, 6 out of 10 employees work in a firm with at least 300 employees, only a third of European employees do.[5] Correspondingly, small firms play a more prominent role in the Euroarea than in the United States.

The finding that for large European firms bond funding makes up a smaller percentage of their debt compared to their US counterparts indicates that bank loans remain popular even among those European firms with access to the bond market. This points to a difference in the two financial markets. Several differences have been highlighted in this context (Langfield and Pagano, 2016): First, the European financial structure is dominated by large, systemically important banks that enjoy an implicit government guarantee resulting in significantly lower funding costs (Lambert et al., 2014) and thus a cost advantage over market debt. Second, the European institutional framework differs from the U.S. framework along several dimensions. On the one hand, the corporate bond market in Europe is strongly fragmented with low trading volume spread across several exchanges (consider, for example, Bleaney et al., 2016). Such fragmentation entails inefficiently high bond issuance cost (Foucault et al., 2013). On the other hand, differences in the efficiency of firm resolution procedures impact banks and bond investors differently (Hackbarth et al., 2007; Becker and Josephson, 2016). In particular, according to the Worldbank's Doing Business Indicators, bankruptcy resolution procedures are more efficient in the United States with a score of 90.5 in 2020, which compares to an average of below 84 for the Euroarea. Becker and Josephson (2016) highlight that a higher bankruptcy efficiency is associated with more bond funding.

A dominance of bank funding has been found to create a misallocation of resources due to excessive fluctuations in credit and has thus been called a *bank bias* (Langfield and Pagano, 2016). These negative consequences arise from two sources: First, banks' lending ability is procyclical (Behn et al., 2016), implying that in a boom, less productive projects are funded in excess, whereas in a recession, more productive projects cannot secure funding, which is inefficient.

employees and/or assets below \$10 million and/or revenues below \$50 million.

[5]According to the statistics of U.S. businesses (SUSB) of the U.S. Census Bureau and the statistics on small and medium-sized enterprises from Eurostat. No restrictions on assets or revenues were applied.

Second, banks tend to continue to fund firms even though they might not be profitable anymore;[6] this is less often the case for debt sources with a large number of investors such as bonds. A bank bias has also been confirmed for the United States, where highly leveraged SMEs borrow more when monetary policy is expansionary (Caglio et al., 2021). In a cross-country comparison, the aggregate systemic risk associated with these bank biases is more pronounced in the Euroarea (Langfield and Pagano, 2016). In line with this observation, Jiménez et al. (2014) find that banks take excessive risks under expansionary monetary policy in a Spanish sample, while Caglio et al. (2021) do not observe such risk-taking in a U.S. sample.

For my analysis, I consider firm size as a first characteristic that impacts firms' debt choice. This means that I interpret firm size as an exogenous characteristic of the firm that determines funding choices. However, a firm's size could also be seen as the outcome of funding choice and constraints. In the aggregate, prior research has shown that the firm size distribution (FSD) is not strongly affected by financial constraints in developed economies. Angelini and Generale (2008) conclude that funding constraints are not a main driver of the FSD across developed economies because in their sample, the FSD of nonconstrained firms is similar to the entire sample for OECD countries. The literature also highlights several nonfinancial factors that shape the firm size distribution among developed economies. These are size-based regulation (Garicano et al., 2016), antitrust laws (Gutiérrez and Philippon, 2018; Covarrubias et al., 2020; Grullon et al., 2019), and the prevalence of certain industries (Beck et al., 2008).

A second firm characteristic that has been shown to impact a firm's choice of debt type relates to a firm's liquidation value. A primary determinant of the liquidation value is the availability of collateral, or the fixed asset share, also referred to as a firms' asset tangibility. The direction of the impact of the liquidation value on debt choice depends on the frictions being considered. Theoretical models motivating funding choices through asymmetric information and improved monitoring by a bank (such as Diamond, 1984, 1991; Leland and Pyle, 1977) typically conclude that tangible assets reduce the information asymmetry and thus benefit bond issuances (Hoshi et al., 1993). By contrast, models that are based on a more efficient liquidation (or threat of liquidation)

[6] This has been referred to as "zombie lending"; see Keuschnigg and Kogler (2020).

achieved through banks conclude that a large share of tangible assets benefits choosing bank loans (Repullo and Suarez, 1998; Park, 2000). In U.S. data, the collateral impacts not only the level of bank credit extended to SMEs, but it is also an important determinant of the impact of monetary policy on lending outcomes (Caglio et al., 2021). The assets of a firm, and thus its collateral, vary along the lines of industries, which can be assumed to be exogenous to the firm's funding decision (Beck et al., 2008).

Estimating counterfactual scenarios based on firm characteristics requires data on the distribution of those characteristics among the firms in both regions. I compile a novel data set for firm balance sheet and bond issuance information in the Eurozone and the United States, which allows me to analyze the debt choice of different firms, including private firms. By combining two data sources (bond issuances from Thomson Reuters / Refinitiv and firm data from Bureau van Dijk's Orbis database), I am able to consider a more diverse picture of bond vs. bank loan choices among different types of firms than in the samples available via the commonly used Compustat and Capital IQ databases (consider, e.g., Darmouni et al., 2019; Darmouni and Papoutsi, 2020).

After data cleaning, the data covers the time period of 2011 until the end of 2018 and includes private and public nonfinancial firms in the Euroarea and the United States. For the Euroarea, the sample represents about 60% of aggregate revenues, 59% of total employment, and 69% of aggregate operating surpluses. For the United States, the counterfactual analysis relies on the characteristics of bond-issuing firms, which are well covered, as is indicated by the total covered bond debt outstanding, which represents more than two-thirds of the aggregate in both regions. The share of bond funding (over total debt funding) is well represented by the micro-level data and amounts to 17% in the Euroarea and 53% in the United States in 2018 (in the aggregate, those shares are 13% and 62%, respectively).

I explore how prevalent bond funding is in the cross-section of firms with different characteristics. My data confirms the patterns that (i) firm size is an essential predictor of bond issuance and that (ii) among the group of very large entities, European firms have a smaller share of bond debt. I observe two additional stylized facts: (iii) the observation that European firms hold smaller shares of bond debt also holds in smaller size categories and (iv) that the cut-off firm size to begin issuing bonds is higher in Europe than it is in the United States. The smallest American firms issuing bonds employ between 100 and 250 employees, while in Europe, bond issuance is almost exclusively seen among firms with at least 5,000 employees. Moreover, I consider the availability of collateral and observe that firms with more such assets tend to issue more bonds in both regions. In this context, I refer to collateral as fixed assets or redeployable assets available to the firm, which does not necessarily imply that these assets are indeed pledged as collateral. The importance of redeployable assets differs in the two regions, pointing to different efficiencies in bankruptcy procedures (which is higher in the United States in line with the Worldbank's ease of doing business indicator).[7]

In the second part of the paper, I introduce a model of debt choice that incorporates heterogeneity along two dimensions: firm size and fixed asset share. An adapted version of the model presented in Becker and Josephson (2016), this model illustrates the interaction between heterogeneous firms and a large set of bond investors, as well as banks. I assume that a firm's business model, the project undertaken, has a specific size and fixed asset requirement that is structural (i.e., exogenous to the debt choice). The agents in the model interact in a Cournot competition that leads to an equilibrium that closely resembles the situation observed in the data: only firms beyond a certain size threshold issue bonds, and this threshold increases with a firm's fixed asset share. In particular, conditional on their size, firms with a higher share of redeployable assets should have a higher share of bond funding. This mechanism results from a bankruptcy consideration. If a firm becomes insolvent, banks are more efficient in recovering their investment since they can engage in an out-of-court restructuring. By contrast, bond holders need to rely on formal bankruptcy procedures. If a firm has few redeployable assets, formal bankruptcy procedures destroy a lot of value. Thus bond investors consider the investment more risky and offer less bond funding. These firms use more bank loans due to equilibrium effects, not necessarily due to pledging of collateral in a specific contract. The baseline version of the model does not consider the specific act of pledging collateral into a contract, which frequently occurs in bank contracts but is rarely seen in corporate bonds. An extended version based on Becker

[7] Finally, I also consider the profitability and leverage of the firms in the cross-section and find that both characteristics are less predictive of firms' debt choices.

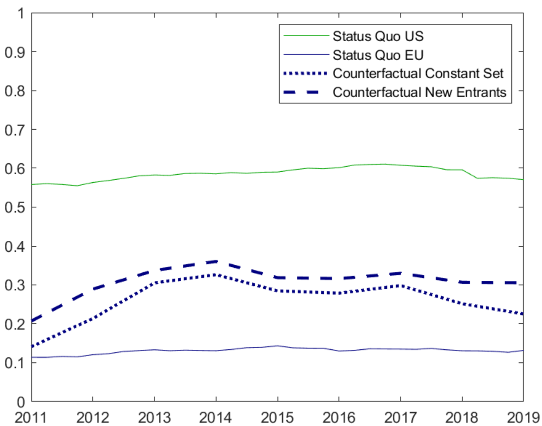
and Josephson (2016) presented in the Appendix shows that under bank seniority (i.e. if bank loans are collateralized) the main conclusions from the model remain the same.

I then estimate two sets of model parameters to best represent the empirically observed patterns on debt choice: one for the Euroarea and one for the United States. Based on these estimates, I present counterfactual scenarios of debt choice on the intensive and extensive margin. These results are depicted in Figure 1.1.

In the Euroarea, the aggregate share of bond funding fluctuates below 15%, while in the United States, it surpasses 50%. If European firms were to face a financial market like their American counterparts, their aggregate bond funding share would on average be about 18 percentage points higher. This is driven by existing bond issuers issuing more bonds ("counterfactual constant set" [of issuers]); the additional entry of smaller firms beginning to issue bonds ("counterfactual additional issuers") increases the aggregate share only slightly.

Overall, my results show that the difference in the bond funding share between the two regions mainly results from different firm fundamentals (this explains two-thirds of the modeled variation). Differences in the financial market structure explain the remaining one-third of the variation.

Figure 1.1: Eurozone counterfactual scenarios



To my knowledge, this is the first paper to present counterfactual debt scenarios for the Euroarea. I thereby contribute to two strands of the literature: first, to the macro-financial literature on debt markets and, second, to the empirical literature on debt choices among heterogeneous firms. From a macro-financial point of view, the papers closest to this work are De Fiore and Uhlig (2011) and Allen et al. (2018). The first presents a model of firm financing that incorporates the composition of corporate debt in order to explain different debt choices in the United States and Europe. The model does not incorporate effects of scale, a firm characteristic that I observe to be the main determinant of funding choice. The second paper, Allen et al. (2018), argues that on a macroeconomic level, real economic structure predicts financial structure. The authors present evidence based on aggregate data for a large cross-section of countries and consider exogenous events, such as the collapse of the Soviet Union, as a shock to the financial structure. From an empirical viewpoint, I present a novel combination of micro-level funding data from both private and public firms to evaluate the funding decision across heterogeneous firms. A distinction between bank and bond funding has so far been drawn mainly based on data from Capital IQ (e.g. Darmouni et al., 2019; Darmouni and Papoutsi, 2020), which, with very few exceptions, only covers public firms. A different perspective on funding choice is achieved by considering supervisory loan-level data (e.g. Caglio et al., 2021; Chodorow-Reich et al., 2021).

My results are also relevant for the policy discussion surrounding the European Union's capital markets union project. This project aims to promote more efficient funding choices by firms to improve the integration and resilience of financial markets. In related studies, the Eurozone is frequently compared to the United States as a more integrated market union with an advanced financial market (consider, for example, Organisation for Economic Cooperation and Development, 2016; Langfield and Pagano, 2016). I highlight in this context that the difference in aggregate funding choices between the United States and Europe and its negative implications for systemic risk in the Euroarea are not exclusively a result of the different financial systems but are in part also caused by structurally different firm characteristics. My results thus provide an insight into the required nature of potential, targeted policies. In particular, they suggest that such interventions focusing on the negative implications of the prevalence of bank funding should balance measures designed to foster debt market access for small firms as well as measures designed to disincentivize banks' amplifying behavior, since a reliance on bank debt appears to be unavoidable in the light of the European firm distribution.

This paper proceeds as follows: The first section details the data sources used in my analysis. The second section discusses the drivers of debt choice in the cross-section of firms and characterizes their relations to funding choices. The third section discusses the theoretical model and the parameter calibration and estimation. The fourth section presents counterfactual scenarios for the debt choice in the Eurozone. The fifth section concludes.

1.1 Data

The research question requires data on firms' bank and bond debt, individual firm balance sheets, as well as additional aggregate information.

I access detailed information on bond issuances in the United States and Europe from Refinitiv, formerly Thomson Reuters. In particular, I extract data on all historic bond issues by nonbank corporates from Thomson Reuters' debt deals database. This data set contains information on bond characteristics and details on the issuing firm at the time of issuance for a wide set of countries and securities. It not only covers different types of bonds, but also includes notes and certain types of commercial paper.[8] I download information on more than 300,000 bond issuances by nonfinancial issuers. For each firm, I deduce the volume of outstanding bond debt at a given balance sheet date from a firm's outstanding bonds. In this process, I take events such as buybacks or reopenings into account.[9]

For firm balance sheet data, I use Bureau van Dijk's Orbis database, which is a common choice in the literature on the Euroarea (for a detailed review on the database's representativeness, see Kalemli-Özcan et al., 2019; Bajgar et al., 2020).

In the existing literature, a distinction between bank and bond funding has been drawn mainly based on data from Capital IQ (e.g. Darmouni et al.,

[8]The exact definition of each security type differs according to the laws and standards of the jurisdiction under which the debt instrument is issued. The more frequently occurring instrument types are: Bonds, Notes, Debentures, Commercial Paper, Negotiable European Commercial Paper (Short-Term or Medium Term) as defined under French law, and Inhaberschuldverschreibungen, a specific bond under German law. I remove all instruments with equity- or option-like features (such as convertible bonds or warrants).

[9]In particular, I determine the remaining outstanding amount for each given bond at each balance sheet cut-off date.

2019; Darmouni and Papoutsi, 2020). Capital IQ provides very detailed data but only covers public firms and a few very large private firms. By combining bond issuance data from Refinitiv with firm balance sheet data from Orbis, I compile a cross-country database covering a history of 9 years for 1.2 million firms (after data cleaning), which also covers private firms. My data set thus improves upon the coverage of small firms in the Euroarea in Capital IQ (as used in Darmouni and Papoutsi, 2020[10]). By considering data for a large international sample including a substantial share of private firms, I am able to include new perspectives on this topic.

To identify the representativeness of my sample, I compare the covered micro-level data to aggregate data. This aggregate data is typically provided for nonfinancial corporates. I apply a very strict definition of 'nonfinancial' to be conservative in this comparison. This is necessary since the definition of financial corporates differs across aggregate data sources in some respects. For aggregate measures, the U.S. Flow of Funds data explicitly mentions not only chartered commercial banks, bank holding companies, credit and savings institutions as financial corporates, but also life insurances and pension funds (Board of Governors of the Federal Reserve System, 2000, Vol.1, p. 20). These definitions are based on a classification with 30 sectors. For European data from the ECB's Statistical Data Warehouse, the definition is based on the European System of Accounts 2010 (ESA 2010) which can additionally include non–life insurance companies (Eurostat, 2013, p. 42).[11]

Firms in both databases can be matched using the Legal Entity Identifier (LEI) or, if unavailable, by matching the bond ticker to the BvD-ID using the firm name and industry. The resulting data set is cleaned to ensure that balance sheet items are in appropriate relation to each other (a detailed description of this process is provided in the appendix).

I also account for the common practice of issuing bonds through a sub-

[10] The authors use a sample of 3,336 public firms. The average observation on total firm debt is €1,246 Mio. In an extension, they consider 47 private firms with rating downgrades of unknown size.

[11] The attribution of micro-level data to these aggregate measures is further complicated by the occurrence of inconsistencies between the industries reported in Refinitiv and Orbis data, which use slightly different classification systems. To be conservative, I drop all firms that may be seen as a financial firm or an insurance firm based on either the Statistical Classification of Economic Activities in the European Community (NACE) or on the field "Entity Type" reported in Orbis. More detail on this can be found in Section A.1 in the appendix

sidiary. Consider the example of automotive manufacturer Volkswagen AG. Volkswagen AG as the group head rarely issues bonds itself, while its fully owned subsidiaries such as Volkswagen International Finance NV issue a variety of bonds that are guaranteed by Volkswagen AG.

To appropriately capture the funding situation of corporate groups, I focus on consolidated accounts, if available. To avoid any double-counting, I drop the accounts of all majority-owned subsidiaries of those consolidated groups on a yearly basis (this approach has also been suggested in Bajgar et al. (2020, p.52) and a similar approach is taken in Caglio et al. (2021, p.12) for bank loans issued to firm subsidiaries).[12] The yearly information on firm ownership can be retrieved from the Orbis Webinterface and provides information on the corporate group structure.[13]

The basic, cleaned full sample for the Euroarea used in this paper contains information on 41.069 firms from Austria, 64.858 firms from Belgium, 136.199 firms from Finland, 734.663 firms from France, 242.772 firms from Germany and 15.792 firms from the Netherlands. I focus on the countries less affected by the sovereign debt crisis (also referred to as *Non-GIIPS* countries) to ensure that the results are not driven by this crisis. The cleaned dataset on bond issuers contains information on 885 bond issuers in the Euroarea and 1.511 bond issuers in the United States. Among the European bond issuers, 48% are listed firms, compared to 63% in the United States. A detailed summary statistic of listing status and legal form can be found in the appendix in Table A.2.1.

To ensure the representativeness of the firm data in Orbis, I consider different aggregate measures. A first, natural measure to consider is total revenue, in this case of nonfinancial corporates. The upper panel of Figure 1.2 depicts

[12]In order to avoid double-counting firms, it is also common to use nonconsolidated accounts when working with Orbis data (Kalemli-Özcan et al., 2019, p. 69) in comparison to aggregate, macroeconomic measures. This approach is difficult in the case of the bond debt attribution for two reasons. First, in non-consolidated accounts of the group head Volkswagen AG, the subsidiary's bond debt is not included in long-term debt, but provisions are included to account for the guarantees provided. These provisions cannot be distinguished from provisions for other contingent liabilities. Second, the bond-issuing subsidiary often only publishes very limited accounts or does not publish any accounts at all.

[13]Consolidated annual reports typically include this information in an appendix, for example, for the case of Volkswagen AG the "Shareholdings of Volkswagen AG and the Volkswagen Group [...] and presentation of the companies included in Volkswagen's consolidated financial statements" confirms the data from the Orbis database and shows that all bond issuing subsidiaries are fully consolidated entities.

Figure 1.2: Data coverage for the Euroarea

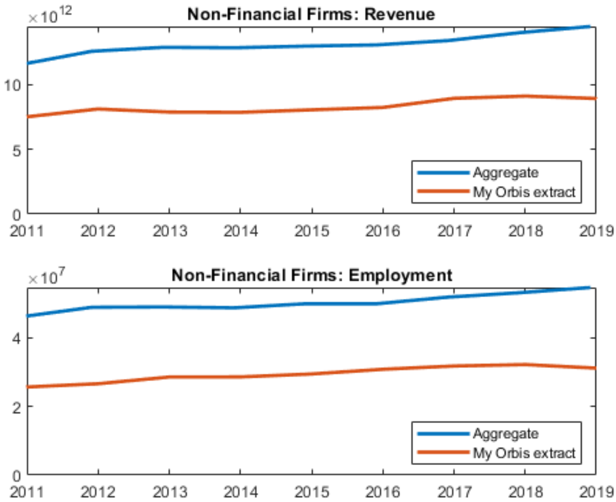


Figure 1.2 compares the coverage of firm turnover and employment in the data sample used in this paper to aggregate observations for these measures. The aggregate data for turnover refers to the time series "Turnover or gross premiums written" from the "Annual enterprise statistics for special aggregates of activities (NACE Rev. 2)" for the total business economy except financial and insurance activities. The aggregate data for employment refers to the time series "Employees - number" from the same data set. If in the micro-level data corporate groups report worldwide employment, this is broken down to the domestic level by the share of local revenue in worldwide revenue.

the aggregate measure of nonfinancial firm revenue in blue and the total coverage in my data set in orange. I observe that the coverage for the Euroarea is high with, on average, 60% of revenue covered. A second measure is the total number of employees in the nonfinancial corporate sector. The lower panel of Figure 1.2 depicts the aggregate measure of nonfinancial firm employment in blue and the total coverage in my data set in orange. For employment, the average coverage in covered countries of the Euroarea is 59%. Figure A.3.3 in the appendix illustrates the coverage in terms of aggregate total operating surplus, for which the Orbis data covers about 69% of the aggregate. [14] A set of summary statistics for all firms and for bond issuers in each country can be found in the appendix in Table A.2.2.

[14] This measure was suggested in Crouzet and Eberly (2021).

Figure 1.3 compares the total volume of outstanding bond debt across the cleaned micro-level data employed in this paper to aggregate data for the two covered regions. The aggregate outstanding volumes of debt securities are depicted in blue, while the micro-level data is depicted in orange (raw bond data, according to the borrower country reported by Refinitiv) and yellow (firm-matched data, by the firm's domicile in Orbis). I observe that my micro-level data set, on average, covers more than two-thirds of the aggregate bond debt.

Figure 1.3: Bond data vs. aggregate debt securities

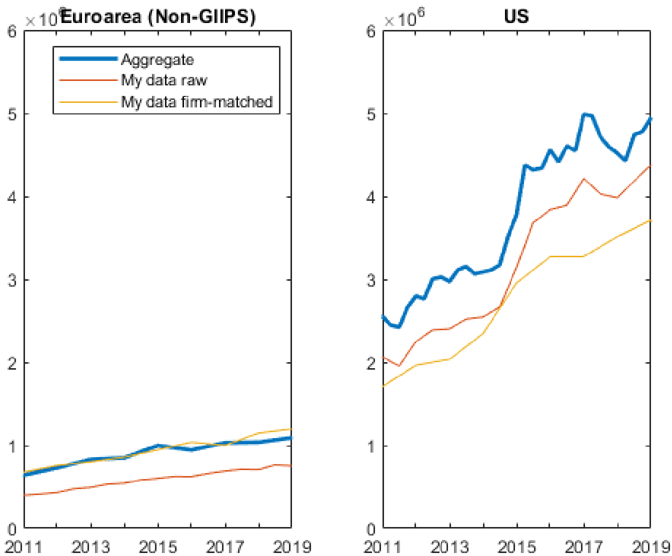


Figure 1.3 compares the total volume of outstanding bond debt across the micro-level data employed in this paper to aggregate data for the two regions: the Euroarea (Non-GIIPS) and the United States. The aggregate data for the Euroarea was derived using the time series Total Debt Securities for all core European countries from the quarterly financial and nonfinancial sector accounts available in the ECB Statistical Data Warehouse.The aggregate data for the United States was derived from the time series Nonfinancial Corporate Bonds (CBLBSNNCB) obtained from Federal Reserve Economic Data. Raw bond data is classified according to the borrower country reported by Refinitiv while firm-matched data is classified according to the firm's domicile reported in Orbis.

I use the combined data set to compute the bond funding share as the share of outstanding bond debt in financial debt as follows:

$$\text{Bond Funding Share} = \frac{\text{Bond Debt Outstanding}}{\text{Total Debt} - \text{Nonfinancial Debt}} \quad (1.1)$$

The bond funding share refers to the share of bond funding in external financial funding. This differentiates financial funding from other forms of debt that do not necessarily result from a firm's financing decisions, such as accounts payable. I therefore compute the volume of outstanding financial debt as the difference between total debt and other nonfinancial debt items.[15]

Figure 1.4 plots the aggregate bond funding share across all covered firms over time. It compares the observation in my micro-level data set to macroeconomic observations describing the aggregate bond funding share, as reported by Eurostat and the Federal Reserve. In the United States, the bond share has increased slightly from around 55% in 2011 to more than 60% in 2018. In the covered countries of the Euroarea, the bond funding share has also increased slightly from approximately 11% to around 13%. I find that my sample slightly overestimates the bond funding share in the Euroarea, while it modestly underestimates it in the United States.

The counterfactual analysis presented in this paper requires detailed coverage for the Euroarea, while for the United States only good coverage among the bond-issuing firms is necessary, since no conclusions are to be drawn about nonissuers in the United States and these are not incorporated into the analysis. The total coverage of U.S. firms in Orbis is smaller than for Europe, as is illustrated in Figures A.3.1 to A.3.3 in the appendix. Nonetheless, the coverage of bond-issuing firms is very good in both regions (according to Figure 1.3).

1.2 The debt choice among heterogeneous firms

The debt choice between bonds and loans has received attention in different strands of the literature. The corporate finance literature focuses on the microeconomic choice of the individual firm (e.g., Denis and Mihov, 2003), while the macroeconomic literature looks at the aggregate volumes of debt and the role of institutional and political factors (consider, for example, Qian and Strahan, 2007; Allen et al., 2018). I draw a connection between those two strands

[15]These are, in particular, other current liabilities (creditors) and other non-current liabilities (provisions).

Figure 1.4: Micro vs. macro firm data

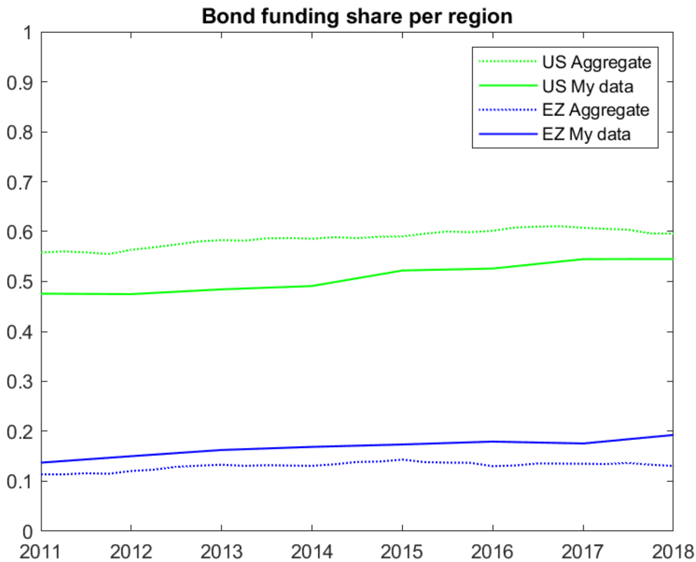


Figure 1.4 compares the average bond share observed across the micro-level data employed in this paper to aggregate data for the two regions: the Euroarea and the United States. The aggregate data for the Euroarea was derived using the time series "Total Debt Securities And Loan"s as well as "Total Debt Securities" for all core European countries from the quarterly financial and nonfinancial sector accounts available in the ECB Statistical Data Warehouse.The aggregate data for the U.S. was derived from the time series "Nonfinancial Corporate Debt Securities Total Liabilities" (NCBDBIQ027S) as well as "Nonfinancial Corporate Business Loans" (NCBLL) obtained from Federal Reserve Economic Data. The micro-level data depicts aggregate values from the micro-level data set compiled using the approach discussed in Section 1.1.

of the literature by estimating to what extent the aggregate (macroeconomic) differences in debt choice between the Euroarea and the United States result from the regions featuring firms with different microeconomic characteristics. If firms with similar characteristics make different funding choices in the Euroarea compared to the United States, and the U.S. financial market is deemed a more efficient, developed financial market, this could be interpreted as a bias. By contrast, if the differences in the aggregate debt choice result from structurally different firms making different decisions, negative implications have more structural underpinnings. The corporate finance literature has suggested a number of underlying factors for the choice between bond and bank debt. My data set covers a variety of heterogeneous firms. These firms differ along several dimensions. In the following, I explore how the debt choice differs with these characteristics.

Firm size

The first factor is **firm size**. The size of a firm is related to its funding needs and can be measured in different ways, for example, by the number of employees. The empirical literature suggests that larger firms are more likely to issue bonds (Denis and Mihov, 2003). This can be rationalized by fixed certification costs associated with bond issuances and minimum issue sizes.[16]

The role of firm size in the cross-sectional distribution of funding choice in the Euroarea compared to the United States is depicted in Figure 1.5. In this graph, firm size refers to the number of employees, as in Cabral and Mata (2003), a choice that allows for a comparison to census data.[17] In particular, the diameter of each circle depicted in Figure 1.5 refers to the share of employees in firms of the respective size group in each region.

First, I observe that the importance of bond funding is increasing with firm size. However, the cut-off point from which bond funding becomes more prevalent differs between the two regions. In the United States, the cut-off is at around 300 employees, while in the Euroarea, the smallest bond-issuing

[16] In the theoretical literature, firm size rarely plays a role, since most models are set up in a scale-invariant manner.

[17] The comparison to census data is an important step since my data set, despite its wide scope, still underestimates the number of very small firms, as is the case for most financial data sets. Matching the data set with information about the firm size distribution from census data, which can be assumed to perfectly cover each country, allows me to still draw conclusions about the importance of firms of different sizes.

Figure 1.5: Bond funding share across the firm size distribution

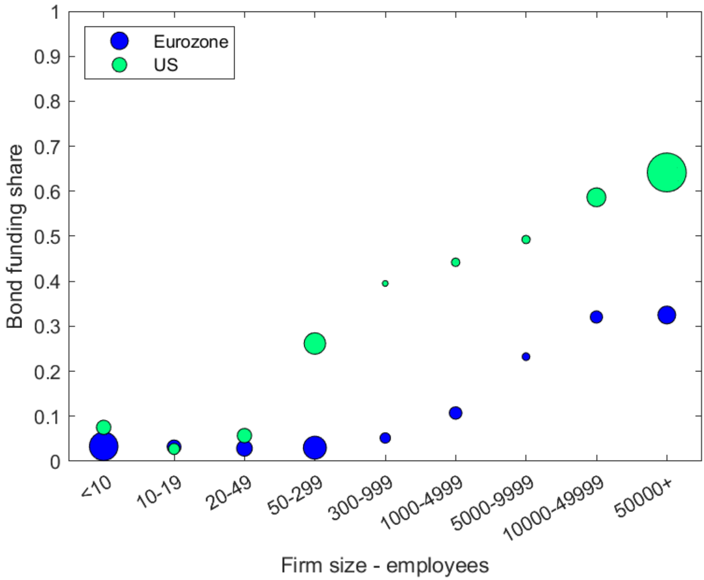


Figure 1.5 details the distribution of the bond funding share across the distribution of firms. The diameter of each circle represents the importance of firms in this size category in terms of total employment. This importance is derived from the Statistics of U.S. Businesses (SUSB) of the U.S. Census Bureau and the statistics on small and medium-sized enterprises from Eurostat (Eurostat's structural business statistics).[a]

[a]Since the U.S. and the European census on firm size do not use consistent bucket sizes, I use the distribution of firms in Orbis in order to adjust buckets. In particular, the European census focuses on small firms and thus groups all firms of at least 250 employees in one bucket, representing 38.55% of all employees. In order to deduce the share of firms in, for example, the group 50-299 in Europe (this metric is available in the U.S. census data), I compute the share of the size group 250-299 in terms of all firms of at least 250 employees across nonfinancial Euroarea firms in Orbis (using Orbis Pivot analysis tool), which is 2.212%. I deduce that 0.85% (0.02212*0.3855=0.0085) of employees work in firms of the size category 250-299 employees. The census data already includes the share of all employees in the size group 50-249 employees, which is 17.39%. This results in the weight for the size category 50-299 employees as depicted in the graph of 0.1739+0.0085=0.1824, or 18.2%. Orbis data has been found to be representative in terms of employment for firms of at least 250 employees; see (Bajgar et al., 2020, p. 22). The three smallest size categories (<10,10-19,20-49) are available as is in both census publications.

firms tend to have more than 5,000 employees. Considering the largest firms, the share of bond funding grows to above 50% in the United States, while in the Euroarea it remains below 35%. Comparing the firm size distribution in the two regions leads to the identification of the first two drivers of the low prevalence of bond funding in the Euroarea: firms with less than 300 employees rarely issue bonds in any of the two regions. However, in the Euroarea these small firms make up a larger share of the total economy, as they account for 62% of total employment (compared to 43% in the United States). Second, for a given firm size, U.S. firms tend to have a higher bond funding share.

For the modelling exercise, it is relevant to determine whether firm size is an exogenous characteristic of the firm. In particular, the differences in firm size between the United States and the Euroarea could be endogenously related to funding decisions or constraints. This would be the case if small and medium-sized firms in the Euroarea were so financially constrained that they were unable to grow despite sufficient growth opportunities. In a survey, the ECB semiannually asks SMEs located in the region to report their major business obstacle. In 2010, 15.4% of these firms reported access to finance as their major obstacle, a share that decreased to below 8% in 2019.[18] Firms more often struggle to find customers (27.8% in 2010, 20.9% in 2019) or skilled employees (12.4%/24.2%), indicating that the firm size distribution (FSD) is more strongly shaped by nonfinancial underlying factors.

The aggregate impact of financial constraints on the FSD is estimated in Angelini and Generale (2008). The authors conclude that the FSD of non-constrained firms is similar to the entire sample for OECD countries, which suggests that the impact of funding constraints on the FSD is small in these countries. By contrast, the authors find a stronger impact of financial constraints on the FSD in non-OECD countries. The authors therefore conclude that funding constraints are not a main driver of the FSD across developed economies. Correspondingly, Beck et al. (2006) find that while for firms in emerging economies firm size and financial constrainedness are strongly related, firm size is not significantly related to financial constrainedness in developed economies (where firm age is the main driver).

The literature highlights several nonfinancial factors that shape the firm

[18] Survey on the access to finance of enterprises (SAFE), series H.U2.SME.A.0.0.0.Q0.ZZZZ.P3.AL.WP.

size distribution among developed economies. A first aspect that has been highlighted in the literature is regulation. In several European countries, larger firms are strongly regulated and face higher labor costs. This effect is estimated in Garicano et al. (2016) by comparing French and U.S. firms. The authors find that the French FSD contains a disproportionate number of firms with less than 50 employees, due to a requirement for a workers' council and other committees setting in at this firm size cut-off. The estimated welfare loss is sizeable (3.5% of GDP) and involves a jump in labor cost at the cut-off of more than 2%. Another regulatory factor shaping the FSD relates to antitrust laws. Gutiérrez and Philippon (2018); Covarrubias et al. (2020) and Grullon et al. (2019) observe an increase in market concentration in several U.S. industries, while more rigorous antitrust laws in the single market of the European Union have limited concentration and thus the prevalence of very large firms.

A second determinant of a country's FSD is the prevalence of certain industries. Beck et al. (2008) highlight that an industry has a technological firm size distribution that results from the required production processes, as well as the capital intensity and associated economies of scale.[19] This is in line with the findings of Poschke (2018), who attributes a large part of the variation in the international FSD to occupational choice and technological progress. Similarly, Gomes and Kuehn (2017) argue that the FSD is a representation of education and public employment; in particular, a more educated work force and a larger share of public servants raises firm size.[20]

Building on the aforementioned literature I assume that the aggregate FSD is predominantly shaped by nonfinancial factors and that it can be interpreted as an exogenous characteristic in shaping the decision between bond vs. bank debt funding.

[19]For example, the authors find that oil refineries employ less than 20 employees only in 0.21% of the cases, while 12.26% of firms manufacturing nonelectric machinery fall in that size category. When a country produces more oil and less machinery (e.g. the United States vs. Germany) this shapes each country's FSD.

[20]Better educated workers earn higher wages and are therefore less inclined to become self-employed. As more high-skilled workers are absorbed by the public sector, a smaller pool of potential entrepreneurs remains. Compared to the Euroarea, the United States have a higher share of workers with a university degree (Barro and Lee, 2013) and a similar level of public employment (Organization for Economic Cooperation and Development, 2015).

Liquidation value/fixed assets

A second set of firm characteristics that the literature has identified as a driver of the debt choice relates to a firm's liquidation value (see Qian and Strahan, 2007). A main determinant of the **liquidation value** is the fixed asset share, also referred to as a firm's **asset tangibility**. The direction of the impact of the liquidation value on debt choice depends on the frictions being considered. Theoretical models motivating funding choices through asymmetric information and improved monitoring by a bank (such as Diamond, 1984, 1991; Leland and Pyle, 1977) typically arrive at the conclusion that tangible assets reduce the information asymmetry and thus benefit bond issuance (Hoshi et al., 1993). By contrast, models that are based on a more efficient liquidation (or threat of liquidation) achieved through banks arrive at the conclusion that a large share of tangible assets benefits choosing bank loans (Repullo and Suarez, 1998; Park, 2000).

Figure 1.6 plots the share of bond funding in the Euroarea and the United States according to the share of fixed assets in a firm's total assets. In both regions, the use of bond funding increases with the prevalence of fixed assets. In the United States, bonds amount to about 20% of financial funding for firms with a small fixed asset share (less than a quarter of total assets) and increases to more than 50% for firms with large fixed assets shares (two-thirds of total assets and above). In the Euroarea, the pattern is also increasing in the fixed asset share but on a smaller scale and with a lower slope (not reaching more than 20% of bond funding for firms with a large amount of fixed assets). Considering the theoretical literature, this speaks to models with a risk-reducing or adverse-selection-mitigating role of collateral. On a different note, Rauh and Sufi (2010) have associated asset tangibility with higher levels of total debt.[21]

For the modelling exercise, it is again relevant to determine whether asset tangibility is an exogenous characteristic of the firm with regard to the firm's

[21] Based on their findings, one could assume that firms with a high share of fixed assets are highly leveraged and therefore resort to bond issuance when looking for additional funding sources. I depict the distribution of tangible assets and equity funding by firm size categories in Figure A.4.8 in the appendix. For the United States, firms with a higher share of tangible assets indeed have less equity across the firm size distribution. For the Euroarea, by contrast, firms with a higher share of tangible assets even tend to have more equity. These differences speak against indebtedness being the main driver behind the higher prevalence of bond funding among firms with a large amount of tangible assets in both regions.

Figure 1.6: Bond funding share and fixed assets

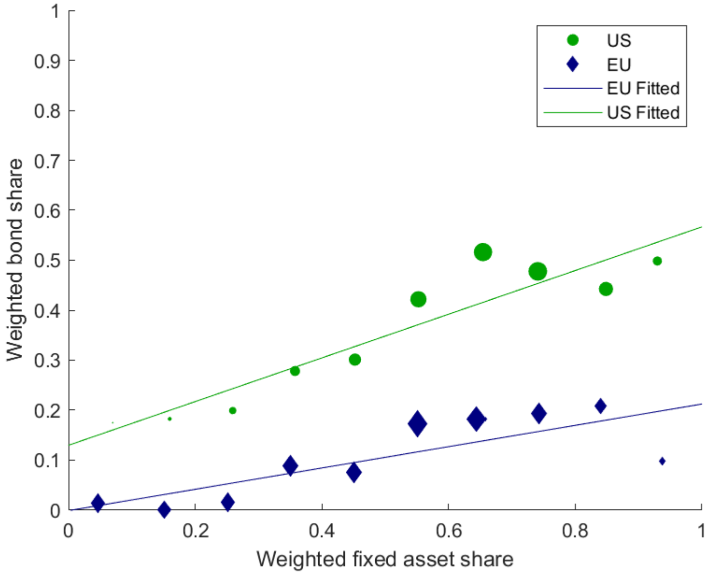


Figure 1.6 details the distribution of the bond funding share among firms of different fixed asset shares. The size of the marker depicts the relative importance of the covered firms in terms of total employees.

debt choice. In my data set, asset tangibility strongly differs according to a firm's industry (see Figure A.4.5 in the appendix). Also, firms rarely change their industry. I therefore assume that asset tangibility can be interpreted as a firm characteristic that is exogenous to the choice of debt type.

Leverage

A third characteristic that has been associated with a firm's debt choice is **leverage**. Holmstrom and Tirole (1997) highlight the monitoring capabilities of banks and argue that they are able to mitigate moral hazard. This implies that well-capitalized firms choose bonds while less capitalized firms choose loans. Since leverage directly results from the firm's funding decisions, it is endogenous to the choice of debt type.

I depict the bond funding share by leverage levels in Figure A.4.6 in the appendix. The graph does not speak to leverage being the main driver of debt choice in the sample.

Profitability

A fourth characteristic that has been suggested as a microeconomic driver of debt choice is the **profitability** of a project. In a modelling exercise for Europe, De Fiore and Uhlig (2011, 2015) argue that an entrepreneur's funding choice depends on her expectation of the project's payout. Entrepreneurs with an intermediate expectation of productivity value a bank's opinion about the project's potential, while firms with a high expectation do not rely on the bank's expertise. In conclusion, their model implies that firms with a high expected profitability choose bond funding while those with an intermediate expectation choose bank funding.

The prevalence of bond funding across firms of different profitability is depicted in Figure A.4.7 in the appendix. I measure the profitability of a firm in terms of its return on total assets (ROA), where return for comparability is measured by the earnings before interest and taxes (EBIT). Across the two regions, no clear relation between bond funding and profitability emerges.

The four aforementioned firm characteristics, firm size, liquidation value, leverage, and profitability, are not the only characteristics suggested in the literature as drivers of debt choice. Additional drivers that have been suggested include a firm's valuation (Hadlock and James, 2002), life cycle (Diamond, 1991; Hackbarth et al., 2007), credit rating (Rauh and Sufi, 2010), or shareholder concentration (Lin et al., 2013). Nonetheless, the four discussed characteristics are the most frequently suggested drivers and apply to all firms, while factors such as shareholder concentration or formal credit ratings only apply to a small subset of the firms considered in this analysis. In order for my data to have the highest possible representativeness including the coverage of small firms, I therefore focus on the four mentioned firm characteristics applying to all of them.

Ranking importance of firm characteristics

The funding decision is a complex problem that needs to be reduced to its most important considerations for the modelling exercise. I decide which factors to include in the model based on the evidence discussed in the last section and the regression analyses reported in Tables 1.1 and 1.2.

In the regression analyses, I consider a firm's size as measured by either the number of employees or total assets as well as the firm's fixed asset share, profitability and leverage. Table 1.1 considers each firm characteristic as a single driver of the bond share in a univariate regression.

The regressions suggest that firm size, either measured by total assets or by the number of employees, is an important driver of the bond share (with R^2s of 12.9 % and 6.7%, respectively). By contrast, profitability is on its own not significantly correlated with the bond share. Profitability and leverage carry R^2s of negligible size.

In addition to firm-individual characteristics the literature has stressed several institutional factors that may impact the choice of debt funding. Such institutional factors are, among others, the efficiency of bankruptcy procedures (Becker and Josephson, 2016), the power of majority shareholders (Lin et al., 2013) and the financial reporting quality (Florou and Kosi, 2015). The quality and efficiency of institutions is evaluated on a yearly basis in the World Bank's Ease of Doing Business reports. To include these considerations in the analysis, Table 1.2 depicts the results of multivariate regressions including all five firm characteristics and four indicators on the topics of: resolving insolvency, enforcing contracts, protecting minority investors and getting credit.

The first set of results in columns (1) and (2) consider the extensive margin

Table 1.1: Univariate regressions

	(1) Bond share	(2) Bond share	(3) Bond share	(4) Bond share	(5) Bond share
Size (Total assets)	0.000006***				
	(20.251374)				
Size (Employees)		0.001637***			
		(7.798685)			
Fixed assets			0.006093***		
			(89.360984)		
Profitability				0.000000	
				(1.040017)	
Leverage					$5.6 \cdot 10^{-11}$***
					(2.669920)
Observations	3'643'746	3'643'746	3'629'437	3'134'386	3'635'937
R^2	0.067372	0.129583	0.006139	0.000000	0.000000

***, **, and * represent significance at a 1, 5, and 10% level, respectively. *t*-statistics are in parentheses. Regressions include heteroscedasticity-robust standard errors. Fixed assets refers to the share of fixed assets in total assets, shown as a percentage. Total assets is measured in euro millions. Employees is measured in thousands. Profitability refers to return on equity, shown in percentage. Leverage refers to debt/equity, shown in percentage. Industry refers to the industry as the NACE Rev. 2's main section.

of the bond funding decision in the form of a logistic regression. In these regressions, the dependent variable is a dummy for issuer status. Both regressions include the aforementioned firm characteristics and financial market indicators, as well as country fixed effects (1) and additionally time (year) fixed effects (2). Regression (2) illustrates the following patterns in the probability of a firm to issue bonds (the extensive margin of bond choice): (a) The probability of a firm to issue bonds increases in the firm size. An American firm with a fixed asset share of 50% and 5'000 employees has a chance of 24.7% to be a bond issuer, which increases to 42.7% if that firm had 10'000 employees. (b) The probability of a firm to issue bonds increases in it's fixed asset share. For example, an American firm employing 5'000 employees and featuring a fixed asset share of 30% has a chance of 15.5% to be a bond issuer, which increases to 24.7% for a fixed asset share of 50%. In Europe, the pattern is similar but on a smaller level (0.3%, 0.5%). (c) The likelihood of a firm to issue bonds also increases in the ease at which an insolvency is resolved. This score reaches 75 points in the Eurozone (on average), and 91 points in the United States. A European firm with 10.000 firms has an average probability of 1.1% to be a bond issuer, which would increase to 3.5% under the American insolvency score. Columns (2) and (3) confirms similar patterns regarding the bond funding share on the intensive margin.

Table 1.2: Multivariate Regressions

	(1) P(Issuer)	(2) P(Issuer)	(3) Bond share	(4) Bond share
Firm size (employees)	0.028068***	0.028034***	0.000809***	0.000810***
	(103.915374)	(103.722122)	(627.782561)	(627.842493)
Profitability	-0.000006	-0.000006	0.000000	0.000000
	(-0.117125)	(-0.102637)	(0.406125)	(0.399055)
Fixed assets	2.813738***	2.816621***	0.001914***	0.001932***
	(52.178195)	(52.169442)	(37.750255)	(38.095475)
Leverage	-0.000003	-0.000003	-0.000000	-0.000000
	(-0.175585)	(-0.170043)	(-0.011151)	(-0.007019)
Resolving insolvency	0.045678***	0.051506***	-0.000008**	0.000039***
	(9.084163)	(9.669104)	(-2.462578)	(6.495991)
Enforcing contracts	-0.059419***	-0.033677***	0.000007	0.000020***
	(-12.396872)	(-6.541511)	(1.257678)	(2.948108)
Protecting minority investors	-0.049750***	-0.105579***	-0.000069***	-0.000126***
	(-10.999053)	(-13.916471)	(-19.224255)	(-16.562249)
Getting credit	-0.029720***	-0.022112***	-0.000001	-0.000025***
	(-6.394290)	(-4.082302)	(-0.257848)	(-3.458164)
Fixed effects	country	country, year	country	country, year
Observations	3108196	3108196	3108196	3108196
R^2			0.279293	0.279367

***, **, and * represent significance at a 1, 5, and 10% level, respectively. *t*-statistics are in parentheses. The first two regressions report the result of a logistic regression with a dummy for bond issuers as the dependent variable. Regressions (3) and (4) report OLS regressions employing the bond share as the dependent variable.
Firm characteristics are measured as before, with the exception of firm size which is measured in sqrt(employees).
All four measures of financial market quality are from the World Bank's Ease of Doing Business indicators.

Based on the distribution of bond funding across firms with different attributes and the regression analyses in Tables 1.1 and 1.2, I come to the conclusion that firm size and fixed assets (asset tangibility) are the most important drivers of debt choice, while profitability and leverage seem to be less important. Therefore, a modelling exercise should take those two factors into account. In this context, I argue that firm size and asset tangibility are characteristics that can be interpreted as being exogenous to the choice of debt type and therefore enter into a partial equilibrium model of the firm debt decision as exogenous characteristics of heterogeneous firms. Finally, the efficiency of insolvency procedures is an important institutional feature for the debt choice and should therefore be incorporated into the model as well.

1.3 Model based on Becker and Josephson (2016)

To accommodate these features, I present an adapted version of the model discussed in Becker and Josephson (2016).

1.3.1 Model description

The original version encompasses firms of different size, while this adapted version accommodates an additional sources of heterogeneity: firms that differ in their share of fixed assets. In particular, the model features a partial equilibrium of funding choice that depends on a firm's characteristics and on the characteristics of the market environment. The market environments in the Eurozone and the United States are allowed to differ in terms of restructuring efficiency and the determinants of balance sheet costs. This is in line with La Porta et al. (2000, p. 3), who describe the legal corporate governance framework as a more important driver of market developments than the "conventional distinction between bank-centered and market-centered" economic systems.

In the following, I first describe the model environment in its original form and then add the second form of heterogeneity through a variation in parameter specification[22]. The environment features a continuum of firms that differ in their project size and in the share of fixed assets involved in the project (θ). A firm demands capital K as a function of the offered interest rate $K(r) = A - Br$. If the firm were able to receive funding without interest cost, the maximum project size A would be attained. The project size decreases in the cost of capital r. The inverse capital demand function is thus $R(K) = \frac{A-K}{B}$. The firm's project is successful with a probability of $1 - q$, implying that, with a probability of q, the debt is not repaid in full.

[22]This implies that the general proofs and derivations presented in Becker and Josephson (2016) apply. I am very grateful for the additional supplementary material on their derivations provided by the authors in private communication; in particular, the case of bank seniority is based on this material.

Firm funding is provided by a mass of atomistic bond investors and n banks; both types of investors are assumed to be risk-neutral. In the main specification, both types of debt claim rank pari-passu. This is a simplification; in reality banks tend to be senior claimants (Hackbarth et al., 2007). Appendix A.5 discusses the case of bank seniority, which leads to similar conclusions about bond choice. Funding is provided by the different investors in a Cournot competition. The differing abilities of banks and bond holders to react in case of default creates the friction that differentiates bond and bank funding. In general, both out-of-court restructurings and formal in-court bankruptcy procedures are available if a firm's project is not successful. Out-of-court restructurings are more efficient than lengthy in-court bankruptcy procedures; therefore, the firm value in restructurings is given by $(1-\beta)K(r)$, while in formal bankruptcy procedures it is $(1-\beta-\sigma)K(r)$ under the assumptions that $\beta, \sigma > 0$ and $(1-\beta-\sigma) > 0$.

Out-of-court restructurings require the participants to bear a fixed cost. Therefore, atomistic bond holders never choose to engage in such out-of-court restructurings and fully rely on in-court procedures. This is mainly motivated by two factors: First, fixed costs involved with out-of-court procedures are prohibitively high compared to the small sums invested per bond holder (for the coordination problem, see Bolton and Scharfstein, 1996). Second, banks obtain additional information on the firm during the banking relationship that is valuable in out-of-court negotiations (Hotchkiss et al., 2008, p.249). For expositional simplicity, the fixed cost in the model is assumed to be zero.

The difference in the efficiency of the two resolution procedures (the welfare loss σ) depends on a firm's business model as well as on the efficiency of the local legal system. This assumption is different from that in the model presented in Becker and Josephson (2016), in which the welfare loss does not depend on firm characteristics. I assume that

$$\sigma = \alpha - \tau \cdot \theta, \tag{1.2}$$

i.e., the welfare loss decreases with the share of fixed assets owned by the firm. This is warranted since fixed assets such as real estate or materials are more easily redeployed than other assets. This mechanism is empirically supported by Gilson et al. (1990), who find that firms with many intangible assets are more likely to engage in out-of-court restructuring since bankruptcy procedures are more detrimental to their value. Using different values for the parameters τ and α, the model is able to incorporate different sensitivities associated with the differing legal systems.

The varying degrees of bankruptcy efficiency across different legal systems are evaluated in Djankov et al. (2008). The authors consider the procedures involved in representative bankruptcies and find that such procedures in common law countries such as the United States often resemble reorganizations, while in civil law countries such as Austria, Germany, or the Netherlands liquidations are more prevalent. This is in line with the more detrimental outcomes of in-court bankruptcy procedures for the recovered values of firms with many intangible assets that are more difficult to redeploy.

The large group of potential bond investors requires a return r^*. The investment is assumed to be a small part of each bond investor's portfolio and there is a sufficiently large number of investors such that there are always those willing to lend at r^*. Atomistic competition, a risk-free rate of zero, and risk-neutrality imply that $r^* = q(\beta + \sigma)/(1 - q)$. To put it differently, the inverse funding supply function of bond investors is flat (perfectly elastic) at r^*.

Banks provide intermediation by accepting deposits and providing bank loans. The banks are regulated and subject to capital requirements and induce a convex cost function:

$$C(L_i) = c\frac{L_i^2}{2}; \tag{1.3}$$

the cost of capital C increases in the total loan sum L_i provided by bank i. Supplying very large loans exposes the bank to idiosyncratic counterparty risks. Issuing smaller loans is therefore beneficial in terms of risk, as the "firm-size adjustment for small or medium-sized entities" incorporated into CRE31.9 of the Basel framework also suggests.[23]

The equilibrium in the funding market is determined under Cournot competition. As long as the market interest rate is below r^*, all n banks provide an equal share of funding to the firms and no bond funding is used. Once the market interest rate reaches r^*, bond investors provide an infinite amount of funding at this break-even rate. I denote the amount of capital demanded by firms at this rate by D. Note that, due to the welfare loss involved with in-court

[23] https://www.bis.org/basel_framework/chapter/CRE/31.htm

bankruptcy procedures, it is always rational for the banks to offer bond holders the same return they would receive under an in-court bankruptcy procedure and engage in an out-of-court restructuring. This allows banks to distribute the welfare gain of $\sigma \cdot K$ among themselves.

Two interesting equilibria, one for small and one for large firms, can be perceived under the aforementioned scenario and reasonable parameter values.[24] Which equilibrium materializes depends mainly on the firm size:

1. Large firms: both banks and bond holders provide funding. Bond holders are the marginal investors and the interest rate is r^*; the equilibrium quantity is D.

2. Smaller firms: banks can provide sufficient funding with a low cost of capital at rates below r^*. The equilibrium quantity is smaller than D. Bond holders do not lend to firms in this size category.

In the following, I first discuss scenario (1), under which both types of funding occur. From this result, I derive the cut-off firm size below which a firm solely relies on bank loans (scenario 2).

Equilibrium with bond and bank debt

In the symmetric equilibrium, n identical banks engage in lending and follow the same symmetric decision problem. The loan sum provided by all other banks is taken into account by the individual bank and is denoted by L_{-i}. The profit-maximization problem of that individual bank reads as follows:

$$U(L_i, L_{i-1}) = (1-q) * R(K) * L_i + q * [\sigma * K * \frac{L_i}{L} - (\beta + \sigma) L_i] - c\frac{L_i^2}{2}. \quad (1.4)$$

In the case of the good outcome, the loan amount L_i is fully repaid with interest. In the case of the bad outcome, banks engage in out-of-court restructuring. The return is equal to the in-court bankruptcy payout plus the welfare gain σ, which is split among the banks. Regardless of the outcome, the bank has to bear capital costs $c\frac{L_i^2}{2}$.

I first consider equilibria in which at least some bond funding is provided. In this scenario, we know that $R(K) = r^* = q(\beta+\sigma)/(1-q)$. The total funding

[24] Becker and Josephson (2016) provide detailed conditions under which these equilibria occur and also discuss corner solutions.

demanded at this rate is $D = K(r^*)$. Inserting the interest rate and simplifying leads to:

$$U(L_i, L_{-i}) = qK\sigma\frac{L_i}{L} - c\frac{L_i^2}{2}. \tag{1.5}$$

An individual bank's first-order condition in this case reads:

$$\frac{\partial U(L_i, L_{-i})}{\partial L_i} = qK\sigma\frac{L - L_i}{L^2} - cL_i = 0. \tag{1.6}$$

Inserting $L = L_i + L_{-i}$, $L_{-i} = (n-1)L_i$ and $L_i = L/n$:

$$q * \sigma * D * (n-1) - c \cdot L^2 = 0. \tag{1.7}$$

Optimal total bank loan supply follows:

$$L = \sqrt{\frac{q * \sigma * D * (n-1)}{c}}. \tag{1.8}$$

The bond share of a firm follows as:

$$\text{Bond Share(BS)} = 1 - \frac{L}{D} = 1 - \sqrt{\frac{q * (n-1) * \sigma}{D * c}}. \tag{1.9}$$

Incorporating the specification of the welfare gain (equation (1.2)):

$$\text{Bond Share(BS)} = 1 - \frac{L}{D} = 1 - \sqrt{\frac{q * (n-1) * (\alpha - \tau \cdot \theta)}{D * c}}. \tag{1.10}$$

A firm's bond share increases in firm size (D) and in the share of fixed assets owned (θ). Structurally, the bond share increases in the bank's cost of capital (c) and it decreases in the probability of bad project outcomes (q) as well as the competition in the banking sector (n).

Equilibrium with bank debt only

The definition of the cut-off below which no bond funding is provided immediately follows from the optimal bank loan supply derived above. If the optimal loan supply at the cut-off rate is at least as large as the funding demanded by the firm at this rate, bank loans will be sufficient.

$$L = \sqrt{\frac{q * (n-1) * (\alpha - \tau \cdot \theta) * D}{c}} \geq D. \tag{1.11}$$

This translates into a critical threshold at which firms begin to receive bond funding. This threshold depends on each firm's size and fixed asset situation. In this case, size relates to the total amount of funding demanded and is defined by:

$$D^{CutOff} = L^{CutOff} = \frac{q * (n-1) * (\alpha - \tau \cdot \theta)}{c}. \tag{1.12}$$

The cut-off below which a firm does not demand bond funding (i.e., the bond funding share is zero) increases with the probability of a bad project outcome (q) and with the competition in the banking sector (n). It decreases with the firm's fixed asset share (θ) as well as with the bank's cost of capital (c).

The size threshold decreases with the share of fixed assets the firm can provide:

$$\frac{\partial L^{CutOff}}{\partial \theta} = -\frac{q\tau(n-1)}{c}. \tag{1.13}$$

The economic rationale behind this decreasing cut-off is the smaller welfare losses incurred by bond holders. For firms with a larger share of fixed assets, in-court bankruptcy procedures are comparatively more efficient since the value of fixed assets tends to be more easily recovered and depends less on continued business operations than for intangible assets. For firms with many fixed assets, bond holders therefore face a more level playing field and thus a more attractive investment.

The partial equilibrium model that I present based on Becker and Josephson (2016) is able to accommodate a set of stylized facts observed in the data. First, it accommodates a mixed debt choice, which is in contrast to the model presented in De Fiore and Uhlig (2011), among others, in which firms only use a single funding source. Second, the firm characteristics that determine the cut-off for the decision to enter the bond market are fixed assets (also referred to as "asset tangibility") and firm size, not leverage (as in Repullo and Suarez, 1998 and Crouzet, 2018), risk (as in Darmouni et al., 2019), or profitability (as in De Fiore and Uhlig, 2011).

In the following section, I calibrate parameter values for the structural parameters to match the empirical observations in my data.

1.3.2 Calibration and estimation

The model calibration follows two steps. First, I set a subset of parameters to match empirical observations on firms' default risks. Second, I determine the remaining parameters by minimizing the squared deviation of the model predictions on the predicted cut-off size and the predicted bond shares (equations (1.10) and (1.12)) from their empirical counterparts.

To calibrate the probability of a negative project outcome q, the literature suggests a decrease of the probability of default with firm size (due to diversification) and different values, depending on a firm's industry (see, for example, Lopez, 2004). To match these observations, I model the default probability as $q_i(D_i, \theta_i) = q_0 + \tau_D D_i + \tau_\theta \theta_i$. To determine the values of τ_D and τ_θ, I collect information on the probability of default of 812 firms based on credit default swaps. From these spreads each firm's probability of default can be computed under the assumption of a recovery rate. In this context, I employ the indicator recovery rate from the World Bank Development Indicator database (RESLV.ISV.RCOV.RT), that estimates the recovery rate in cents on the dollar with a standardized questionnaire that ensures comparability across economies and over time. The data is available for the United States and the Euroarea member countries for the time period 2014 to 2020. Since time trends are not apparent, I use the mean of 75 Cts/$ for the Euroarea and 82 Cts/$ for the United States over the whole period. The higher recovery rate for the United States points to a higher bankruptcy efficiency.[25] Table

Table 1.3: Prob. of default

	Prob(default)
Constant	0.181***
	(9.208)
Fixed Assets θ	-0.030***
	(-2.582)
Firm Size D	-0.006***
	(-5.305)
Fixed Effects	Year
Observations	1,344
Within R^2	0.028

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[25]There is a strand of literature on the legal origins of differences in the efficiency of debt collection and associated creditor rights; for a detailed summary see (La Porta et al., 2013,

1.3 depicts the result of this regression, including time fixed effects. Based on these results, I set $\tau_D = -0.006$ and $\tau_\theta = -0.030$.

To estimate the remaining parameters, I first summarize the observed micro-level data by the yearly distribution of the bond funding share across firms of different size and fixed asset share in 9, respectively 10, categories each. This results in a data set containing average observations for firm size $D_{i,r}$, fixed share $\theta_{i,r}$ and bond funding share $BS_{i,r}$ of 90 data points per year per region, $r = US/EZ$. I define the cut-off size and cut-off fixed share via the aggregate distribution; in particular, I use a cut-off value of a bond share of 1%.[26]

I calibrate the model parameters c and τ for the Euroarea and the United States to minimize the squared deviations of the model predictions for the cut-off size and the bond share (equations (1.10) and (1.12)) from their empirical counterparts. The estimated values for the United States are $c = 0.077^{***}$, and $\tau = 0.395^{***}$; as well as $c = 0.083^{***}$, and $\tau = -0.058$ for the Euroarea. The scaling parameters are set to $n = 10$ and $\alpha = .5$ in both regions. The fitted values using the estimated parameters are depicted in Figure 1.7. The model matches the observed empirical data reasonably well considering that all parameters are time-constant. This implies that all observed time variation in the fitted values results from variation in the underlying firm distribution and the probabilities of default.

1.4 Counterfactual scenarios

I present two sets of counterfactual results. First, I compute how large the European bond share would be if all existing bond issuers were facing the same financial market conditions as in the United States (intensive margin). Formally, this result stems from the model prediction of the firm bond share presented in equation (1.10), while holding the set of bond issuers (i.e., the firm cut-off described by equation (1.12)) constant. The evolution of this counterfactual bond funding share is depicted in Figure 1.8 with the blue, dotted line: If European bond issuers were faced with the market conditions that are

p. 438).

[26]That implies that if, for a certain combination of firm size and fixed share, the aggregate bond funding share in the category is below 1%, this observation point is deemed to be below the cut-off. All data points with a larger fixed asset share or a larger firm size are deemed to be above the cut-off.

Figure 1.7: Model fit

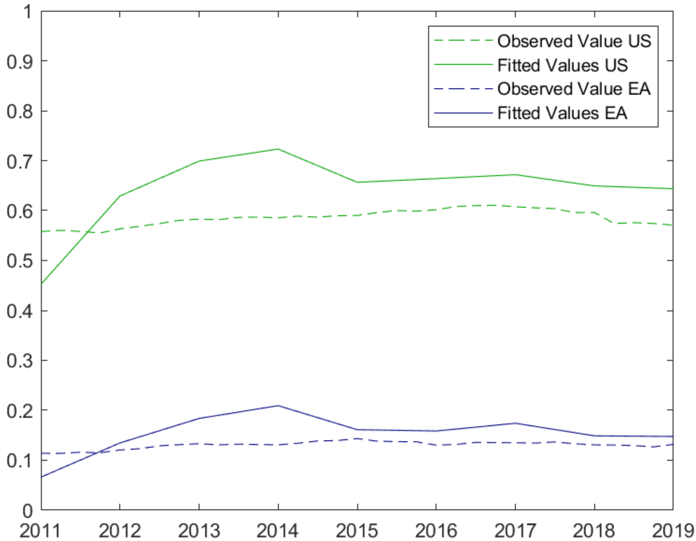
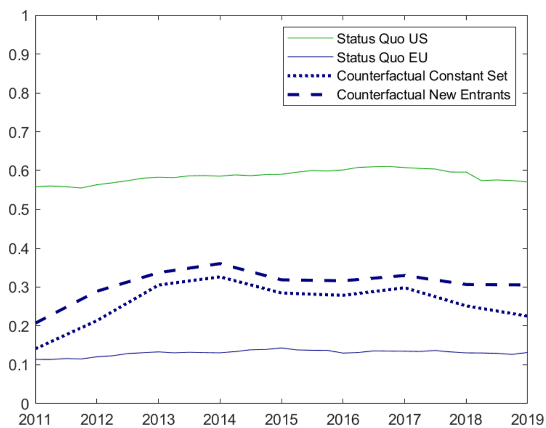


Figure 1.7 displays the model prediction for the firm funding share in each region over time. The model predicts the bond share by firm size decile and per fixed asset category. The plotted lines result from weighting each observation by the number of employees and aggregating the data per region per year.

Figure 1.8: Eurozone counterfactual scenarios



prevalent in the U.S. funding market, they would issue 10.5 percentage points more bonds than they do currently. These different funding conditions explain around a quarter of the observed difference in the bond funding share between the two regions.

In a second step, I consider the increase in the bond funding share resulting from additional firms beginning to issue bonds (extensive margin). In the framework of the model, this refers to the increase in bond funding that results from a shift in the cut-off level. The resulting aggregate bond share is depicted with a blue, dashed line in Figure 1.8. I observe that the changes in the extensive margin only lead to a smaller increase in the aggregate bond funding share of, on average, less than 5 percentage points. This implies that, in the counterfactual scenario of European firms facing the market conditions of their American counterparts, only a small number of nonissuers would begin to issue bonds.

The counterfactual scenario leaves a difference of 32.6 percentage points in bond funding shares between the observed firms in the United States and the Eurozone that is attributed to fundamental differences.[27] This implies, that more than two-thirds of the observed funding difference (of the average bond share across time, which is 58.4% in the United States and 13.1% in the Eurozone, resulting in an average difference of 45.3%) can be attributed to different firm characteristics, while the remaining one-third is associated with different market conditions. This finding underlines the importance of small firms in the Euroarea, as depicted in the census firm size distribution in Figure (1.5). This implies that, even if the European financial landscape were reshaped to resemble the United States', the level of bond funding would still be significantly smaller.

In recent years, the Euro area implemented several policies to facilitate market access, such as the Prospectus Directive and subsequent Prospectus Regulation that standardizes issuance prospectuses. New SME bond market segments were opened, such as the "Mittelstandsanleihen" in Germany and the "ExtraMOT PRO" for Italian minibonds. Although these new measures have been well received (Eisele and Nowak, 2018), the aggregate funding situation

[27] The average bond share in the United States over the time period 2011 to 2019 is 58.4%, while the average share for the Eurozone counterfactual analysis (intensive + extensive margin) is 25.8%.

did not change significantly (see Fig. 1.4). My results underline why the potential for such policies to impact the aggregate market structure is limited.

1.5 Conclusion

The reliance of European firms on bank funding has been described as excessive in comparison to their American counterparts. I provide the first counterfactual analysis of how the European market would be shaped if its financial structure resembled the United States. I find that the funding differences can be largely explained by different types of firms operating in the two areas: (i) European firms tend to be smaller, on average, than their U.S. counterparts, and small firms tend to rely more on bank funding. (ii) The size cut-off at which firms begin to consider bond funding is considerably higher in the United States, and (iii), European firms with large fixed asset shares tend to rely more on bank debt than U.S. firms with comparable fixed asset shares. These differences imply that two-thirds of the observed funding difference can be attributed to different firm characteristics, while the remaining one-third is related to different financial market conditions.

A prevalence of bank funding has been shown to increase systemic risk and has therefore been referred to as a bank bias. This bank bias can be observed in both regions, while it has been found to lead to a more substantial increase in systemic risk in the Euro area. The European Union's Capital Markets Union project aims to promote more efficient funding choices by firms to improve the integration and resilience of financial markets. My results highlight that policies focusing on the negative implications of the prevalence of bank funding should not only focus on fostering debt market access for small firms but should also disincentivize banks' amplifying behavior since a pronounced reliance on bank debt seems to be unavoidable in the light of the current European firm distribution.

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Appendix

A.1 Data cleaning

1. Dropping data points that either point to incomplete data or inactive firms:
   - All data points with unknown or negative equity (field 'Shareholders Funds').
   - All data points with unknown or zero operating revenue (field 'Operating Revenue / Turnover').
2. Dropping data points with observations in unreasonable size relations:
   - All data points reporting a fixed asset share of below zero or above one.
   - All data points reporting a bond funding share of below zero or above one.
   - All data points reporting revenues of more than 500 million and less than 5 employees.
3. Ensuring coverage of only domestic non-financial corporates by cleaning the following observations from the dataset:
   - All firms with Entity type = 'Financial company'.
   - All firms with Entity type = 'Insurance company'.
   - All firms with unknown NACE (Rev.2) main section.
   - All firms with NACE (Rev.2) core code starting with 64.
   - All firms with NACE (Rev.2) main section = 'U - Activities of extraterritorial organisations and bodies'.
   - All firms with NACE (Rev.2) main section = 'T - Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use'.

A.2 Summary statistics

Table A.2.1: Summary Statistics by Listing Status and Legal Type

			Listing Status		Standardized Legal Form			
		Total	Listed	Listed Share	Private lim. companies	Public lim. companies	Partnerships	Other
Full Sample	AT	41069	63	0.15%	98.01%	1.17%	0.33%	0.49%
	BE	64858	102	0.16%	53.23%	33.74%	3.36%	9.67%
	DE	242772	627	0.26%	96.28%	1.75%	1.15%	0.82%
	FR	734663	617	0.08%	88.34%	10.49%	0.85%	0.32%
	FI	136199	152	0.11%	98.41%	0.17%	1.21%	0.22%
	NL	15792	112	0.71%	86.05%	2.86%	2.87%	8.23%
Bond Issuers	AT	95	30	31.58%	38.95%	61.05%	0.00%	0.00%
	BE	74	35	47.30%	1.35%	78.38%	0.00%	20.27%
	DE	360	155	43.06%	33.06%	65.28%	1.39%	0.28%
	FR	237	142	59.92%	13.92%	85.23%	0.84%	0.00%
	FI	63	37	58.73%	23.81%	74.60%	1.59%	0.00%
	NL	56	27	48.21%	26.79%	69.64%	1.79%	1.79%
	US	1511	960	63.53%	28.26%	63.27%	1.46%	7.02%

Table A.2.2: Summary Statistics by Country

Country	Statistic	Full Sample		Bond Issuers	
		Mean	Standard deviation	Mean	Standard deviation
Austria	Domestic Employment	94.6	1,013.7	3,439.3	6,546.3
	Domestic Revenue	5,767.0	44,189.9	53,123.6	126,568.7
	Total Assets	39,140.3	555,990.0	2,611,075.5	5,122,009.9
	Outside Funding	16,660.6	265,687.2	1,052,683.0	1,706,541.4
Belgium	Domestic Employment	79.1	1,622.8	5,593.3	21,871.3
	Domestic Revenue	1,216.2	62,262.2	185,144.6	1,275,339.1
	Total Assets	39,493.9	1,037,018.1	5,454,930.3	19,767,302.9
	Outside Funding	15,598.7	506,996.1	2,446,706.0	10,009,477.3
Germany	Domestic Employment	206.9	2,497.9	10,234.0	26,327.1
	Domestic Revenue	7,641.2	87,099.2	183,108.6	562,585.6
	Total Assets	74,215.8	2,225,597.7	10,206,503.2	34,455,576.6
	Outside Funding	25,929.9	920,959.8	3,944,565.7	14,356,861.5
Finland	Domestic Employment	26.1	409.5	3,776.4	8,438.5
	Domestic Revenue	367.9	9,137.7	67,833.6	176,115.0
	Total Assets	7,887.9	218,773.2	3,178,303.1	5,904,648.0
	Outside Funding	2,499.7	71,911.5	1,142,966.6	1,883,141.5
France	Domestic Employment	40.4	1,469.7	16,245.5	44,795.0
	Domestic Revenue	482.7	23,616.0	262,228.6	766,962.7
	Total Assets	16,630.6	1,023,999.6	12,909,037.5	34,521,407.7
	Outside Funding	6,789.0	570,351.8	5,796,161.0	19,739,446.8
Netherlands	Domestic Employment	536.8	4,454.7	17,052.7	41,311.1
	Domestic Revenue	14,622.3	135,127.7	373,456.4	819,114.8
	Total Assets	330,614.5	2,813,911.9	14,190,151.0	22,349,638.5
	Outside Funding	139,649.8	1,285,133.4	6,014,715.1	9,601,494.9
United States	Domestic Employment	not considered		16,466.5	61,071.8
	Domestic Revenue	not considered		570,827.9	1,719,824.2
	Total Assets	not considered		11,168,410.5	28,908,812.7
	Outside Funding	not considered		4,160,843.7	11,475,106.5

A.3 Firm coverage

Figure A.3.1: Coverage: Total Revenue of Nonfinancial Corporates

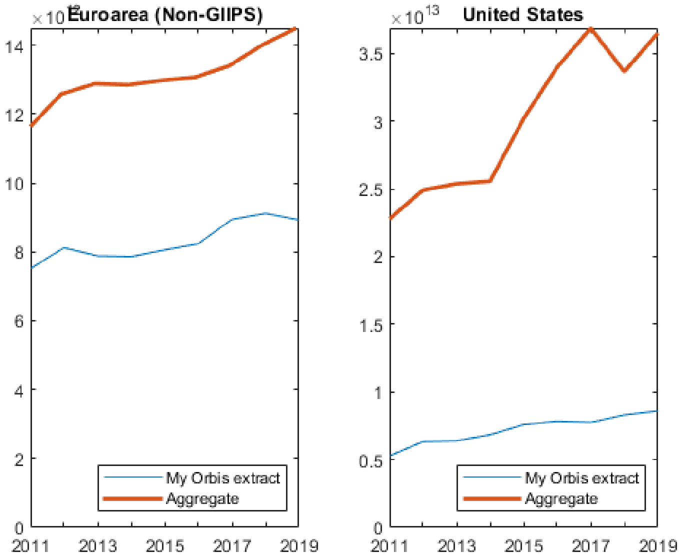


Fig. A.3.1 compares the aggregate total revenue of nonfinancial firms to the total revenue across the micro-level data employed in this paper for the two regions: the Euroarea and the United States. The aggregate data for the Euroarea refers to the time series 'Turnover or gross premiums written' from the 'Annual enterprise statistics for special aggregates of activities (NACE Rev. 2)' for the total business economy except financial and insurance activities. The aggregate data for the U.S. depicts the time series 'Nonfinancial Corporate Business; Revenue from Sales of Goods and Services, Excluding Indirect Sales Taxes' (labeled BOGZ1FA106030005Q in the FRED database). Unfortunately, the consistency of this time series has been questioned, because "This series is identical to the gross value added for the non-financial corporate sector reported in NIPA table 1.14 (FRED series A455RC1Q027SBEA), indicating that the Flow of Funds series likely measures value added, not gross revenue, despite its name (Crouzet and Eberly, 2021, p.A59, footnote 37).

Figure A.3.2: Coverage: Total Employment of Nonfinancial Corporates

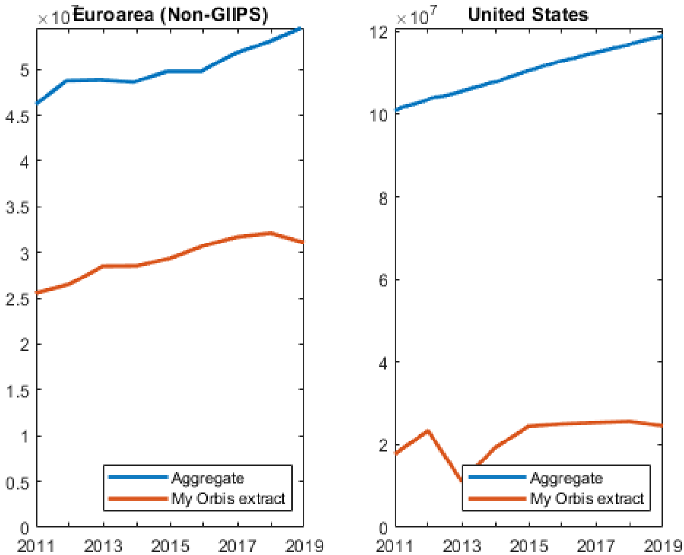


Fig. A.3.2 compares the aggregate total employment of nonfinancial firms to the total employment across the micro-level data employed in this paper for the two regions: the Euroarea and the United States. The aggregate data for the Euroarea countries refers to the time series 'Employees - number' from the 'Annual enterprise statistics for special aggregates of activities (NACE Rev. 2)' for the total business economy except financial and insurance activities. The data for the United States stems from the Bureau of Labor Statistics and were retrieved from FRED. The times series is calculated as the difference of the series 'All Employees, Total Private [USPRIV]' and the series 'All Employees, Financial Activities [USFIRE]'. If on the micro-level data corporate groups report worldwide employment, this is broken down to the domestic level by the share of local revenue in worldwide revenue.

Figure A.3.3: Coverage: Domestic Aggregate Operating Surplus

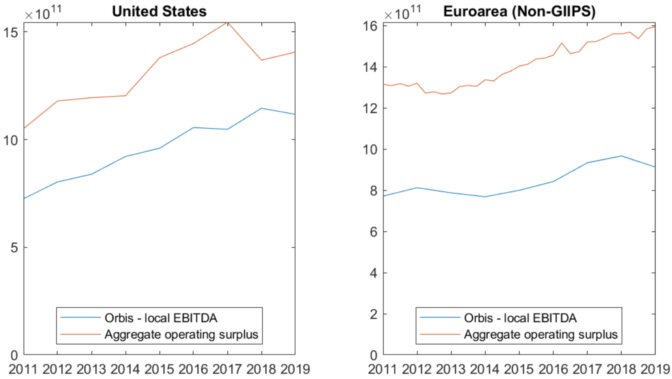


Fig. A.3.3 compares the aggregate total operating surplus of nonfinancial firms to the total operating profit across the micro-level data employed in this paper for the two regions: the Euroarea and the United States. The aggregate data for the Euroarea countries refers to the time series 'Gross operating surplus and mixed income of Non financial corporations' from the ECB's Statistical Data Warehouse. The data for the United States were retrieved from FRED (time series NCBOSNA027N). If on the micro-level data corporate groups report worldwide operating profit, this is broken down to the domestic level by the share of local revenue in worldwide revenue. If gross operating profit is not reported by a firm, the measure EBITDA or EBIT are used instead, which are smaller measures.

A.4 Information on the distribution of bond funding in the economy

Figure A.4.4: Bond funding share asset share across industries

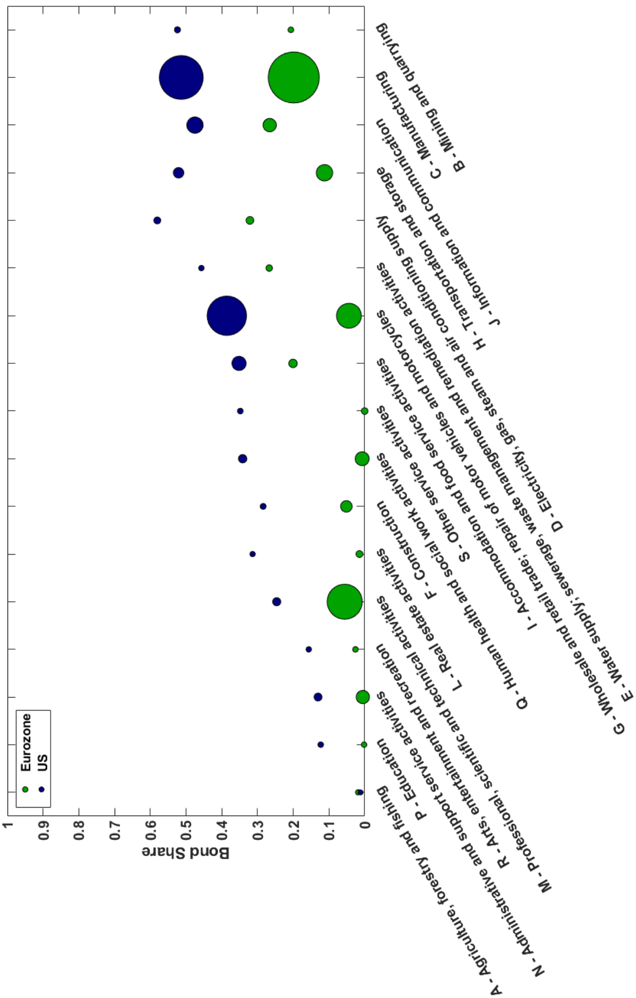


Figure A.4.5: Fixed asset share asset share across industries

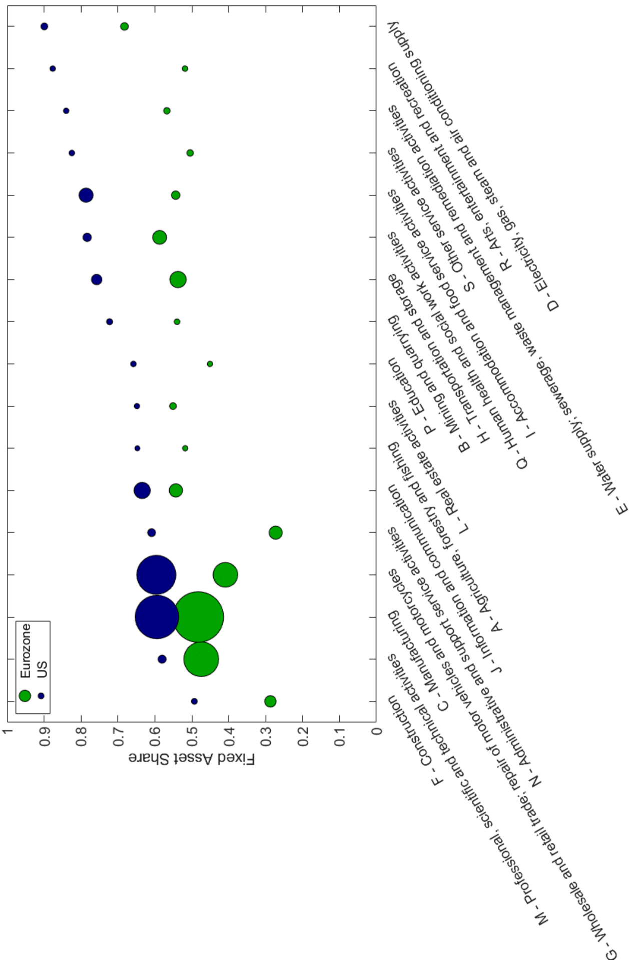


Figure A.4.6: Bond funding sharing and leverage

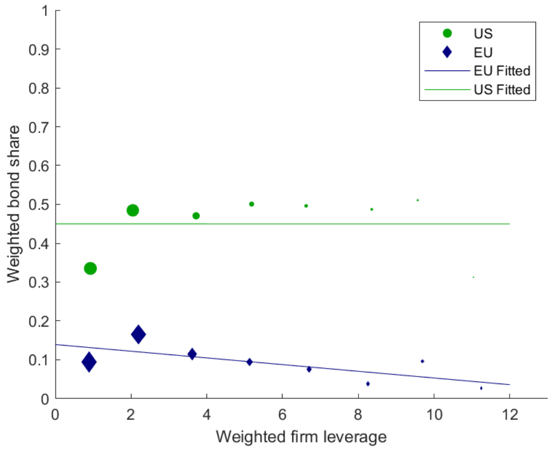


Figure A.4.7: Bond funding sharing and profitability

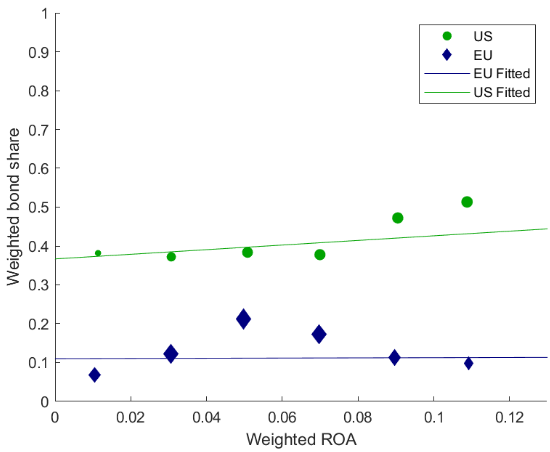


Figure A.4.8: Leverage by Fixed Assets and Firm Size

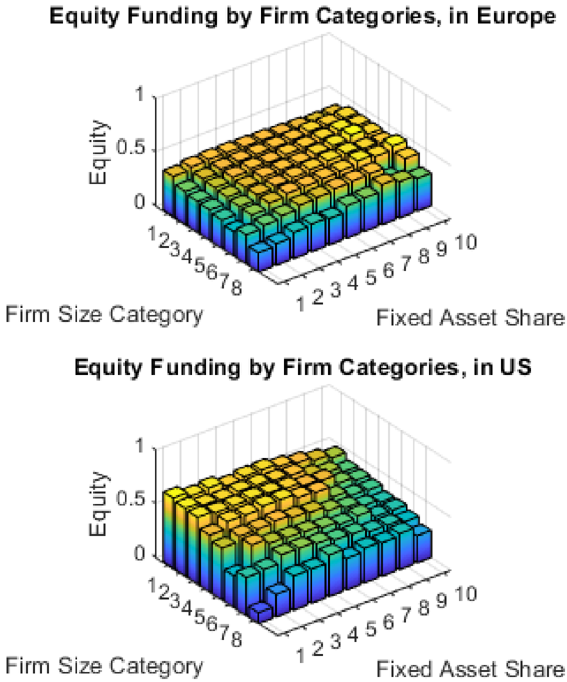


Fig. A.4.8 depicts the distribution of leverage among firms of different sizes and fixed asset shares. The firm size categories translate into the number of employees as follows: (1) - less than 100, (2) from 100 to 249, (3) from 250 to 499, (4) from 500 to 999, (5) from 1000 to 4999, (6) from 5000 to 9999, (7) from 10000 to 49999, (8) at least 50000. The fixed asset share refers to the fixed asset categories as defined per the deciles of the distribution.

A.5 Model with bank seniority

In the main specification, the model assumes that debtor claims rank pari-passu, implying that bond and bank holders claims are of equal seniority in the case of default. This simplifies the model exposition but is not in line with observations in reality, since firms typically give seniority to bank claims. This version with bank seniority as the main specification is nearly identical to the variants presented in Becker and Josephson (2016) with a parameter specification adjustment in terms of the welfare loss of the in-court bankruptcy procedures that accommodates the application to this paper[28].

The model set-up and variables are identical to the base specification, the role of bank seniority becomes relevant only in the case of the bad project outcome, occurring with a probability q. In that case, banks' claims are paid out first. If the remaining project value is too low to pay all debtors, bond holders take the first losses. As in the base case, out-of-court restructurings are more efficient than lengthy in-court bankruptcy procedures, therefore the firm value in restructurings is given by $(1-\beta)K(r)$, while in formal bankruptcy procedures it is $(1-\beta-\sigma)K(r)$ under the assumptions that $\beta, \sigma > 0$ and $(1-\beta-\sigma) > 0$. In a minor adaption of the model presented in Becker and Josephson (2016), I assume that $\sigma = \alpha - \tau \cdot \theta$, i.e. that the welfare loss decreases in the share of fixed assets owned by the firm. Under the assumption that participation in out-of-court restructuring only involves a small cost it is always rational for banks to engage in it. Banks are then able to offer bond holders a return that is equal their in-court bankruptcy payout and earn the welfare gain σ.

Which equilibrium materializes depends on the parameter specification, in particular on the remaining firm value in bankruptcy. In the following, I assume that the firm value under the bad project outcome (BO) and formal in-court bankruptcy procedures is sufficiently large to fully repay the senior claimants (the banks) but not necessarily the subordinate claimants (the bondholders). Denoting the firm value under that case as $K_{BO} = (1-\beta-\sigma)D$, implies that

$$K_{BO} > L(1+r). \tag{1.14}$$

[28] I am very thankful for receiving additional supplementary material on the bank seniority case from Jens Josephson in private communication.

The bond holders receive the remaining value of $K_{BO} - L(1 + r)$.

To derive the implications for the bond funding share I am interested in the case in which both types of funding are used. Participation of the subordinate bond holders occurs once they break even on the investment under the following condition:

$$(1 - q) * (D - L) * (1 + r^{BE}) - q * [K_{BO} - L(1 + r^{BE})] = 0 \tag{1.15}$$

Inserting K_{BO} and solving for r^{BE} leads to:

$$r^{BE} = \frac{q(\beta + \sigma)}{(1 - q - L/D)} \tag{1.16}$$

The profit-maximization problem of an individual bank reads as follows:

$$\begin{aligned} U(L_i, L_{i-1}) =&(1 - q) * r^{BE} L_i + q * [D(1 - \beta) - (K_{BO} - L(1 + r^{BE}))]\frac{L_i}{L} - qL_i - c\frac{L_i^2}{2} \\ =&r^{BE} L_i + q\sigma D\frac{L_i}{L} - c\frac{L_i^2}{2} \end{aligned} \tag{1.17}$$

In the case of the good outcome, the loan amount L_i is fully repaid with interest. In case of the bad outcome banks jointly engage in out-of-court restructuring to recoup a value of $D*(1-\beta)$ after paying bond holders their in-court bankruptcy payout $(K_{BO} - L(1 + r^{BE}))$. The individual bank receives its pro-rata share of the difference. Regardless of the outcome, each bank has to bear capital costs $c\frac{L_i^2}{2}$.

The first order condition is:

$$\begin{aligned} \frac{\partial}{\partial L_i} =&r^{BE} + q\sigma D\frac{L - L_i}{L^2} - cL_i = 0 \\ =&r^{BE} + q\sigma D\frac{(n-1)}{n^2 L_i} - cL_i = 0 \end{aligned} \tag{1.18}$$

Solving for L_i leads to the optimal loan provision for each symmetric bank:

$$\begin{aligned} r^{BE} + q\sigma D\frac{(n-1)}{n^2 L_i} - cL_i &= 0 \\ L_i^2 - L_i\frac{r^{BE}}{c} - q\sigma D\frac{(n-1)}{cn^2} &= 0 \\ L_i^* = \frac{r^{BE}}{2c} + \sqrt{(\frac{r^{BE}}{2c})^2 + q\sigma D\frac{(n-1)}{cn^2}} \end{aligned} \tag{1.19}$$

inserting $\sigma = \alpha - \tau \cdot \theta$:

$$L_i^* = \frac{r^{BE}}{2c} + \sqrt{(\frac{r^{BE}}{2c})^2 + q(\alpha - \tau \cdot \theta)D\frac{(n-1)}{cn^2}} \tag{1.20}$$

This leads to a firm bond share of:

$$BS = 1 - \frac{n * L_i^*}{D} = 1 - \frac{r^{BE}n}{2cD} - \sqrt{(\frac{r^{BE}}{2c})^2\frac{n^2}{D^2} + q(\alpha - \tau \cdot \theta)\frac{(n-1)}{cDn}} \tag{1.21}$$

For reasonable parameter values a firm's bond share under bank seniority behaves similar to the base case with equal seniority. The bond share also increases in firm size (D) and in the share of fixed assets owned (θ). Structurally, the bond share increases in bank's cost of capital (c) and it decreases in the probability of bad project outcomes (q), as in the baseline.

Chapter 2

Monetary policy disconnect

Benedikt Ballensiefen, Angelo Ranaldo and Hannah Winterberg[1]

Although designed to support monetary policy, two crucial aspects of the central bank framework can disconnect the monetary policy transmission: banks' access to central bank deposits and Quantitative Easing (QE). We show how both hinder the transmission through the main short-term funding market, the repurchase agreement (repo) market. First, lending rates of banks with access to the deposit facility are less responsive to the monetary policy rate. Second, repo rates secured by assets eligible for QE are more disconnected from the policy rate. Both effects create rate dispersion and add to one another in weakening the monetary policy transmission.

JEL classification: E40, E43, E50, E52, E58, G18.

[1]We thank Farshid Abdi, Andrea Barbon, Roman Baumann, Alexander Bechtel, Patrick Bolton, Martin Brown, Pierre Collin-Dufresne (discussant), Stefano Corradin, Cody Couture (discussant), Florian Heider, Marie Hoerova, Sebnem Kalemli-Özcan, Christian Keuschnigg, Oliver Krek (discussant), Thomas Nellen, Patrick Schaffner, and Kerstin Westergren (discussant) and conference participants at the American Economic Association virtual annual meeting (2021), the Young Swiss Economist virtual meeting (2021), the ECB-RFS Macro-Finance virtual conference (2021), the Eastern Finance Association virtual annual meeting (2021), the virtual SFI Research Days (2021), the virtual annual congress of the Swiss Society of Economics and Statistics (2021), the virtual World Finance Conference (2021), the 52nd virtual annual conference of the Money, Macro and Finance Society (2021) and the SNB Research Conference (2021) as well as seminar participants at the University of St.Gallen (2020), the Goethe University Frankfurt (2020), the Norges Bank (2021) and the Swiss National Bank (2021) for their valuable comments and suggestions. This work is supported by the Swiss National Science Foundation [grant number P1SGP1_188111].

> “...there is a risk that, under the current framework, some short-term market rates would **not respond fully** to changes in our key interest rates or, even if they would, that a continued dispersion of short-term rates would **adversely impact** the transmission of our monetary policy stance."
>
> —*Benoît Cœuré in May 2018*

An important question at the center of the political and academic debate is what makes the transmission of monetary policy effective. To answer this question, we need to consider the money market which “plays a crucial part in the transmission of monetary policy decisions" as “changes in the monetary policy instruments affect the money market first" (European Central Bank, 2011). In outlining its monetary policy framework, the European Central Bank (ECB) also emphasizes that “a deep and integrated money market is a precondition for an efficient monetary policy, since it ensures an even distribution of central bank liquidity and a homogeneous level of short-term interest rates." However, institutional and political features of the central bank framework can generate dispersed money market rates raising the risk of central banks losing control over short-term interest rates (Cœuré, 2019).

This paper is the first empirical study showing that two key aspects of the central bank framework that were designed to support the monetary policy transmission can actually *disconnect* it. To do this, we analyze how two elements of the monetary policy framework affect the main short-term funding market, the repurchase agreement (repo) market. The first hurdle for the monetary policy transmission stems from the access to the central bank's refinancing operations and its deposit facility. We demonstrate that the lending rates of banks with access to the central bank's facilities are less responsive to the monetary policy target rate, especially when money market rates are below the central bank's deposit rate discouraging interbank lending. The second hurdle emanates from unconventional measures such as Quantitative Easing (QE) targeting the purchase of only certain assets and creating their scarcity. We show that short-term rates secured by assets eligible for QE programs diverge more from the monetary policy rate. Both effects lead to rate dispersion and add to one another, suggesting a joint impact in weakening the monetary policy transmission.

The way the central bank's institutional setting is conceived and policies are implemented determines the effectiveness of the monetary policy transmission and thus establishes the rationale for our analysis. Their effects should arise in the part of the financial system through which monetary policy is channeled in the first place, i.e., the money market. A consistent and uniform response of money market rates to the monetary policy stance is the first sign of an effective pass-through mechanism. By contrast, a *"wider dispersion in short-term money market rates"* could cause *"a reduction in the efficacy and transmission of monetary policy"* (Bank for International Settlements, 2017, p.32). The ideal laboratory to examine this idea is the ECB and the repo market for at least three reasons: First, with its sheer size of more than EUR 7.5 trillion in outstanding contracts (International Capital Market Association, 2019), the European repo market is the largest repo market worldwide and dominates the unsecured market, it therefore represents the main channel for the monetary policy transmission.[2] Second, we compute a dispersion indicator in repo rates based on Duffie and Krishnamurthy (2016) and show that various interest rates relevant for the real economy (e.g., corporate borrowing and housing rates) respond less to changes in monetary policy when the dispersion of money market rates is wider. All this provides suggestive evidence of the crucial role of the repo market for the monetary policy transmission and that dispersed money market rates hinder it. Third, the infrastructure of the European repo market features central clearing and anonymous centralized order book platforms, which ensures homogeneous counterparty risk and collateral policy, no bargaining issues, and an efficient price formation process.

Understanding whether and how the institutional design and policy framework impact the monetary policy transmission through the main short-term funding market is relevant for central banks and market participants. First, unresponsive short-term rates limit the central bank's ability to fulfill its mandate (European Central Bank, 2011). Second, since the Global Financial Crisis of 2007/2008, the repo market has emerged as the predominant source of funding liquidity. Thus, the repo market is key for an efficient allocation of money

[2] The euro repo market is now 20 times bigger than the unsecured segment (European Central Bank, 2018).

and assets. Third, the repo rate acts as a benchmark in financial markets. To study the monetary policy pass-through, we analyze a unique and highly representative data set for the entire Euro repo market including all repos exchanged on the three major trading platforms (BrokerTec, Eurex, and MTS) from the beginning of 2010 to the end of 2018. In this setting, a large variety of sovereign debt securities are eligible as collateral. The asset being used as collateral can either be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral or GC repo"). While the GC repo is mainly funding-driven, special repos are often collateral-driven. To achieve a comprehensive result, we study how both markets influence the transmission of monetary policy.

The first key aspect of the institutional framework we investigate is that only a given set of banks have exclusive access to the ECB refinancing operations and its deposit facility. We expand the theoretical framework proposed in Duffie (1996) to outline two separate demand curves for investing liquidity (lending) in the *GC market*, one for access and one for nonaccess banks. In the wake of a negative supply shock (i.e., fewer banks need to borrow liquidity), the GC rate decreases and it can fall below the deposit facility rate. Rather than encouraging interbank lending, this creates an incentive to deposit liquidity at the central bank for banks that have the opportunity to do so. The demand of nonaccess banks for investing liquidity instead remains inelastic and at lending rates closer to the monetary policy rate.[3] As a consequence, the dispersion of repo rates increases as access banks lend less and at higher rates compared to nonaccess banks. Hence, our first testing hypothesis for the monetary policy disconnect is that banks with (without) access to the ECB deposit facility lend at repo rates less (more) aligned to the monetary policy target rate.

The second key aspect of the policy framework is represented by the eligibility criteria of the QE program. We model this mechanism with two distinct demand curves in the *special* market, one for eligible assets and one for noneligible assets.[4] Assets being targeted by QE programs are scarcer, thus leading

[3]As discussed in more detail later, the literature provides various reasons for an inelastic demand including the benefits from obtaining collateral and safe assets as well as regulatory issues.

[4]One may argue that the special market is less relevant for funding than the GC market. However, special trades are the predominant type of repos and they also involve a funding motive on the part of the borrower. Thus, even if less funding-oriented, special repo rates are still sensitive towards funding conditions.

to a higher demand (positive demand shock) for those assets in the repo market. The overall effect is that repo rates for eligible assets fall below those for noneligible assets (Arrata et al., 2020; Corradin and Maddaloni, 2020). As a consequence, the specialness premium of eligible assets increases and the repo rates secured by eligible assets become predominantly driven by collateral demand disconnecting them from the policy rate. This wedge between eligible and noneligible assets is an unintended consequence of QE. Our second testing hypothesis is therefore that rates of repos whose collateral asset is (not) eligible for QE programs are less (more) responsive to the monetary policy rate.

For the empirical analysis, we proceed in three steps. First, we perform a comprehensive panel regression analysis to test our first hypothesis. As a first step, we identify which banks benefit from access to the deposit facility and at which rate they lend in the interbank market. We observe that the share of access banks' lending in the GC market decreased when GC rates fell below the rate on the deposit facility, during those periods, access banks tend to lend at higher rates than nonaccess banks. Then, we regress (changes in) *GC* repo rates on (changes in) the monetary policy rate to determine systematic differences between access and nonaccess banks. We clearly find that access banks lend at rates less aligned to the policy rate when the repo rate is lower than the deposit rate corroborating the monetary policy disconnect featured by those banks. In addition to the statistical significance, our findings appear economically relevant. For instance, a more accommodative monetary policy that results in a decrease in the target rate by one percentage point translates into a decrease in GC rates involving access banks of 45 basis points. For banks without access, the decrease is 72 basis points. Once GC rates are below the rate on the deposit facility, the effect magnifies as the rates of nonaccess banks decrease by 94 basis points (pointing to an almost one-to-one pass-through) while the rates of access banks only decrease by 4 basis points.

Second, we carry out a set of panel analyses to test our second hypothesis. We identify which specific collateral asset is eligible for QE and at which interbank rate it is traded. The trading volume in the special market has increased since the start of QE, predominantly driven by transactions collateralized with assets eligible for central bank purchases. Repos secured by eligible assets tend to trade at lower rates compared to noneligible assets. We then regress (changes in) *special* repo rates on (changes in) the monetary policy rate. Our results clearly show that repo rates secured by eligible assets diverge more from the policy rate validating the monetary policy disconnect induced by QE asset purchases. We also apply the initial implementation provisions retrospectively to compare time trends between (hypothetically) eligible and noneligible assets, which creates a difference-in-difference estimation setting. We find that in the period after the introduction of QE, a loose monetary policy with a decrease of the target rate by one percentage point is associated with a 50% lower sensitivity of eligible assets relative to the overall sensitivity of special repo rates to changes in funding conditions. We observe a similar behavior of (hypothetically) eligible and noneligible assets in the periods prior to QE and diverging patterns during QE, suggesting a causal impact of central bank asset purchases on the monetary policy disconnect. To augment our idea of a positive demand shock for eligible assets, we show that their sensitivity to the monetary policy rate decreases with the time an asset is eligible for QE purchases.

Third, we conclude our work by considering the combined effects of QE and accessibility to central bank's facilities on repo rates. We find that when the share of securities eligible for QE programs in a GC basket is large, then the GC rate is less reactive to the monetary policy target rate after controlling for the effect of bank's access to the deposit facility. Similarly, when the 'cheapest-to-deliver' collateral asset in a basket is eligible for QE, then the GC rate of that basket reacts less. In the special market, repo rates of access banks are less responsive to the monetary policy rate even after accounting for asset eligibility for QE programs. One interpretation of these findings is that asset scarcity associated with QE purchases together with the incentive to hold reserves on the central bank's deposit facility (rather than e.g., interbank lending) jointly weigh on monetary policy pass-through efficiency.

We perform a number of additional analyses ensuring the comprehensiveness and robustness of our results. These analyses can be summarized in four categories: (1) We conduct our analyses for different groups of countries including (i) Germany, (ii) core European countries, and (iii) all European countries and (2) different term types; (3) we replicate our panel regression analyses by considering all conceivable combinations of standard error and fixed effect specifications; (4) and regarding the policy rate that the ECB could possibly target, we experiment with all secured and unsecured overnight interest rates as well as derivatives-based, forward-looking overnight interest rates.[5] In all specifications, the results remain statistically and economically consistent indicating their general validity and dispelling any doubts that they depend on a specific way to measure the monetary policy stance.

Notice that our setting allows us to take advantage of the legal and technical rules that the Eurosystem imposes to avoid any endogeneity concerns related to reverse causality. In particular, the set of nonaccess banks is constant over our sample period, whether a bank is legally formed in- or outside of the euro area is unrelated to monetary policy and the repo market, and thus a source of exogenous variation. Moreover, both groups feature similar balance sheet characteristics. Similarly, the implementation provisions for asset purchases are a source of exogenous variation as to which securities meet the respective criteria.

Our analysis mainly contributes to two strands of the literature. First, we add to the literature on the effectiveness of monetary policy. Focusing on the introduction of the reverse repurchase facility and new Basel regulation, Duffie and Krishnamurthy (2016) analyze the pass-through of monetary policy in the United States. Drechsler et al. (2017) show that the pass-through of the interest rate on excess reserves to the interest paid on saving accounts is imperfect due to market power in deposit markets.[6] This is the first paper showing and quantifying how the transmission of monetary policy into the secured short-term funding market is impeded by two key features of the policy framework, i.e., QE and accessibility to central bank's facilities.

Second, we contribute to the literature on short-term funding markets. Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) investigate the effects of QE purchases on the level of special repo rates. Other papers analyze the unsecured money market; for instance,

[5] In addition to the EONIA rate as the key ECB target rate (European Central Bank, 2011), we analyze all measures commonly used in event studies based on high-frequency monetary policy, for example, Altavilla, Brugnolini, Gürkaynak, Motto, and Ragusa (2019) and Leombroni, Vedolin, Venter, and Whelan (2021).

[6] On a macro-wide level, Avouyi-Dovi et al. (2017) find a slowdown of the overall interest rates transmission mechanism, which Al-Eyd and Berkmen (2013) have associated with segmentation along country lines. By analyzing the cointegration between policy rates and banks' weighted cost of capital, Illes et al. (2019) find that the sensitivity of banks' average funding costs to policy rates has declined in recent years. Kalemli-Özcan (2019) analyzes the pass-through in the context of emerging markets. For a detailed literature review on interest rate pass-through, see Andries and Billon (2016) and Horvath et al. (2018).

Kraenzlin and Nellen (2015) examine market segmentation coming from different access levels to the facilities of the Swiss National Bank and Bech and Klee (2011) evaluate the impact of bargaining power in a segmented and unsecured market in the U.S. The novelty in our analysis is threefold: First, it is the first study on the reactiveness of money market rates to monetary policy depending on who lends (access versus nonaccess banks) and which assets secure the loan (eligible or not for QE purchases). Second, extending Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020), we study the QE impact on GC rates (in addition to special repos) and how this depends on whether a bank has access to the central bank's facilities. Third, we show how the two above-mentioned features of the monetary framework create dispersion and adverse effects on repo rates.[7]

2.1 Monetary policy

It is worthwhile to start our work by describing the main aspects of the monetary policy transmission in the context of the ECB framework. The three components that deserve special attention are (i) the operational target to implement it, (ii) the transmission through interest rates, and (iii) its ultimate goal.

2.1.1 Operational framework

Regarding the first component, the short-term interest rate benchmark (EONIA) is considered "the key ECB interest rate" in its operational framework (European Central Bank, 2011). We focus on the EONIA rate as the monetary policy target rate for three reasons. First, it is usually referred to as the operational target by the ECB (Cœuré, 2018) and its comovement with other interest rates has been shown in, for example, Hristov et al. (2014) and Altavilla et al. (2020). Second, the EONIA is a standard choice on interest rate pass-through in the literature (see, e.g., Hristov, Hülsewig, and Wollmershäuser, 2014, Altavilla, Canova, and Ciccarelli, 2020, as well as Ciccarelli, Maddaloni, and Peydró, 2015, all three papers employ the EONIA rate as the ECB's policy

[7] Recent papers on repo rate dispersion in European markets include e.g., Mancini et al. (2016); Boissel et al. (2017), and Ranaldo et al. (2021).

instrument[8]). Furthermore, an unsecured money market rate such as the EONIA or the U.S. federal funds rate are commonly considered as the main policy rule to fulfill the central bank's mandate, which is well reflected in the widely used Taylor rule (Taylor, 1999). Third, it is much more informative than other key rates set by the ECB. This last point warrants a more detailed discussion.

The ECB sets three key interest rates: The rate on the main refinancing operations and the rates on the deposit and marginal lending facility. The rates on the deposit and marginal lending facility define the corridor for the EONIA as the unsecured, overnight interest rate at which banks lend to each other.[9] The two rates do not lend themselves to a pass-through analysis since they only move in infrequent, discrete jumps. Importantly, the deposit facility rate is an exogenous rate set by the ECB and only the amounts deposited at the deposit facility are endogenously determined by banks with access to it. Policy interventions such as QE programs are not reflected in the deposit facility rate, it only changes rarely. The EONIA rate, by contrast, evolves continuously and is an endogenously determined rate which is much more informative to central banks (and market participants) as it also captures, for example, time-varying funding conditions and unconventional monetary policy effects. These aspects make the EONIA rate the most appropriate choice for our main monetary policy target rate.

In Section 2.5, we validate our findings based on the EONIA rate with a comprehensive set of alternative monetary policy rates. In particular, the period studied involves a transition in the economy's benchmark interest rate. The ECB has chosen the €STR rate, an unsecured rate, as the new short-term interest rate benchmark to replace the EONIA rate, thereby highlighting the ECB's renewed commitment to an unsecured target rate. We show that our results are valid for the EONIA in the prior benchmark's period and for

[8]Ciccarelli, Maddaloni, and Peydró (2015) also employ the 3-month Euribor rate and the overnight interest swap rate as robustness checks, which we present as well.

[9]The evolution of the EONIA within the corridor is depicted in the Appendix in Figure A.1.1. Within the corridor, the ECB steers the short-run liquidity conditions with its open market operations by providing liquidity for a period of one week or three months. Although these transactions are secured, open market operations are distinct from regular repo transactions in three ways: First, open market operations are conducted via fixed-rate full-allotment or benchmark allotment auctions, which are executed at the same rate for all participants. Second, these auctions occur on a weekly to monthly basis and thus do not provide for a viable alternative to obtain day-to-day short-term funding. And third, the maturities of one week or three months are longer term than typical overnight repo transactions.

the €STR since its inception. In addition, to account for monetary policy not being centered around one (unsecured) interest rate, we employ different policy rates such as derivative-based measures and the rate on the ECB GC pooling basket. We thereby ensure that the monetary policy disconnect stems from institutional aspects pertaining to the central bank framework as opposed to a segmentation between the secured and unsecured market.[10]

2.1.2 Transmission through interest rates

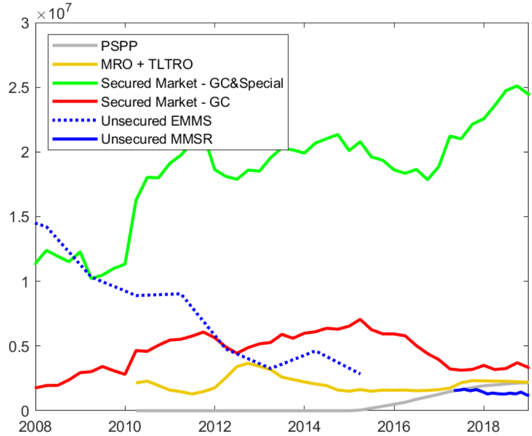
We now move to the second major component of the monetary policy framework, its transmission through interest rates. The first but crucial step in this transmission relies on the linkage between monetary policy and money markets, which we analyze in this paper. As highlighted in the introduction, changes in the monetary policy affect the money market first.

The most important instrument used in money markets is the repo, which represents the main short-term funding market for banks.[11] It plays a more important role for the transmission of monetary policy than the unsecured market for three reasons: First, Figure 2.1 illustrates that trading in the European money market has moved towards the secured market segment since the Global Financial Crisis. According to the Euro Money Market Survey, the size of the secured market is about twenty times the size of the unsecured market. In particular, an increase in risk aversion after the recent crisis shifted bank activity towards the secured segment (European Central Bank, 2018).[12] Thus, the repo market is now the predominant source of funding liquidity and is therefore key for the central bank's monetary abilities. To put this into perspective, repo trading volume by far exceeds, for example, volumes of cumulative purchases

[10]Given that the EONIA rate is unsecured, one may be concerned that the EONIA rate is exposed to certain factors, such as risk in the banking sector, to which repo rates are not exposed. This is less of a concern in our analysis since it is performed at high frequency while such factors move only slowly. Moreover, we show that the market participants covered in this study feature similar balance sheet characteristics (see Section 2.3). Finally, the robustness check employing the rate on the ECB GC pooling basket is not exposed to similar factors and confirms our results.

[11]The influence of the EONIA on repo rates is also reflected in the EONIA being the reference rate for floating rate repos.

[12]The decision problem of banks involved in secured and unsecured markets has been in the focus of the theoretical literature, highlighting that the linkage between the two markets can be impacted by opportunity cost of collateral (Piquard and Salakhova, 2019) or constrained arbitrage (Nyborg, 2019). Banks do indeed trade in both the secured and the unsecured markets, actively linking the two segments (Di Filippo et al., 2021).



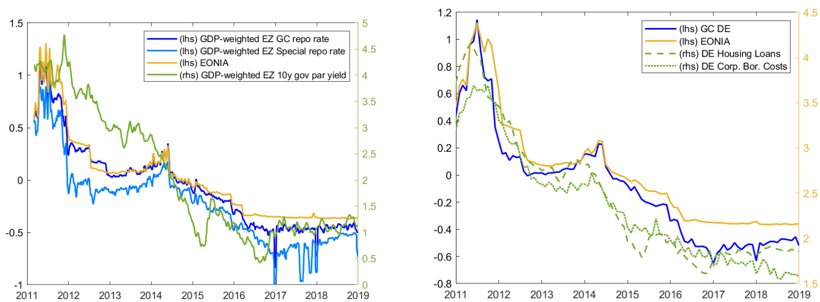
The figure depicts the aggregate cumulative quarterly trading volumes in the secured and unsecured market segments as well as the total cumulative PSPP purchases and volumes of the ECB's main refinancing operations (MRO) and targeted longer-term refinancing operations (TLTRO). The data for the secured market refer to our total data set as described in Section 2.3. The data for the unsecured market stem from the Euro Money Market Survey (EMMS) until 2015 and from the Money Market Statistical Reporting (MMSR) thereafter. To be conservative, we sum reported borrowing and lending activity in the unsecured market, which may entail double-counting. The data on PSPP purchases and refinancing operations are from the ECB. All data are in euro million.

Figure 2.1: Different market turnovers

of the largest ECB QE program, the Public Sector Purchase Program (PSPP) or of the ECB's main refinancing operations. Second, repo market frictions not only impact the funding conditions of banks, but also the borrowing conditions faced by other financial institutions and governments, as has been shown for the U.S. Treasury market by He et al. (2021). Given that governments are the largest debt issuers, this is another avenue through which the repo market affects monetary policy transmission. Finally, the repo market in the euro area plays an important role for the redistribution of reserves (Bank for International Settlements, 2017, p.16) which is an important step in the process of monetary policy implementation.

2.1.3 Monetary policy objective

The third main component of the monetary policy framework is its ultimate goal, which is the promotion of stable prices and growth by influencing the real sector, in particular lending conditions faced by businesses and consumers. The interest rate environment plays an important role in investment and price setting decisions. As bank loans are the main source of funding for large parts of the economy, the pass-through of monetary policy to the banking sector is crucial. To support the importance of the repo market for the monetary policy transmission into the real sector, Figure 2.2a shows the co-movement of GC and special repo rates with a GDP-weighted average Eurozone government bond yield, while Figure 2.2b illustrates for Germany that repo rates correlate with credit conditions faced by corporate borrowers and private households. The graphical intuition points towards the repo market playing an important role in the transmission of monetary policy into borrowing costs of the public debt and bank lending rates, which is why it is important to monitor the repo market for indications of distress.

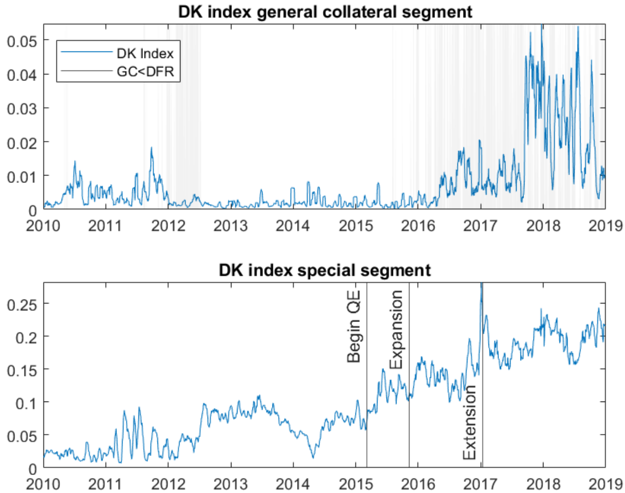


(a) Eurozone government bond rates **(b)** German real sector lending rates

Figure 2.2a depicts the GDP-weighted average government bond yield within the Eurozone as well as the GDP-weighted mean GC and Special repo rates. Figure 2.2b depicts the co-movement of the mean German GC rate with two real sector lending rates, one depicting the borrowing costs for private homeowners and one for non-financial corporations in Germany. Both lending rates stem from the ECB's MFI Interest Rate Statistics (MIR). The mean GC rate refers to the volume-weighted mean observed in our dataset. For reference, we also include the EONIA rate in both graphs.

Figure 2.2: Interest rate co-movements

One prime indicator for pass-through inefficiency in money markets has been proposed by Duffie and Krishnamurthy (2016, p.36): a volume-weighted absolute dispersion index. In Figure 2.3 we present dispersion measures for the GC and special repo market segments in that spirit which we accordingly refer to as the 'DK index'.



The figure depicts two DK dispersion indices defined as the volume-weighted average of the absolute deviation of repo rates from the volume-weighted mean repo rate in the spirit of Duffie and Krishnamurthy (2016, p.36). For the first DK index in the special market, we differentiate between rates on repos secured by eligible and noneligible collateral. For the GC segment, we consider rates of trades involving access versus nonaccess lenders.

Figure 2.3: Repo market dispersion

We observe that the dispersion in the GC segment increases once the GC rate drops below the rate on the deposit facility. Similarly, we observe an increase in the dispersion in the special segment since the introduction of QE that has further increased with extensions and expansions of the QE program. Both indices point towards a weakening in the monetary policy transmission.

To formalize this idea in a simple empirical setting, we examine the pass-through of changes in the monetary policy target rate into lending rates faced by corporate borrowers and private households, depending on the conditions in the repo market resulting from policy conditions and the monetary policy framework. The dependent variable is the change of a given lending rate

Table 2.1: Repo dispersion and the pass-through to lending rates

	(1)	(2)
	Non-Fin. Corporate Δr^L b/t	New Housing Δr^L b/t
$\Delta PolRate$	0.506***	0.787**
	(3.449)	(2.816)
$\Delta PolRate \cdot D^{DK_{GC}}$	-0.522***	-0.689**
	(-3.271)	(-2.335)
$\Delta PolRate \cdot D^{DK_{Special}}$	-0.445	-0.553***
	(-1.669)	(-3.279)
N	1,145	1,070
R^2	0.124	0.171

The table reports the regression results examining the pass-through of changes in the monetary policy target rate into lending rates faced by corporate borrowers and private households. The dependent variable is the change of a given lending rate Δr^L. Non-financial corporate borrowing rates refer to the annualized borrowing costs of non-financial firms for new loans, while new housing rates refer to bank interest rates on new loans to households for house purchases with an initial rate fixation period of between one and five years. Both lending rates are available from the ECB's monetary financial institutions (MFI) interest rate statistics. $\Delta PolRate$ denotes the change in the policy rate (EONIA). $D^{DK_{GC}}$ equals 1 if the dispersion measure for the GC market is above its median. $D^{DK_{Special}}$ equals 1 if the dispersion measure for the Special market is above its median. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include country-year fixed effects and standard errors accounting for clustering at the year level. Data are at a monthly frequency for all European countries for the time-period 2010–2018.

Δr^L, for which we consider borrowing costs of non-financial firms and loans to households for house purchases. $\Delta PolRate$ denotes the change in the policy rate (EONIA). $D^{DK_{GC}}$ equals 1 if the dispersion measure for the GC market is above its median, while $D^{DK_{Special}}$ equals 1 if the dispersion measure for the special market is above its median.[13] Table 2.1 reports the results of our panel regressions. Regression (1) relates changes in non-financial corporate borrowing rates to changes in the monetary policy target rate, depending on the dispersion in GC and special repo rates. The results highlight that lending rates react strongly: A one-percentage-point decrease in the target rate is accompanied by a decrease in corporate borrowing rates of about 51 basis points. The effect is almost muted when the dispersion in repo rates is high. Regression (2) confirms our results for residential housing rates. In both regressions, we account for country-year fixed effects. The results provide empirical support for Duffie and Krishnamurthy (2016) who highlight that a dispersion across money market interest rates is a primary indicator of the inefficiency of monetary policy pass-through. Although the monetary policy transmission into the real economy involves additional steps that deserve a detailed analysis beyond short-term rates, our results clearly speak to the importance of the repo market for the monetary policy transmission. Since the repo market is the predominant source of short-term funding, the repo market determines bank funding conditions and ultimately impacts the transmission of monetary policy into the real sector.

Our results highlight that the monetary policy disconnect is associated with an increased dispersion in repo rates that reduce the sensitivity of lending rates to changes in the monetary policy rate. In the remainder of the paper, we look at two features of the central bank framework which have contributed to that dispersion in repo rates and thus weakened the monetary policy transmission.

2.2 Repo market

As discussed above, the repo is the first crucial step in the monetary policy transmission. In this section, we discuss three aspects of it: (i) the main features of the European repo market; (ii) how access to central bank deposit

[13] We obtain consistent results by employing different measures of dispersion for the GC market and considering the QE purchasing volume for the special market.

can affect banks' behavior in the repo market; (iii) how the eligibility of a security for the QE program can affect the repo for which that security serves as collateral. We conclude this section by offering a theoretical framework that rationalizes the mechanisms discussed in (ii) and (iii) and lays the foundation for the hypotheses we test later.

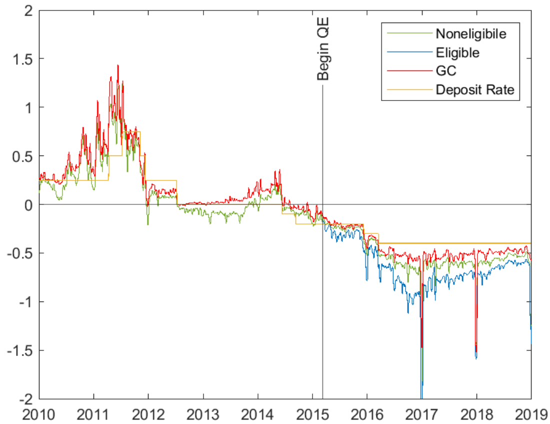
2.2.1 Characteristics of the European repo market

In the repo market, two counterparts exchange cash for collateral for a predefined time period with a fixed repurchase obligation. The asset being used as collateral can be a particular asset ("special repo") or any asset from a predefined basket of assets ("general collateral or GC repo"). The lender in a repo transaction provides a short-term loan (over-)collateralized by sovereign debt and thus benefits from the ability to use the collateral (convenience) for the time between the purchase and repurchase. In a special repo, the lender accepts a lower interest rate than in a GC repo since a particular asset is specified as collateral; GC repo rates provide the upper bound for special repo rates. The GC market is generally more funding-driven while the special repo market is more collateral-driven. However, in each transaction there is always a funding motive on the part of the borrower.

The European market infrastructure features (i) central clearing, (ii) anonymous electronic order book trading, and (iii) a large variety of eligible collateral (Mancini et al., 2016).[14] Figure 2.4 illustrates two important developments of the German GC rate and the average repo rates for eligible and noneligible German assets relative to the development of the ECB's deposit facility rate.

First, the GC rate has fallen below the ECB's rate on the deposit facility at the height of the European sovereign debt crisis in 2012 and during the recent period of unconventional monetary policy. Second, during the QE period repo rates secured by assets eligible for QE have fallen below those for noneligible assets. Each observation points to a different feature of the central bank

[14] Our setting provides several benefits compared to the bilateral, over the counter (OTC) repo market: First, its anonymity alleviates frictions associated with bargaining power. Second, since all market participants have the same counterparty (the CCP), the observed rates are not confounded by risk adjustments. Third, the comparability of rates is ensured by homogeneous haircuts. And finally, the bilateral repo market is very small and does not allow for a clear differentiation between general and special collateral repos. More detailed information about the European repo market infrastructure can be found in, for example, Nyborg, 2016; Bank for International Settlements, 2017 and European Central Bank, 2018.



The figure shows the development of the average volume-weighted repo rates for eligible and noneligible German assets as well as the GC rate relative to the development of the ECB's deposit facility rate.

Figure 2.4: Repo rate development for Germany

framework that we analyze. The first observation speaks to the importance of access to central bank facilities as it indicates that depositing funds at the deposit facility is attractive, in particular when the GC rate is below the deposit rate. The second observation highlights the role of asset scarcity induced by QE programs. Market participants are willing to accept a lower interest rate to lend cash against eligible than noneligible assets. The spread between eligible and noneligible rates has been present since the introduction of QE and peaked at the end of 2017 when the ECB's Securities Lending Programme was introduced (Brand et al., 2019), while specialness and asset scarcity in general also occurred before QE.

2.2.2 ECB access

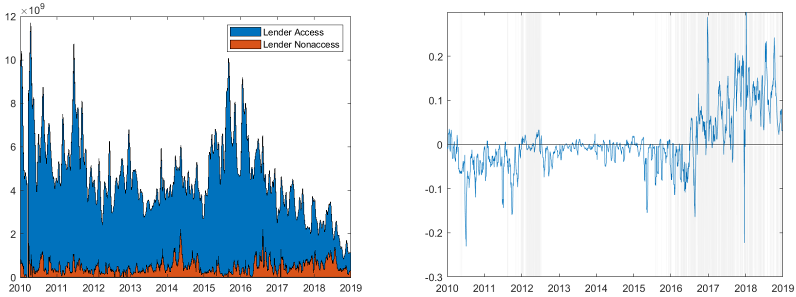
The ECB operates two standing facilities that allow banks to deposit or access liquidity on an overnight basis: The deposit facility allows for overnight deposits, while the marginal lending facility provides overnight central bank liquidity. Access to the ECB's facilities is, however, limited to eligible counterparties, most importantly to those banks that are subject to the Eurosystem's minimum reserve requirements. The minimum reserve system applies to banks and credit institutions established in the euro area.[15] Whether a bank is formed in- or outside of the euro area is unrelated to monetary policy and the repo market, and thus a source of exogenous variation.

In our analysis, we exploit the eligibility criteria for access to the deposit facility. In particular, we consider the restriction that only euro area banks can access the deposit facility in order to classify lenders in a repo transaction into *access* and *nonaccess* banks. This implies that access banks can safely invest liquidity in the repo market or place it at the deposit facility, whereas nonaccess banks can only rely on the former.[16] Depositing money at the deposit facility typically offered a smaller return than other overnight lending or investment options since central bank reserves are considered the safest and most liquid asset. However, since 2015, repo rates in almost the entire European repo market have fallen below the rate on the deposit facility. This implies that storing funds at the deposit facility has become a more attractive option for those banks that have access to it.

Figure 2.5a shows the development of the total German GC trading volume for access and nonaccess banks while Figure 2.5b depicts the spread between the average GC rate received by access and nonaccess lenders. In the two periods during which GC rates fell below the rate on the deposit facility (i.e., in 2012 and since 2015), we observe a drop in GC trading volume. This drop is accompanied by an increase in the volume of funds deposited at the ECB's deposit facility (see Figure A.2.1 in the Appendix). For example, since 2015, we observe a drop in GC trading volume to about a third of its original size. This reduction was mainly driven by banks that had access to the ECB's deposit

[15] Additional criteria, for example on financial soundness, allow the ECB to suspend eligibility for institutions under certain circumstances. The full set of eligibility criteria can be found in EU Guideline 2015/510 of the European Central Bank on the implementation of the Eurosystem monetary policy framework available at `https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014O0060`.

[16] Banks could also invest in government bonds directly as opposed to investing liquidity in the (reverse) repo market or – when having access – placing funds at the deposit facility. However, direct government bond investments have several drawbacks and do not provide the same low-risk and liquid store of value as repos (Bank for International Settlements, 2017). First, investing in government bonds exposes banks to a larger set of risks (e.g., market risks or duration risk / interest rate risk). Second, bond trades involve comparatively large transactions cost, in particular when bonds are purchased and sold on a daily basis to manage liquidity. Third, bond and repo markets differ in terms of their market structure. For example, bond trades are OTC and banks do not benefit from netting and central clearing.



(a) General collateral trading volumes **(b)** Spread between average GC lending rates

Figure 2.5a depicts the total trading volume in the German GC market for trades involving a lender with and without access to the ECB facilities. Figure 2.5b depicts the spread between the average GC rate received by access and nonaccess lenders (nonaccess banks' average rate minus access banks' average rate). Grey shaded areas denote time periods in which the average GC rate was below the deposit rate.

Figure 2.5: General collateral repo market

facility. Correspondingly, the share of lending volume by access banks dropped by around 15 percentage points (see Section A.3 in the Appendix). To our knowledge, this is a new stylized fact which suggests a first form of segmentation between access and nonaccess banks induced by the central bank framework. Access banks increasingly deposit funds at the deposit facility when repo rates fall below the rate on the deposit facility, while nonaccess banks continue to lend in the GC market obtaining a (safe) deposit of liquidity. The excessive usage of the deposit facility by access banks raises concerns about discouraging interbank trading which inhibits price determination (Keister et al., 2008).

Repo rates have been lower than the deposit rate for an extended period of time. This raises the question whether an arbitrage opportunity for access banks exist by borrowing in the repo market and storing the borrowed funds at the deposit facility. Although an exhaustive answer to this question deserves research in its own right, some brief consideration must be given. First, this direct comparison of the repo rate and the deposit rate errs in assuming that central bank reserves are equivalent to repo loans and abstracts from the value of the collateral. A bank engaging in such a seemingly arbitrage trade needs to hold the collateral (e.g., a scarce German Bund) to secure the repo borrowing and by delivering it into a repo foregoes its service flows, which can be interpreted as an opportunity cost of the trade. Second, there is evidence that a spread between the repo rate and deposit rate attracts this sort of arbitrage trading but to a limited extent, e.g., due to small margins and other regulatory costs (Ranaldo et al., 2019). Third, obtaining collateral is not only a motivation for trading in the special market but also in the GC segment explaining why access banks still trade in the GC market when GC rates fall below the rate on the deposit facility. We conduct a preliminary analysis showing that once the average GC rate falls below the deposit facility rate, access banks reduce their cash lending and concentrate it to trade in either baskets of high-quality collateral (such as German Bunds) or lower quality baskets that are still trading above the deposit facility rate (this is illustrated in the Online Appendix). These results suggest that there are two reasons why access banks still lend in the GC segment even when average GC rates are below the deposit facility rate: First, they attribute a higher marginal value on high quality collateral and for this they are willing to receive a lower interest rate. Second, the higher lending rates associated with lower quality baskets represent a lucrative opportunity to store funds. A more in-depth study of these issues could be the subject of future research.

It is worth noting that the regulatory framework plays a negligible role in explaining our main findings for at least three reasons: First, access and nonaccess banks in our sample are similarly regulated. Nonaccess banks also need to fulfill Basel regulations in their home countries (even though those countries are outside the euro area). Second, the new Basel (liquidity and capital) regulation considers all assets under inspection to be of the highest quality (Level 1 assets) from the perspective of the Liquidity Coverage Ratio (LCR) and liquidity regulation (Bank for International Settlements, 2017). For example, we depict results which only consider repo transactions collateralized by German government bonds (which are safe and liquid). Furthermore, all maturities under inspection are shorter than the thirty-day LCR cut-off time. Third, by focusing our analysis on the lending side, the banks' incentive to reduce the leverage ratio (window-dressing) does not apply. In fact, reverse repos do not enter the Basel III leverage ratio calculation because the lender is not exposed to the risk of collateral (Ranaldo et al., 2021).

The importance of the access to the central bank's facilities is stressed in the literature. The deposit rate as the rate of remuneration for reserves is a general and important feature of financial intermediaries' decision problems that is incorporated into macro-financial models (Cúrdia and Woodford, 2011; Bech and Monnet, 2016; Williamson, 2019). In these models, a single deposit rate applies uniformly to all market participants. However, different values of the rate would entail different equilibria in line with the mechanism that we discuss. Segmentation induced by different access levels to central bank facilities is also supported empirically. For instance, Bech and Klee (2011) argue that the level of the effective federal funds rate was pushed downward by government agencies that could not receive interest on reserves.[17] Kraenzlin and Nellen (2015) find that banks without access to central bank facilities pay more interest in the unsecured money market to borrow liquidity.

2.2.3 Asset eligibility

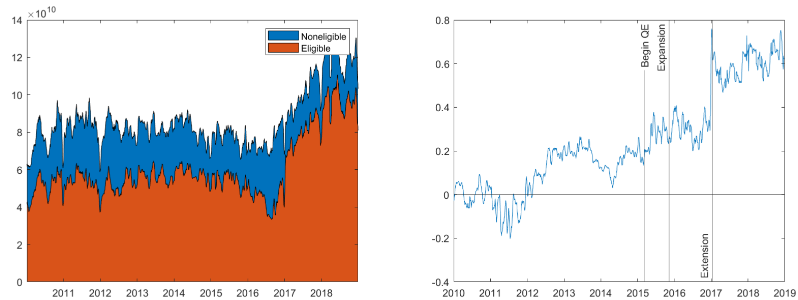
The ECB followed other major central banks in 2015 by announcing its intention to conduct large-scale asset purchases. Since the beginning of these programs, cumulative net purchases amounted to more than 2.5 trillion euro. The Public Sector Purchase Program is the largest of the programs implemented in the Eurosystem, it focuses on the purchase of government bonds.[18] The sheer size of these purchases has contributed to scarcity effects for government bonds, which are an important category of safe assets and serve as collateral in repo transactions. QE programs in general aim to influence longer-term rates in an environment where short-term rates are at the zero lower bound (by affecting term premia, see Eser et al., 2019). An impact of QE-induced asset scarcity on short-term rates is thus an unintended side effect that can increase rate dispersion and thereby limits control over the pass-through. The effect of asset purchases on bond scarcity comes on top of tighter regulation of financial institutions under the new Basel framework (e.g., the introduction of

[17]Bech and Klee (2011) differ from our study in many key aspects. First, they evaluate different interest rate levels, not the pass-through of a policy rate to another short-term interest rate. Second, their analysis is confined to the unsecured market, while we look at the secured funding market. Finally, the financial friction to which their effects are attributed is bargaining power, a friction that should not occur in a centrally-cleared setting like ours.

[18]Under the umbrella of the PSPP, the ECB buys nominal and inflation-linked government bonds as well as securities issued by recognized agencies, regional and local governments, international organizations, and multilateral development banks located in the euro area. Overall, around 90% of purchases correspond to government bonds.

the Leverage Ratio rules). The ECB has therefore constituted implementation provisions to limit market impacts and distortions. These provisions specify the conditions under which the ECB (via local central banks) is allowed to purchase government bonds: they contain (i) a maturity restriction that specifies the minimum and maximum remaining maturity of a security, (ii) a yield restriction that states that the yield of a security needs to be above the ECB's deposit facility rate, and (iii) it only allows for the purchase of bonds denominated in euro.[19] The implementation provisions for asset purchases provide a source of exogenous variation as to which securities meet the respective criteria.

In our analysis, we exploit the implementation provisions to classify collateral in a repo transaction into *eligible* and *noneligible* depending on the provisions that were valid at a specific point in time. We further apply the initial implementation provisions retrospectively to compare time trends between *(hypothetically) eligible* and *noneligible* assets, which creates a difference-in-difference estimation setting. Observing similar reactions of both types of assets before QE would imply common trends and would allow us to interpret the post-QE results as causal.



(a) Special collateral trading volume **(b)** Spread between (hypothetically) eligible and noneligible assets

Figure 2.6a depicts the total trading volume in the special collateral market for trades involving eligible and noneligible collateral. Figure 2.6b depicts the spread between the average repo rate on noneligible and eligible securities (average rate for noneligible collateral minus average rate for eligible collateral).

Figure 2.6: Special collateral repo market

[19]Over time, the ECB has adjusted and modified the initial implementation provisions. For example, the yield restriction ceased to exist at the end of 2017.

Figure 2.6a shows the development of the total trading volume in special collateral for eligible and noneligible securities while Figure 2.6b depicts the spread between the average repo rate on noneligible and eligible securities. During the recent period of unconventional monetary policy, repo rates for eligible assets have fallen below those of noneligible assets. The spread between noneligible and eligible assets was always positive during the QE period and has increased further after the expansion and extension of the program. A second, new stylized fact emerges as we observe an increase in special collateral trading volume since the start of QE, an increase that is predominantly driven by eligible assets.[20]

The interplay of central bank asset purchases, financial intermediation, and collateral has been featured prominently in the theoretical literature. Gertler and Karadi (2013) show that if limits to arbitrage exist in the banking sector, central bank purchases of securities cause yields to fall. Araújo et al. (2015) stress that the direction of the impact of asset purchases depends on the way collateral constraints are impacted. Piquard and Salakhova (2019) highlight how monetary policy affects unsecured and secured markets in a different way once the central bank purchases marketable collateral. Their mechanism is motivated by an increase in the opportunity cost of pledging collateral. Divergent QE effects on financial markets are also supported empirically. For instance, Arrata, Nguyen, Rahmouni-Rousseau, and Vari (2020) and Corradin and Maddaloni (2020) show that asset purchases lowered the special repo rates. Schlepper, Riordan, Hofer, and Schrimpf (2017) show that QE increased prices and lowered liquidity in purchased German bonds. Koijen, Koulischer, Nguyen, and Yogo (2017) show that in response to the ECB's purchasing programs, foreign investors sold most of their QE eligible bond holdings to domestic investors pointing to a strong home bias in eligible securities.[21]

[20] Since the implementation provisions have changed during the course of the program, the increase in the trading share of eligible assets is partly driven by an easing of the restrictions. The decline in eligible trading volume towards the end of 2017 was driven by German collateral trading at a yield below the ECB's deposit facility. The ECB therefore decided in January 2017 to void the yield restriction.

[21] This shift was also documented in aggregate data by Avdjiev et al. (2019).

2.2.4 Theoretical mechanisms at work

Building on the framework proposed in Duffie (1996), we illustrate the two features of the central bank framework affecting the GC and special repo market in a supply and demand diagram. While Duffie (1996) focuses on the special market, we extend his framework to GC repos.

Figure 2.7 depicts the supply and demand diagram in the *GC* market: the x-axis shows the GC rate, the y-axis the quantity (per institution). The borrower in the GC market is searching for funding, the supply curve therefore has a negative slope (i.e., the lower the repo rate on a loan, the larger the supply of collateral to be temporarily sold to borrow funds).[22] On the demand side, we present two distinct demand curves: one for access banks and one for nonaccess banks. This is needed since the decision problem of those two types of banks is different; one is able to deposit funds at the deposit facility while the other is not.

The demand of nonaccess banks for investing liquidity is inelastic. While we do not model the behavior of nonaccess banks explicitly, this is suggested for several reasons: First, banks without central bank access face the decision problem of investing in the secured or unsecured money market. Repos are mostly secured by government bonds, which are safe assets per se, carrying convenience yields in the form of safety and liquidity benefits. The benefits from obtaining collateral (Piquard and Salakhova, 2019) therefore create a net demand for safe assets (Infante, 2020), which is particularly inelastic when QE programs render them scarce. Second, financial regulation incentivizes directly and indirectly banks to hold secured deposits (Ranaldo et al., 2021). Finally, capacity constraints as well as limits to arbitrage in the unsecured money market can even lead the unsecured rate to fall below the secured rate (Nyborg, 2019), rendering unsecured investments unattractive. Access banks can always access the deposit facility. This option becomes more attractive when the GC rate falls below the rate on the deposit facility, leading to a lower demand of access banks. We illustrate this change in the demand via a kink in the demand curve.[23] The demand of access banks to deposit liquidity in the

[22] In the traditional model of Duffie (1996), the supply curve is upward-sloping since the x-axis shows the “specialness” instead of the GC rate (reverse direction).

[23] To provide empirical evidence for the kinked demand curve, we show that the share of access banks as lenders in repo transactions declines once the GC rate falls below the deposit facility rate (since access banks can place their funds at the central bank), while their share

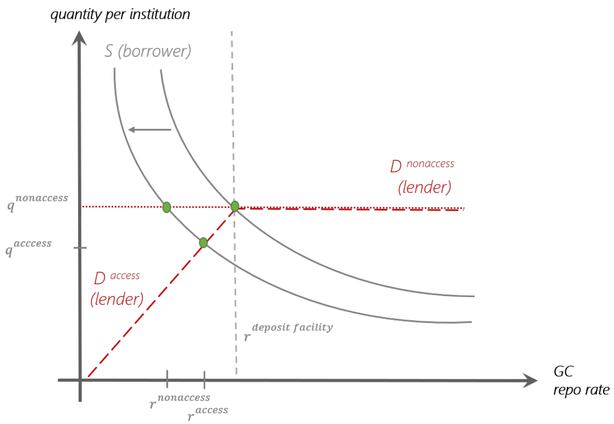


Figure 2.7: Impact of supply shock in the GC repo market

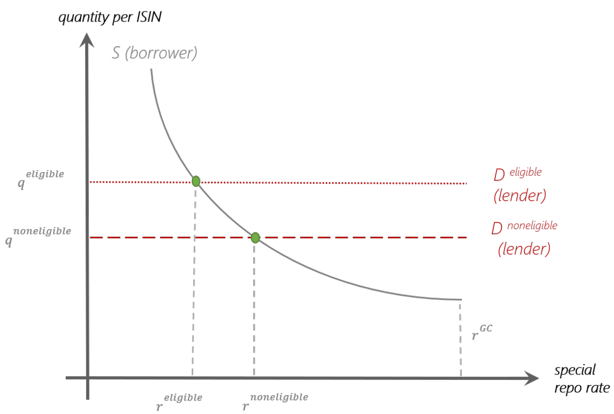


Figure 2.8: Impact of demand shock in the special repo market

repo market does not immediately vanish due to benefits of obtaining collateral over holding cash, for example, to pledge it in margin accounts.[24]

Since the start of QE, excess liquidity in the euro area has strongly risen (e.g., Arrata, Nguyen, Rahmouni-Rousseau, and Vari, 2020). This is graphically illustrated in a negative supply shock, that is, fewer banks need to borrow liquidity in the repo market. Two effects emerge from this negative supply shock: First, GC rates can fall below the rate on the deposit facility. This leads access banks to deposit an increasing share of their liquidity at the deposit facility, thus the size of the GC market and the trading share of access banks in the GC market declines. Second, and important to our regression analysis, interest rates between access and nonaccess banks diverge in the sense that the former institutions tend to lend at rates closer to the central bank deposit rate. As preliminary evidence, Figure 2.5a shows the decline in the size of the GC market accompanied by a decrease in the trading share of access banks, while Figure 2.5b illustrates the difference in GC rates by access status. Our first testing hypothesis is therefore that banks with access to the central bank's deposit facility are less responsive to changes in the monetary policy stance when the GC rate is lower than the deposit rate.

Figure 2.8 depicts the supply and demand diagram in the *special* market: the x-axis now shows the special rate, the y-axis the quantity (per bond). In the special market, the trading behavior is characterized by the collateral leg of the repo transaction: Following Duffie (1996), some security holders are only willing to lend (supply) those securities at a premium (i.e., at a repo rate below the GC rate). This translates into a negatively sloped supply curve. The demand in the form of short sellers is completely inelastic. Asset purchases of eligible securities have led to asset scarcity and an additional demand for eligible assets (Bank for International Settlements, 2017, p.16). This is graphically illustrated in two demand curves, one at a higher level (for eligible assets) and one at a lower level (for noneligible assets). Two effects emerge from this positive demand shock for eligible assets: First, the size of the special market increases with an increasing share of trading in eligible (collateral) assets. Second, repo rates

as borrowers remains constant (Section A.3 in the Appendix).

[24] The current spread at Eurex on cash denominated in euro pledged in margin accounts is, for example, 20 basis points, thus rendering cash collateral less attractive (https://www.eurex.com/ec-en/services/collateral-management/cash-collateral/interest-rates-on-cash-collateral).

diverge as rates for eligible assets fall below those for noneligible assets (i.e., eligible asset is more "special"). Figure 2.6a shows the increase in the size of the special market accompanied by an increase in the trading share in eligible assets, while Figure 2.6b illustrates that repo rates for eligible assets have fallen below repo rates for noneligible assets since the start of QE. Our second testing hypothesis is therefore that QE eligible assets are in scarce supply and thus respond less to changes in the monetary policy rate.

2.3 Data

We employ high-frequency data for the European repo market for the time period from 2010 to 2018. Our data includes all electronically traded repo transactions in euro on the three main trading platforms (i.e., BrokerTec, Eurex, and MTS) and covers more than 70% of the entire repo market. For each transaction, we observe the date, the term, the volume, the rate, the collateral identified by a unique ISIN or basket, the lender, the borrower, the aggressor type and the trading platform. We focus on the term types Overnight (ON), Tomorrow-Next (TN), and Spot-Next (SN), with the purchase date being tonight, tomorrow, or the day after tomorrow, respectively, and the repurchase date one day thereafter. These three term types make up 97% of the entire repo market trading volume. Trading in the GC market predominantly takes place in the ON and TN market segments, whereas trading in the special repo market segment predominantly takes place in the TN and SN market segments. We exclude three sub-groups of repos that represent a very small share of our data: First, we exclude special repos secured by corporate securities. Second, we exclude repos with floating rates, repos with open term type, bilaterally pre-arranged repos as well as repos that are not cleared via a central counterparty (CCP). Third, we remove trading days that are holidays and trading days associated with end-of-year effects. Finally, we exclude repos that are traded infrequently.[25] We perform our analyses for three different groups of countries: (i) Germany, (ii) core European countries, and (iii) all European countries.[26]

[25] To be included in our analysis, a repo needs to be traded at least 100 times. In addition, between the issuance and maturity of the underlying collateral, a repo needs to be traded at least once every two weeks 95% of the time. Our results are robust to different specifications.

[26] Core European countries include Austria, Belgium, Finland, France, Germany and the Netherlands, all European countries include in addition EU, Ireland, Italy, Portugal and Spain.

To identify banks, we follow the approach of Ranaldo et al. (2019) as well as Di Filippo et al. (2021) based on supervisory data. We can then classify banks into access and nonaccess institutions depending on whether they need to fulfill the reserve requirements of the Eurosystem and have access to the deposit facility. Banks trading in the repo market are, for example, Deutsche Bank AG and Nordea Bank Danmark A/S. The former is a euro area bank with access to the deposit facility, while the latter is a foreign bank without access.[27] Our data contains GC repo trades involving 98 different banks, of which 85 are access banks and 13 are nonaccess banks. We observe information on both the lending and borrowing bank for trades featuring 59% of the entire trading volume; among those trades, 22% are associated with a nonaccess bank. To ensure that the two groups of access and nonaccess banks are comparable, we analyze their important characteristics. For instance, at the end of our sample period, access banks had, on average, assets worth 290 million euro compared to 240 million euro for nonaccess banks, the leverage ratios were about 17 for both types of banks.

Moreover, we classify assets as eligible and noneligible for QE according to the PSPP's implementation provisions. Our data set contains special repo trades involving more than 2,000 different collateral assets (ISINs). Seventy-six percent of our sample involves repo trades collateralized by (hypothetically) eligible assets, 24% collateralized by noneligible assets.

2.4 Empirical results

We first analyze the monetary policy pass-through into the GC market by access and nonaccess banks. Second, we analyze how QE asset eligibility affects the monetary policy transmission through the special market. Finally, we study their combined effects.

2.4.1 Access/nonaccess banks

We want to understand whether the access restrictions to central bank facilities lead to a monetary policy disconnect. In particular, we ask whether access

[27] For our classification, we assume that local subsidiaries of global banking institutions operate independently in the short-run. Thus, euro area subsidiaries of foreign banking groups have access to the deposit facility while foreign subsidiaries of euro area banking groups do not have access to the deposit facility.

and nonaccess banks behave differently in the monetary policy transmission process. Access banks always have the possibility to deposit funds at the deposit facility; our first testing hypothesis is therefore that access banks react less strongly to changes in the monetary policy target rate. Given that "in an idealized money market, any change in the main monetary policy rate should pass through perfectly to all money market rates" (Corradin et al., 2020, p.13), this would imply less control of the monetary policy transmission for central banks and indicate pass-through inefficiencies.

We provide a first graphical intuition of the analysis in Figure 2.9 that illustrates the lower sensitivity of access banks to changes in the monetary policy target rate in the form of impulse response functions. We compute the impulse response function for trades involving access and nonaccess banks separately for periods during which the GC rate is above the deposit rate (left panel) and below the deposit rate (right panel). The left panel highlights that access and nonaccess banks react similarly during periods when the GC rate is above the deposit rate, with the point estimate for access banks being slightly smaller.[28] However, once the GC rate is below the rate on the deposit facility, the sensitivity of access banks is completely muted, while nonaccess banks exhibit an even higher sensitivity. Nonaccess banks do not have the outside option of storing funds at the deposit facility, thus, they are still active in the repo market. However, since they are accepting a lower rate to invest funds, they tend to be more sensitive to changes in the policy rate. The graphical results point towards a less effective monetary policy transmission once GC rates fall below the rate on the deposit facility associated with access banks reacting less to changes in the monetary policy target rate and a larger dispersion in repo rates of access and nonaccess banks.

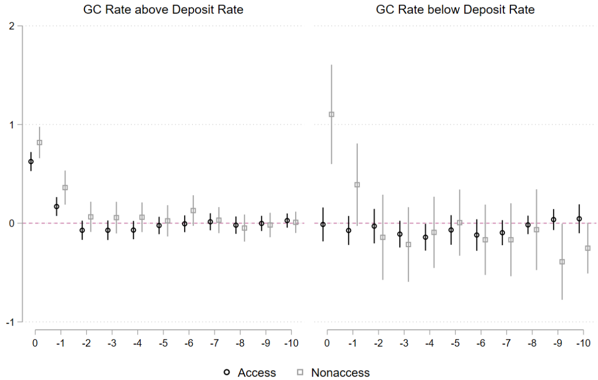
For the empirical analysis, we formalize the graphical intuition in a set of panel regressions. Our main regression equations read as follows:

$$\Delta r^{GC}_{t,i,l} = \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D^{Dep}_{t,n} + \beta_3 \cdot \Delta PolRate_t \cdot D^{Dep}_{t,n} + \beta_4 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t \tag{2.1}$$

$$\begin{aligned}\Delta r^{GC}_{t,i,l} = {} & \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D^{Access}_{t,l} + \beta_3 \cdot \Delta PolRate_t \cdot D^{Access}_{t,l} \\ & + \beta_4 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t\end{aligned} \tag{2.2}$$

$$\begin{aligned}\Delta r^{GC}_{t,i,l} = {} & \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D^{Dep}_{t,n} + \beta_3 \cdot D^{Access}_{t,l} + \beta_4 \cdot \Delta PolRate_t \cdot D^{Dep}_{t,n} \\ & + \beta_5 \cdot \Delta PolRate_t \cdot D^{Access}_{t,l} + \beta_6 \cdot \Delta PolRate_t \cdot D^{Dep}_{t,n} \cdot D^{Access}_{t,l} + \beta_7 \cdot \Delta r^{GC}_{t-1,i,l} + \epsilon_t,\end{aligned} \tag{2.3}$$

[28]Even if the deposit facility provides a smaller remuneration than a repo trade, the storage of liquidity at the facility is convenient.



The figure depicts the impulse response function of repo rates to changes in the monetary policy target rate for trades involving access and nonaccess banks in the period when the average GC rate is above (left panel) and below the rate on the deposit facility (right panel).

Figure 2.9: Impulse response for German trades involving access/nonaccess banks

where $\Delta r^{GC}_{t,i,l}$ denotes the log-change in GC repo rates of basket i and lender type (access / nonaccess) l at time t and $\Delta PolRate_t$ denotes the log-change in the EONIA. Moreover, we employ two dummy variables: $D^{Dep}_{t,n}$, which is equal to one if country n's average GC rate is below the deposit facility rate, and $D^{Access}_{t,l}$, which is equal to one if the lender l has access to the deposit facility.[29] Additionally, we add basket-month-term fixed effects and employ heteroscedasticity-robust standard errors. Trading in the more liquidity-driven GC repo market is concentrated in the ON and TN term types; we therefore show our main results as a pooled regression of both term types in Table 2.2. We report our results for (i) Germany in columns 1–3, (ii) core European countries in columns 4–6, and (iii) all countries in columns 7–9.

Although we will provide general validity to our results later, as a first step we restrict our sample to repo transactions collateralized by German government securities. Since German collateral is considered to be safe and liquid, we limit concerns about cross-country differences in sovereign risk and liquid-

[29]The denominations are: $\Delta r^{GC}_{t,i,l}$ is the log change in the volume weighted average daily repo rate per basket and lender type in percentage points. Correspondingly, $\Delta PolRate_t$ refers to the log change in the EONIA denoted in percentage points.

Table 2.2: ECB access

		Germany			Core			All	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.539***	0.717***	0.675***	0.472***	0.683***	0.643***	0.424***	0.589***	0.560***
	(15.700)	(10.745)	(8.781)	(23.035)	(16.875)	(14.261)	(24.699)	(16.774)	(15.106)
D^{Dep}	−0.046**		−0.047**	−0.032***		−0.032***	0.001		0.002
	(−2.265)		(−2.338)	(−2.940)		(−2.922)	(0.143)		(0.221)
$\Delta PolRate \cdot D^{Dep}$	−0.176**		0.265**	−0.048		0.298***	0.011		0.384***
	(−2.216)		(2.082)	(−0.897)		(3.968)	(0.220)		(5.668)
D^{Access}		−0.001	−0.000		−0.005	−0.004		−0.003	−0.003
		(−0.071)	(−0.035)		(−0.819)	(−0.743)		(−0.755)	(−0.709)
$\Delta PolRate \cdot D^{Access}$		−0.264***	−0.177**		−0.284***	−0.222***		−0.223***	−0.184***
		(−3.549)	(−2.100)		(−6.242)	(−4.423)		(−5.687)	(−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.719***			−0.561***			−0.595***
			(−4.970)			(−5.885)			(−6.733)
$\Delta repo^{GC}$ lagged	−0.332***	−0.332***	−0.332***	−0.337***	−0.335***	−0.335***	−0.372***	−0.371***	−0.371***
	(−14.230)	(−14.147)	(−14.151)	(−24.685)	(−24.388)	(−24.410)	(−30.291)	(−30.133)	(−30.167)
N	10,001	10,001	10,001	35,082	35,082	35,082	58,183	58,183	58,183
R^2	0.210	0.213	0.220	0.180	0.185	0.187	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility rate. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

ity. Regression (1) relates changes in GC rates to changes in the monetary policy target rate, depending on whether the GC rate is above or below the rate on the deposit facility. The results highlight that GC rates react strongly: A one-percentage-point decrease in the target rate is accompanied by a decrease in GC rates of about 54 basis points. The effect is smaller at 36 basis points when the GC rate is below the rate on the deposit facility. In Regression (2), we analyze the different reactions of access and nonaccess banks. We find that GC trades involving a lender with access to the deposit facility react less strongly. A decrease in the target rate by one percentage point relates to a decrease in GC rates involving access banks of 45 basis points as compared to 72 basis points for nonaccess banks. Considering our main Regression (3), which includes both dummy variables, we observe a combined effect: GC rates involving lenders with access tend to react less. Their reaction is particularly weak when GC rates are below the rate on the deposit facility. In this setting, the effect of changes in the monetary policy target rate on GC rates is 68 basis points for nonaccess banks as compared to 50 basis points for access banks. Once GC rates are below the rate on the deposit facility, the effect increases to 94 basis points for nonaccess banks while it decreases to 4 basis points for access banks. This indicates that lenders with access to the deposit facility do not react to changes in the target rate once GC rates are below the rate on the deposit facility, while lenders without access are very sensitive to it. As is graphically illustrated by the DK index in Figure 2.3, this leads to an increased dispersion in short-term GC rates, a natural indicator for monetary policy pass-through inefficiency. We observe a significant negative autocorrelation in repo rates, which is expected under mean reversion.

We perform a number of additional robustness checks to confirm our main results. First, columns 4–9 expand our analysis by looking at larger samples consisting of core European countries as well as all European countries. Overall, the results remain statistically and economically consistent. This indicates that the impact of having access to central bank facilities is not only present in the German "safe haven" market but across European countries as well. Second, we report consistent results for each term type and regional classification separately in the Online Appendix. Finally, the results are also robust for different standard error and fixed effect specifications, these results are also reported in the Online Appendix.

2.4.2 Eligible/noneligible assets

We also want to understand whether the eligibility criteria for QE programs impede the monetary policy transmission and lead to a monetary policy disconnect. Eligible collateral is scarce and in high demand; our second testing hypothesis is therefore that repo rates secured by assets eligible for QE are less aligned to the monetary policy target rate. Similar to the previous analysis, a lower sensitivity implies more difficulties in controlling the monetary policy transmission from the unsecured to the secured funding market. Again, we perform a set of panel analyses. Our main regression equations read as follows:

$$\begin{aligned}
\Delta r_{t,i,l}^{Special} &= \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D_t^{QE} + \beta_3 \cdot \Delta PolRate_t \cdot D_t^{QE} \\
&\quad + \beta_4 \cdot \Delta r_{t-1,i,l}^{Special} + \epsilon_t && (2.4)\\
\Delta r_{t,i,l}^{Special} &= \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D_{t,i}^{Eligible} + \beta_3 \cdot \Delta PolRate_t \cdot D_{t,i}^{Eligible} \\
&\quad + \beta_4 \cdot \Delta PolRate_t \cdot D_t^{QE} \cdot D_{t,i}^{Eligible} + \beta_5 \cdot \Delta r_{t-1,i,l}^{Special} + \epsilon_t && (2.5)\\
\Delta r_{t,i,l}^{Special} &= \beta_1 \cdot \Delta PolRate_t + \beta_2 \cdot D_t^{QE} + \beta_3 \cdot D_{t,i}^{Eligible} + \beta_4 \cdot \Delta PolRate_t \cdot D_t^{QE} \\
&\quad + \beta_5 \cdot \Delta PolRate_t \cdot D_{t,i}^{Eligible} + \beta_6 \cdot \Delta PolRate_t \cdot D_t^{QE} \cdot D_{t,i}^{Eligible} + \beta_7 \cdot \Delta r_{t-1,i,l}^{Special} + \epsilon_t, && (2.6)
\end{aligned}$$

where $\Delta r_{t,i,l}^{Special}$ denotes the log-change in special repo rates and $\Delta PolRate_t$ denotes the log-change in the EONIA. Moreover, we employ two dummy variables: $D_{t,i}^{Eligible}$, which is equal to one if *security* i is (hypothetically) eligible for purchase under the PSPP, and D_t^{QE}, which is equal to one after the introduction of the PSPP in March 2015. Additionally, we add ISIN-month-term fixed effects[30] and heteroscedasticity-robust standard errors. Trading in the special repo market is concentrated in the TN and SN term types; we therefore show our main results as a pooled regression in Table 2.3. We report our results for (i) Germany in columns 1–3, (ii) core European countries in columns 4–6, and (iii) all countries in columns 7–9.

Regression (1) relates changes in special repo rates to changes in the monetary policy target rate in the period prior to and after the introduction of the QE program. A more accommodative monetary policy that results in a decrease in the target rate by one percentage point translates into a decrease of around 11 basis points in special repo rates in the period prior to the PSPP. During the current period of unconventional monetary policy, the effect has

[30]The fixed effects capture all bond-specific properties that are constant within a month, for example, issue size or on-the-run status.

Table 2.3: Asset eligibility

	Germany			Core			All		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.106*** (19.644)	0.098*** (12.937)	0.109*** (13.130)	0.105*** (31.179)	0.095*** (17.681)	0.103*** (17.810)	0.099*** (30.205)	0.094*** (18.394)	0.101*** (18.358)
D^{QE}	−0.016 (−1.462)		−0.016 (−1.434)	−0.008 (−1.187)		−0.008 (−1.158)	−0.017* (−1.752)		−0.016* (−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.150*** (−15.837)		−0.120*** (−8.154)	−0.126*** (−19.814)		−0.104*** (−9.643)	−0.108*** (−17.339)		−0.089*** (−8.198)
$D^{Eligible}$		0.004 (0.454)	0.004 (0.440)		0.005 (0.972)	0.005 (0.969)		0.004 (0.669)	0.004 (0.649)
$\Delta PolRate \cdot D^{Eligible}$		0.006 (0.537)	−0.005 (−0.463)		0.011 (1.592)	0.002 (0.295)		0.004 (0.562)	−0.004 (−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.172*** (−14.035)	−0.052*** (−2.737)		−0.137*** (−17.552)	−0.033** (−2.453)		−0.117*** (−15.319)	−0.028** (−2.119)
$\Delta repo^{Special}$ lagged	−0.364*** (−20.719)	−0.364*** (−20.716)	−0.364*** (−20.719)	−0.357*** (−39.267)	−0.357*** (−39.259)	−0.357*** (−39.264)	−0.362*** (−51.918)	−0.362*** (−51.911)	−0.362*** (−51.915)
N	301,608	301,608	301,608	705,633	705,633	705,633	943,349	943,349	943,349
R^2	0.119	0.119	0.119	0.115	0.115	0.115	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing programs on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; *t*-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for Germany, core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

been muted. Although well expected, a new stylized fact emerges as special rates react less strongly to changes in the monetary policy target rate than more liquidity-driven GC rates. Still, also a special repo trade involves a funding motive and reacts to changes in funding conditions. In Regression (2), we consider the impact of market segmentation along the lines of asset eligibility for QE in a difference-in-difference setting. The dummy variable $D_{t,i}^{Eligible}$ measures whether the underlying collateral asset fulfills the eligibility criteria since the start of the program and whether it had (hypothetically) fulfilled the criteria in the prior periods. In order to be able to interpret the effect of asset eligibility as causal, we need to verify that the common trend assumption holds. This assumption holds if eligible and noneligible collateral asset behave similarly in the period prior to QE. We therefore apply the initial implementation provisions retrospectively. We observe that trades involving hypothetically eligible collateral asset do not exhibit significantly different changes in repo rates prior to QE; eligible and noneligible collateral assets also respond similarly to changes in the monetary policy rate during that period. In the pre-QE period, the common trend assumption therefore holds. However, since the start of QE, repo trades involving eligible collateral assets have a 17-basis-point lower sensitivity compared to noneligible collateral assets. This speaks to an effect caused by unconventional monetary policy. Our main Regression (3) captures both effects. The impact of changes in the monetary policy target rate on special repo rates is almost muted during QE, which is in particular driven by trades involving eligible collateral assets. In the period after the introduction of QE, a decrease in the target rate by one percentage point implies a decrease in the rates of noneligible collateral assets by five basis points more relative to eligible collateral assets. While the overall size of this effect seems to be small, it represents a 50% reduction relative to the overall sensitivity of special repo rates to changes in funding conditions. Graphically, this entails an increasing dispersion of special repo rates as depicted in Figure 2.3. This dispersion of money market rates results from the implementation of QE and is a sign of the central bank losing control of the yield curve and thus indicates monetary policy pass-through inefficiency.

Similar to the previous analyses, we perform a number of additional robustness checks to confirm our main results. First, columns 4–9 extend our analysis to core and all European countries, respectively. Second, we report the results for each term type and regional classification, and the results for different standard error and fixed effect specifications in the Online Appendix.[31] Overall, the results remain statistically and economically consistent.

Table 2.4: Asset eligibility: time since eligibility

	Germany		Core		All	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.106***	0.106***	0.105***	0.105***	0.099***	0.099***
	(19.643)	(19.643)	(31.179)	(31.179)	(30.205)	(30.205)
D^{QE}	−0.015	−0.016	−0.008	−0.008	−0.016*	−0.016*
	(−1.380)	(−1.423)	(−1.102)	(−1.157)	(−1.699)	(−1.736)
$\Delta PolRate \cdot D^{QE}$	−0.094***	−0.120***	−0.080***	−0.103***	−0.070***	−0.082***
	(−9.018)	(−8.469)	(−11.341)	(−9.773)	(−10.103)	(−7.509)
$\Delta PolRate \cdot TSE$	−0.001***		−0.001***		−0.001***	
	(−9.635)		(−9.882)		(−10.592)	
$\Delta PolRate*$						
TSE^1_{Bucket}		−0.008		−0.010		−0.022*
		(−0.486)		(−0.847)		(−1.802)
TSE^2_{Bucket}		−0.279***		−0.086**		−0.036
		(−5.995)		(−2.491)		(−1.344)
TSE^3_{Bucket}		−0.470***		−0.459***		−0.382***
		(−6.521)		(−9.542)		(−11.200)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.357***	−0.357***	−0.362***	−0.362***
	(−20.715)	(−20.716)	(−39.263)	(−39.265)	(−51.913)	(−51.917)
N	301,608	301,608	705,633	705,633	943,349	943,349
R^2	0.119	0.119	0.115	0.115	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through under particular consideration of the number of days an asset is eligible for purchase. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. TSE refers to the time since eligibility (i.e, the cumulative time an asset is eligible for purchase under the PSPP), which we split in three buckets: TSE^1_{Bucket} for assets which have (cumulatively) been eligible for up to 200 days, TSE^2_{Bucket} for assets which have been eligible for up to 400 days, and TSE^3_{Bucket} for assets which have been eligible for more than 400 days. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

To better understand the economic determinants of our results, we extend

[31] The presented results are also robust to shortening the period of analysis to the time before the changes to the QE program were implemented as well as to the inclusion of differently defined QE dummies (results are available from the authors).

our analysis by looking at asset scarcity associated with unconventional monetary policy in more detail. Our idea is that asset scarcity is stronger for those assets which have been QE eligible for a longer period (since the ECB had more opportunities to purchase those securities). We therefore introduce a new variable "time since eligibility" (TSE) which captures the number of days an asset has been eligible for purchase under the PSPP.[32]

Table 2.4 reports the regression results focusing on asset scarcity effects. We show two regression specifications: (i) by employing our new TSE variable, and (ii) by employing three TSE buckets with TSE^1_{Bucket} for assets which have been QE eligible for up to 200 trading days, TSE^2_{Bucket} for assets which have been eligible for up to 400 days, and TSE^3_{Bucket} for assets which have been eligible for more than 400 days. For all regressions, we replace our previous $D^{Eligible}_{t,i}$ dummy with the newly introduced TSE variable, interacted with the log-change in the monetary policy rate $\Delta PolRate_t$.

Regression (1) relates changes in special repo rates to changes in the monetary policy target rate under consideration of the TSE variable. We observe that the monetary policy pass-through into repo rates is weaker for those assets that have been eligible for purchase for a longer period. A one-percentage-point change in the target rate translates into a 0.1 basis points lower sensitivity in special repo rates for each day an asset is eligible for purchase. To put this number into perspective: Assets which are 100 days eligible for purchase have a 10 basis points lower sensitivity. Regression (2) shows that the lower sensitivity of eligible assets is particularly driven by those assets which have been eligible for the longest period. For example, assets which have been eligible for less than 200 trading days do not show a significantly different sensitivity compared to assets which have never been eligible for purchase. However, assets which have been eligible for up to 400 days, have a 28-basis-point lower sensitivity. For assets which have been eligible for more than 400 days, the effect increases to 47-basis-points. The results are consistent for core and all European countries as shown in columns 3–6.

Clearly, our results speak to the role of asset scarcity, as assets which have been eligible for purchase by the ECB for a longer period (scarcer assets) are

[32]TSE is a continuous variable which increases by one if asset i on day t was eligible for purchase under the PSPP. If an asset was eligible in the past but is not at the moment, the TSE variable keeps its value.

less sensitive to changes in the policy rate. This is in line with an upward movement in the demand curve for eligible assets.

2.4.3 Joint effects

So far, we have considered how accessibility to central bank deposits and eligibility for QE programs impact the monetary policy transmission independently. Now we analyze whether bank's access and QE might jointly contribute to the monetary policy disconnect. To our knowledge, we are the first to analyze (i) the QE impact on GC repos and (ii) whether lending rates of access and nonaccess banks diverge in the special market.

In the GC repo market, certain baskets contain a higher share of collateral assets that are eligible for asset purchases; thus, these baskets are more convenient for sourcing collateral assets that have become scarcer due to QE programs. This implies that lenders might accept lower rates on those baskets, which would be an additional source of rate dispersion impeding the monetary policy pass-through. We therefore compute the share of securities eligible for QE programs within the pool of collateral assets potentially deliverable into a GC basket as an indicator for the likelihood of obtaining a QE eligible asset as collateral, even in a GC transaction. Our data features a cross-section of 46 GC baskets for which we compute, at each point in time, the share, weighted by issuance volume, of the securities that can be used as collateral that are also (hypothetically) eligible for central bank asset purchases.[33]

For the panel regression, we ask whether baskets with a higher share of eligible securities react less strongly to changes in the monetary policy target rate, even after accounting for the banks' access to the ECB's deposit facility as a first form of market segmentation. For the regression, we follow the previously introduced approach for the GC market and newly introduce the dummy variable $D_{t,i}^{Eligible}$ for the GC market, which is equal to one if a basket i at time t has a (hypothetical) eligibility share higher than the median eligibility share across all baskets of that country at time t. As before, we add basket-

[33] Consider, for example, the Eurex GC Basket "German Bond GC." All bonds issued by the German sovereign with a fixed or zero coupon and a minimum issue size of 100 million euro can be used as collateral for this basket. For each trading day and basket, we compile a list of all bonds that meet these basket-specific criteria and evaluate whether these securities are (hypothetically) eligible for QE purchases. The sample is slightly smaller compared to the previous analysis for the GC market due to data availability.

Table 2.5: Joint effects of both forms of segmentation

	Germany			Core			All		
	(1a)	(1b)	(2)	(3a)	(3b)	(4)	(5a)	(5b)	(6)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{Special}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{Special}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{Special}$
	ON/TN b/t	ON/TN b/t	TN/SN b/t	ON/TN b/t	ON/TN b/t	TN/SN b/t	ON/TN b/t	ON/TN b/t	TN/SN b/t
$\Delta PolRate$	0.475***	0.599***	0.159***	0.576***	0.606***	0.154***	0.606***	0.653***	0.160***
	(5.030)	(6.026)	(12.959)	(10.521)	(10.483)	(17.617)	(12.420)	(12.430)	(18.668)
D^{Dep}	−0.067**	−0.066**	0.015***	−0.037***	−0.037***	0.005	−0.024**	−0.024**	0.006**
	(−2.456)	(−2.400)	(2.794)	(−2.699)	(−2.733)	(1.575)	(−2.077)	(−2.095)	(2.147)
$\Delta PolRate \cdot D^{Dep}$	0.361***	0.458***	0.012	0.383***	0.389***	0.103***	0.349***	0.362***	0.105***
	(2.692)	(2.814)	(0.416)	(4.260)	(4.343)	(4.510)	(4.165)	(4.358)	(4.686)
D^{Access}	−0.004	−0.003	−0.005***	−0.006	−0.006	−0.005***	−0.005	−0.005	−0.005***
	(−0.265)	(−0.193)	(−2.582)	(−1.018)	(−0.940)	(−4.127)	(−0.908)	(−0.794)	(−4.455)
$\Delta PolRate \cdot D^{Access}$	−0.181**	−0.183*	−0.062***	−0.260***	−0.265***	−0.063***	−0.311***	−0.311***	−0.074***
	(−2.015)	(−1.836)	(−5.181)	(−4.594)	(−4.732)	(−7.875)	(−6.132)	(−6.135)	(−9.305)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.606***	−0.795***	−0.161***	−0.456***	−0.525***	−0.225***	−0.402***	−0.477***	−0.214***
	(−3.775)	(−4.232)	(−5.413)	(−4.341)	(−4.890)	(−9.418)	(−4.035)	(−4.719)	(−8.988)
D^{QE}	−0.113	−0.119	−0.014	−0.047	−0.053	−0.007	−0.056	−0.062	−0.012
	(−1.489)	(−1.519)	(−1.231)	(−1.340)	(−1.503)	(−0.983)	(−1.071)	(−1.191)	(−1.309)
$D^{Eligible}$	−0.017	−0.008	0.003	−0.010**	0.010*	0.005	−0.010**	0.007	0.005
	(−1.509)	(−0.681)	(0.371)	(−2.047)	(1.910)	(0.911)	(−2.180)	(1.603)	(0.908)
$\Delta PolRate \cdot D^{Eligible}$	0.252***	0.045	−0.006	0.141***	0.077*	0.006	0.102**	0.006	0.005
	(3.338)	(0.490)	(−0.541)	(3.255)	(1.782)	(0.816)	(2.576)	(0.138)	(0.643)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.315***	−0.040	−0.097***	−0.429***	−0.301***	−0.104***	−0.349***	−0.220***	−0.110***
	(−2.872)	(−0.261)	(−5.713)	(−6.802)	(−5.256)	(−9.822)	(−5.467)	(−3.633)	(−11.432)
$\Delta repo$ lagged	−0.340***	−0.341***	−0.364***	−0.338***	−0.338***	−0.357***	−0.337***	−0.338***	−0.360***
	(−11.817)	(−11.603)	(−20.711)	(−22.734)	(−22.683)	(−35.249)	(−24.814)	(−24.821)	(−40.685)
N	6,802	6,484	301,475	30,314	29,996	628,208	37,453	37,135	759,772
R^2	0.262	0.255	0.119	0.239	0.237	0.115	0.233	0.231	0.118

The table reports the regression results examining the simultaneous impact of ECB access and asset eligibility on the pass-through of the monetary policy target rate into GC and special repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$ respectively the change in the special rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility rate. D^{Access} equals 1 if a lending bank has access to the deposit facility. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 in the GC segment in columns 1a/3a/5a if a basket i at point t has a higher share of eligible securities than the median basket for that country. In columns 1b/3b/5b it equals 1 if the cheapest-to-deliver bond in basket i at point t is eligible. In the special segment $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-/ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC and special repo transactions for Germany, core European countries and all European countries pooled across the term types ON, TN, and SN for the time-period 2010–2018.

month-term fixed effects and employ heteroscedasticity-robust standard errors. We show our main results as a pooled regression of the term types ON and TN in Table 2.5. We report our results for (i) Germany in column 1a, (ii) core European countries in column 3a, and (iii) all countries in column 5a.

In addition to confirming our previous results, we find in Regression (1a) that trades involving baskets with high and low eligibility shares respond differently to changes in the monetary policy rate, even after controlling for the banks' access to the deposit facility. Prior to the introduction of QE, baskets with a hypothetically higher share of eligible collateral assets tended to react slightly more. However, since the start of QE, repo trades involving baskets with a higher share of eligible securities are less sensitive to changes in the monetary policy target rate, more than undoing the baseline effect. In the period after the introduction of QE, an accomodative monetary policy with a decrease in the target rate by one percentage point is associated with a seven-basis-point smaller decrease in the rates of baskets with a higher eligibility share relative to baskets with a lower eligibility share. Comparing the economic magnitude, access to central bank facilities remains the more pronounced effect.

In a GC repo, certain collateral assets may be more likely to be delivered than others. In particular, it is possible to identify the 'cheapest-to-deliver' collateral asset, which is the asset that commands the highest repo rate in the special market segment and thus features the smallest specialness. As an alternative to our volume-based measure of basket eligibility, we also employ the eligibility of the cheapest-to-deliver bond as a measure of basket eligibility. The results based on this classification are reported for (i) Germany in column 1b, (ii) core European countries in column 3b, and (iii) all countries in column 5b. We find that our results are robust to this alternative specification.

We now turn to the joint effects on special repos. To do this, we perform a similar set of panel regressions as introduced for the GC market to jointly account for both forms of segmentation. In the regression setting, $D_{t,i}^{Eligible}$ equals one if *security* i is (hypothetically) eligible for purchase under the PSPP. We add ISIN-month-term fixed effects and employ heteroscedasticity-robust standard errors. The results for the pooled regression for the term types TN and SN are shown for (i) Germany in column 2, (ii) core European countries in column 4, and (iii) all countries in column 6.

Regression (2) confirms that both forms of market segmentation are also present in the special repo market. A one-percentage-point change in the monetary policy rate translates into a 16 basis point lower sensitivity of access banks relative to nonaccess banks during periods when the GC rate is below the rate on the deposit facility, and into a 10 basis point lower sensitivity of eligible collateral relative to noneligible collateral during the recent period of unconventional monetary policy. The overall sensitivities of access and nonaccess banks in the special market are smaller than in the GC market, however, the relative magnitude of the effect is comparable. For a graphical comparison, the impulse response functions of access and nonaccess banks in the two market segments are depicted in Figure A.4.1 in the Appendix. Columns 3–6 expand our analysis by looking at larger samples. Again, the results remain statistically and economically consistent when we extend our sample to core and all European countries.

Overall, two new findings arise from the analysis of the joint effects: First, the pass-through of the monetary policy target rate in the GC market has been additionally impeded by the implementation of QE suggesting a pervasive effect of the asset scarcity coming from QE in the entire repo market. Second, the monetary policy disconnect through special repos depends on the access to central bank's operations. Apparently, the co-existence of both forms of rate dispersion complicates the monetary policy implementation even further.

2.5 Alternative policy measures

To underline the robustness of our results we experiment with alternative policy rates. Our (i) baseline rate is the EONIA, a weighted average of the interest rates on unsecured overnight lending transactions denominated in euros, as reported by a panel of contributing banks. It is (indirectly) determined by the rates that the ECB sets on its standing facilities. In 2017, the ECB announced that the euro short-term rate (€STR) will replace the EONIA as the new short-term interest rate benchmark in the euro area. The €STR rate reflects the wholesale euro unsecured overnight borrowing costs of banks located in the euro area, and thus covers the borrowing cost of a larger set of banks as compared to the EONIA. Historical €STR rates date back to the 15th of March 2017. As a (ii) second rate, we therefore consider an EONIA-€STR combination with the €STR rate replacing the EONIA after its publication. As a (iii) third, unsecured reference rate, we consider the overnight euro LIBOR rate. Since monetary policy shapes expectations about future short-term interest rates, we also consider a set of derivatives-based, forward-looking overnight interest rates. We employ (iv) the overnight point of the Overnight Index Swap (OIS)–implied zero curve which uses one-month, three-month, and six-month OIS derivatives, as well as (v) the overnight point of the EURIBOR-implied zero curve, which uses one-month, three-month, and six-month EURIBOR derivatives. As an (vi) additional rate, we consider the one-week OIS rate.[34] Finally,

[34]Since we observe daily closing prices for the derivatives-based measures from Thomson Reuters/Refinitiv Eikon, we relate changes in policy rates over two days to daily rate changes in repo rates.

Table 2.6: ECB access: alternative policy measures

	(1) EONIA $\Delta repo^{GC}$ ON/TN b/t	(2) €STR $\Delta repo^{GC}$ ON/TN b/t	(3) euro LIBOR $\Delta repo^{GC}$ ON/TN b/t	(4) zero OIS $\Delta repo^{GC}$ ON/TN b/t	(5) zero EURIBOR $\Delta repo^{GC}$ ON/TN b/t	(6) OIS 1W $\Delta repo^{GC}$ ON/TN b/t	(7) GC Pooling $\Delta repo^{GC}$ ON/TN b/t
$\Delta PolRate$	0.675***	0.705***	0.480***	0.334***	0.179***	0.329***	0.723***
	(8.781)	(9.274)	(9.220)	(6.013)	(5.055)	(4.349)	(14.246)
D^{Dep}	−0.047**	−0.026**	−0.051**	−0.021	−0.029**	−0.029**	−0.041**
	(−2.338)	(−2.059)	(−2.520)	(−1.564)	(−2.061)	(−2.249)	(-2.108)
$\Delta PolRate \cdot D^{Dep}$	0.265**	0.253**	0.356***	0.268**	0.179**	0.363***	0.277**
	(2.082)	(2.086)	(4.003)	(2.571)	(2.196)	(3.249)	(2.320)
D^{Access}	−0.000	0.002	0.004	0.001	−0.004	0.001	−0.005
	(−0.035)	(0.183)	(0.339)	(0.120)	(−0.361)	(0.090)	(−0.482)
$\Delta PolRate \cdot D^{Access}$	−0.177**	−0.128	−0.117*	−0.165***	−0.072*	−0.046	−0.162***
	(−2.100)	(−1.474)	(−1.743)	(−2.702)	(−1.887)	(−0.516)	(−2.702)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.719***	−0.648***	−0.670***	−0.378***	−0.264***	−0.258*	−0.657***
	(−4.970)	(−4.425)	(−5.607)	(−3.377)	(−3.058)	(−1.740)	(−4.166)
$\Delta repo^{GC}$ lagged	−0.332***	−0.311***	−0.420***	−0.323***	−0.311***	−0.324***	−0.307***
	(−14.151)	(−12.972)	(−15.125)	(−12.711)	(−12.876)	(−12.113)	(−11.913)
N	10,001	10,158	9,952	9,778	9,758	10,078	10,060
R^2	0.220	0.231	0.187	0.124	0.114	0.144	0.297

The table reports the robustness results examining the impact of access to the ECB's deposit facility on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in different policy rates. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

we employ the (vii) rate on the ECB GC Pooling Basket. The GC Pooling Basket is the primary GC funding basket, the basket not only enables the re-use of received collateral for central bank refinancing operations it also features a large trading volume and no counterparty credit risk due to trading via a central counterparty.

Table 2.6 reports the results of our baseline specification in the GC market for the seven policy rates described above. We present the results for German repo transactions. In the GC market, the estimations are statistically and economically consistent across all specifications. Three key results emerge from this analysis: First, GC repo rates are more sensitive to changes in unsecured overnight rates as compared to derivative-based implied overnight rates. This makes sense intuitively since we expect the conditions in the unsecured market to be a key determinant of trades in the secured market. In line with this intuition, the explanatory power of our panel regressions is largest for changes

Table 2.7: Asset eligibility: alternative policy measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.109***	0.109***	0.105***	0.054***	0.046***	0.101***	0.117***
	(13.130)	(13.130)	(11.394)	(9.442)	(9.250)	(12.053)	(13.854)
D^{QE}	−0.016	−0.016	−0.040***	−0.028**	−0.031**	−0.039***	0.042***
	(−1.434)	(−1.421)	(−3.105)	(−2.303)	(−2.465)	(−3.456)	(3.461)
$\Delta PolRate \cdot D^{QE}$	−0.120***	−0.116***	−0.109***	−0.025***	−0.019***	−0.039**	0.406***
	(−8.154)	(−7.867)	(−9.346)	(−3.565)	(−2.984)	(−2.427)	(6.250)
$D^{Eligible}$	0.004	0.004	0.003	0.003	0.002	0.002	0.002
	(0.440)	(0.435)	(0.316)	(0.314)	(0.254)	(0.187)	(0.202)
$\Delta PolRate \cdot D^{Eligible}$	−0.005	−0.005	−0.000	0.015**	0.002	−0.022**	0.013
	(−0.463)	(−0.463)	(−0.015)	(1.987)	(0.355)	(−2.059)	(1.172)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.052***	−0.044**	−0.023	−0.031***	−0.017**	−0.023	−0.216***
	(−2.737)	(−2.289)	(−1.491)	(−3.346)	(−2.021)	(−1.086)	(−2.972)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.365***	−0.363***	−0.363***	−0.359***	−0.356***
	(−20.719)	(−20.719)	(−20.277)	(−19.856)	(−19.668)	(−20.195)	(−69.536)
N	301,608	301,608	299,889	290,153	289,058	298,718	303,446
R^2	0.119	0.119	0.120	0.119	0.120	0.116	0.119

The table reports the robustness results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; *t*-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

in unsecured overnight rates, which confirms our approach of employing the EONIA across our baseline specifications. Second, our results hold true if we employ the rate on the ECB GC Pooling Basket as our policy rate, which reinforces our interpretation that the monetary policy disconnect stems from institutional differences within the central bank framework as opposed to a segmentation between different market segments. And third, all regressions arrive at the same conclusion, that is, access banks are less sensitive to changes in monetary policy target rates, in particular, when the GC rate is below the rate on the deposit facility.

Table 2.7 reports the results of our baseline specification in the special market. Our results on special repos are also consistent if we employ alternative policy measures. Again, special repo rates are more sensitive to changes in unsecured overnight rates as compared to derivative-based implied overnight rates. Overall, the results confirm that eligible securities are less sensitive to changes in monetary policy target rates since the start of the ECB's QE program. This lower sensitivity has not been present in prior periods.

2.6 Conclusion and outlook

Monetary policy is most effective if money market rates react consistently and uniformly to the monetary policy stance. We point out that two key aspects of the current central bank framework lead to a dispersion in money market rates thus weakening the transmission of monetary policy.

The first aspect of the central bank framework relates to banks' access to the central bank's deposit facility. We show that those banks with access lend at short-term rates that are more misaligned from the monetary policy target rate when repo rates hover below the deposit facility rate. This new finding provides a novel perspective for assessing the effectiveness of monetary policy transmission depending on who has access to the central bank's facilities. Its consequences are relevant for some recent policies. For instance, the European Commission issued amendments to the Capital Requirements Regulation (CRR), at the heart of which is the (temporary) exclusion of central bank reserves from the calculation of the leverage ratio (European Commission, 2020). Similarly, the two-tier system partially exempts banks from negative rates currently applicable on the deposit facility. Both measures could encourage further accumulation of central bank reserves thereby weakening the monetary policy transmission.

The second aspect of the central bank framework relates to unconventional asset purchasing programs. We show that secured loans whose collateral assets are the target of Quantitative Easing programs are more disconnected from the monetary policy rate. The notion that unconventional policies "safeguard the transmission of our monetary policy," as pointed out by ECB President Christine Lagarde (European Central Bank, 2020) should also consider that those programs can indeed create rate dispersion leading to unintended consequences such as the monetary policy disconnect.

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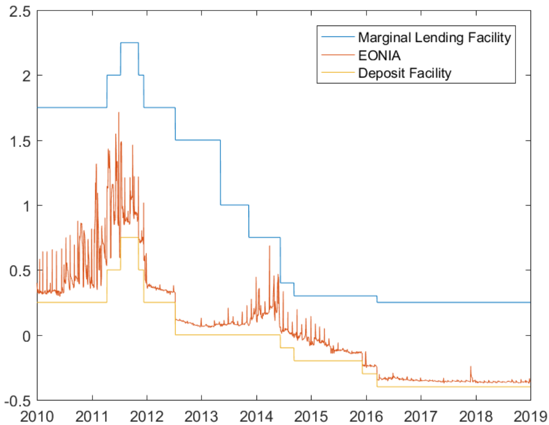
Appendix

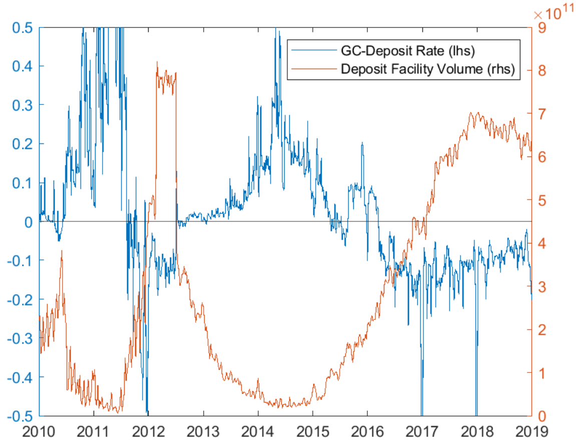
A.1 Monetary policy



The figure depicts the development of the rates on the deposit and marginal lending facility as well as the EONIA rate. The rates on the deposit and marginal lending facility define the corridor for the EONIA as the unsecured, overnight interest rate at which banks lend to each other.

Figure A.1.1: Interest rate corridor

A.2 Deposit facility volume

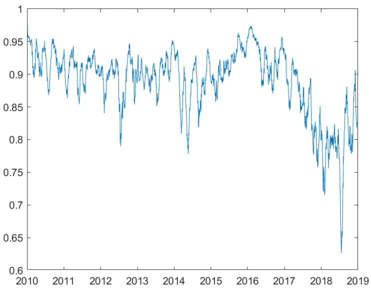


The figure depicts the spread between the German GC rate and the ECB's rate on the deposit facility as well as the total volume deposited at the ECB deposit facility.

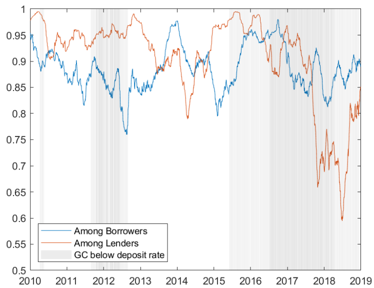
Figure A.2.1: Deposit facility volume and spread between GC and deposit facility rate

A.3 Trading share of access banks

Since 2015, when repo rates fell below the rate on the deposit facility, GC trading volume declined to about a third of its original size. This reduction was mainly driven by banks that had access to the central bank's deposit facility, banks without access to the deposit facility still used the lending side in GC repo transactions to deposit their liquidity. Figure A.3.1a depicts the trading share of access banks in general collateral repo transactions collateralized by German government bonds. The share of trading volume by access banks dropped from around 95% in the period prior to QE to around 80% more recently.



(a) Total share by access banks



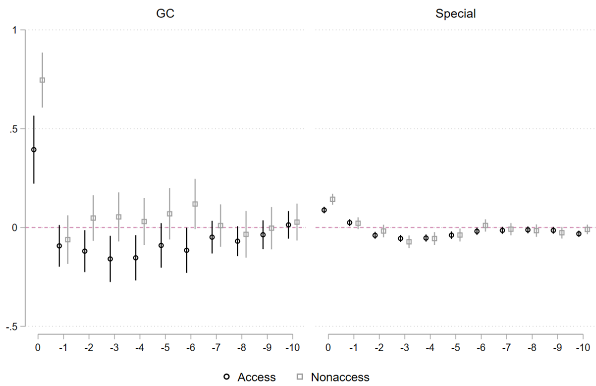
(b) Share by access borrowers/lenders

Figure A.3.1a depicts the trading share of access banks in general collateral repo transactions collateralized by German government bonds. Figure A.3.1b depicts the share of access banks among borrowers and among lenders in the German GC market.

Figure A.3.1: Trading shares of access banks

In section 2.2.4 we argue that the GC market is characterized by a kinked demand curve from access banks while the demand from nonaccess banks is inelastic. We thus conclude that the increase in trading volume by nonaccess banks as depicted in Figure A.3.1a results from fewer lending activities by access banks. This can be observed in the data, as shown in Figure A.3.1b. In this graph, we depict the share of access banks among borrowers and among lenders in the GC market. While we observe that the share of access banks among borrowers has been stable over time, we observe that the share of access banks among lenders has dropped in recent years. We thus conclude that the drop in trading by access banks has been caused by a reduction in their lending activity.

A.4 Nonaccess banks in the special market

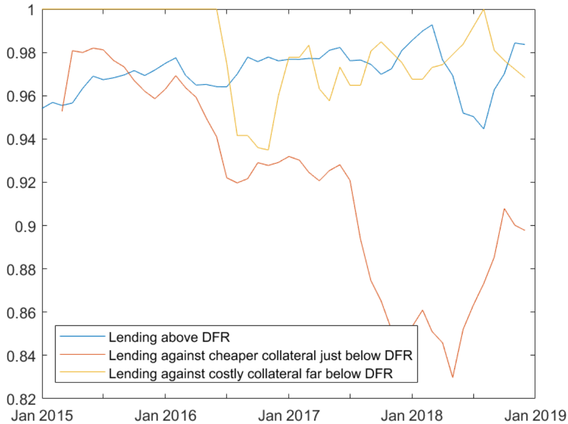


The figure depicts the impulse response function of repo rates to changes in the monetary policy target rate for trades involving access and nonaccess banks in the GC market (left panel) and the special market (right panel).

Figure A.4.1: Impulse response for German trades in the GC and special market involving access/nonaccess banks

Online appendix

OA.1 Trading share of access banks in the GC below DFR environment



The figure depicts the volume-weighted share of access banks in total trading volume during the most recent period in which GC rates hovered below the deposit facility rate (DFR). The share is depicted in three subgroups: trades against collateral baskets trading above the DFR, trades involving cheaper collateral baskets just trading below the DFR and trades involving costly collateral baskets trading far below the DFR (by at least 20BP).

Figure OA.1.1: Trading share of access banks in the GC<DFR environment

OA.2 Robustness results for ECB access

Results by region, pooled across term types

Table OA.2.1: ECB access: Germany

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.539***	0.717***	0.675***
	(15.700)	(10.745)	(8.781)
D^{Dep}	−0.046**		−0.047**
	(−2.265)		(−2.338)
$\Delta PolRate \cdot D^{Dep}$	−0.176**		0.265**
	(−2.216)		(2.082)
D^{Access}		−0.001	−0.000
		(−0.071)	(−0.035)
$\Delta PolRate \cdot D^{Access}$		−0.264***	−0.177**
		(−3.549)	(−2.100)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.719***
			(−4.970)
$\Delta repo^{GC}$ lagged	−0.332***	−0.332***	−0.332***
	(−14.230)	(−14.147)	(−14.151)
N	10,001	10,001	10,001
R^2	0.210	0.213	0.220

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.2: ECB access: Core countries

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.472***	0.683***	0.643***
	(23.035)	(16.875)	(14.261)
D^{Dep}	−0.032***		−0.032***
	(−2.940)		(−2.922)
$\Delta PolRate \cdot D^{Dep}$	−0.048		0.298***
	(−0.897)		(3.968)
D^{Access}		−0.005	−0.004
		(−0.819)	(−0.743)
$\Delta PolRate \cdot D^{Access}$		−0.284***	−0.222***
		(−6.242)	(−4.423)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.561***
			(−5.885)
$\Delta repo^{GC}$ lagged	−0.337***	−0.335***	−0.335***
	(−24.685)	(−24.388)	(−24.410)
N	35,082	35,082	35,082
R^2	0.180	0.185	0.187

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for core European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.3: ECB access: All countries

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.424***	0.589***	0.560***
	(24.699)	(16.774)	(15.106)
D^{Dep}	0.001		0.002
	(0.143)		(0.221)
$\Delta PolRate \cdot D^{Dep}$	0.011		0.384***
	(0.220)		(5.668)
D^{Access}		−0.003	−0.003
		(−0.755)	(−0.709)
$\Delta PolRate \cdot D^{Access}$		−0.223***	−0.184***
		(−5.687)	(−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.595***
			(−6.733)
$\Delta repo^{GC}$ lagged	−0.372***	−0.371***	−0.371***
	(−30.291)	(−30.133)	(−30.167)
N	58,183	58,183	58,183
R^2	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for all European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.4: ECB access: Germany, core countries and all countries

		Germany			Core			All	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.539*** (15.700)	0.717*** (10.745)	0.675*** (8.781)	0.472*** (23.035)	0.683*** (16.875)	0.643*** (14.261)	0.424*** (24.699)	0.589*** (16.774)	0.560*** (15.106)
D^{Dep}	−0.046** (−2.265)		−0.047** (−2.338)	−0.032*** (−2.940)		−0.032*** (−2.922)	0.001 (0.143)		0.002 (0.221)
$\Delta PolRate \cdot D^{Dep}$	−0.176** (−2.216)		0.265** (2.082)	−0.048 (−0.897)		0.298*** (3.968)	0.011 (0.220)		0.384*** (5.668)
D^{Access}		−0.001 (−0.071)	−0.000 (−0.035)		−0.005 (−0.819)	−0.004 (−0.743)		−0.003 (−0.755)	−0.003 (−0.709)
$\Delta PolRate \cdot D^{Access}$		−0.264*** (−3.549)	−0.177** (−2.100)		−0.284*** (−6.242)	−0.222*** (−4.423)		−0.223*** (−5.687)	−0.184*** (−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.719*** (−4.970)			−0.561*** (−5.885)			−0.595*** (−6.733)
$\Delta repo^{GC}$ lagged	−0.332*** (−14.230)	−0.332*** (−14.147)	−0.332*** (−14.151)	−0.337*** (−24.685)	−0.335*** (−24.388)	−0.335*** (−24.410)	−0.372*** (−30.291)	−0.371*** (−30.133)	−0.371*** (−30.167)
N	10,001	10,001	10,001	35,082	35,082	35,082	58,183	58,183	58,183
R^2	0.210	0.213	0.220	0.180	0.185	0.187	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for Germany, core European countries, and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.5: ECB access: Core countries and all countries

		Core			All	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.472*** (23.035)	0.683*** (16.875)	0.643*** (14.261)	0.424*** (24.699)	0.589*** (16.774)	0.560*** (15.106)
D^{Dep}	−0.032*** (−2.940)		−0.032*** (−2.922)	0.001 (0.143)		0.002 (0.221)
$\Delta PolRate \cdot D^{Dep}$	−0.048 (−0.897)		0.298*** (3.968)	0.011 (0.220)		0.384*** (5.668)
D^{Access}		−0.005 (−0.819)	−0.004 (−0.743)		−0.003 (−0.755)	−0.003 (−0.709)
$\Delta PolRate \cdot D^{Access}$		−0.284*** (−6.242)	−0.222*** (−4.423)		−0.223*** (−5.687)	−0.184*** (−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.561*** (−5.885)			−0.595*** (−6.733)
$\Delta repo^{GC}$ lagged	−0.337*** (−24.685)	−0.335*** (−24.388)	−0.335*** (−24.410)	−0.372*** (−30.291)	−0.371*** (−30.133)	−0.371*** (−30.167)
N	35,082	35,082	35,082	58,183	58,183	58,183
R^2	0.180	0.185	0.187	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for core European countries and all European countries pooled across the term types ON and TN for the time-period 2010–2018.

Results by region and term type

Table OA.2.6: ECB access: Germany

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON	TN	ON/TN	ON	TN	ON/TN	ON	TN	ON/TN
	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t
$\Delta PolRate$	0.742***	0.456***	0.539***	0.646***	0.760***	0.717***	0.601***	0.719***	0.675***
	(10.017)	(11.476)	(15.700)	(6.547)	(8.970)	(10.745)	(5.285)	(7.428)	(8.781)
D^{Dep}	−0.042	−0.045*	−0.046**				−0.043	−0.047**	−0.047**
	(−1.102)	(−1.890)	(−2.265)				(−1.136)	(−1.986)	(−2.338)
$\Delta PolRate \cdot D^{Dep}$	−0.130	−0.210**	−0.176**				0.238	0.287	0.265**
	(−0.891)	(−2.229)	(−2.216)				(1.477)	(1.614)	(2.082)
D^{Access}				−0.003	0.001	−0.001	−0.001	0.001	−0.000
				(−0.142)	(0.067)	(−0.071)	(−0.080)	(0.074)	(−0.035)
$\Delta PolRate \cdot D^{Access}$				0.114	−0.424***	−0.264***	0.194	−0.337***	−0.177***
				(0.912)	(−4.685)	(−3.549)	(1.387)	(−3.274)	(−2.100)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$							−0.625**	−0.760***	−0.719***
							(−2.461)	(−4.037)	(−4.970)
$\Delta repo^{GC}$ lagged	−0.311***	−0.326***	−0.332***	−0.311***	−0.321***	−0.332***	−0.313***	−0.321***	−0.332***
	(−7.411)	(−11.237)	(−14.230)	(−7.531)	(−10.978)	(−14.147)	(−7.491)	(−11.027)	(−14.151)
N	2,828	7,173	10,001	2,828	7,173	10,001	2,828	7,173	10,001
R^2	0.332	0.161	0.210	0.332	0.172	0.213	0.336	0.179	0.220

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German GC repo transactions separate for each and pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.7: ECB access: Core countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON b/t	TN b/t	ON/TN b/t	ON b/t	TN b/t	ON/TN b/t	ON b/t	TN b/t	ON/TN b/t
$\Delta PolRate$	0.679*** (15.740)	0.376*** (16.033)	0.472*** (23.035)	0.810*** (13.089)	0.624*** (11.957)	0.683*** (16.875)	0.801*** (10.747)	0.576*** (10.245)	0.643*** (14.261)
D^{Dep}	−0.020 (−1.132)	−0.037*** (−2.682)	−0.032*** (−2.940)				−0.017 (−1.014)	−0.038*** (−2.794)	−0.032*** (−2.922)
$\Delta PolRate \cdot D^{Dep}$	−0.219*** (−2.637)	0.030 (0.438)	−0.048 (−0.897)				0.045 (0.472)	0.450*** (4.129)	0.298*** (3.968)
D^{Access}				−0.002 (−0.231)	−0.006 (−0.801)	−0.005 (−0.819)	−0.002 (−0.226)	−0.005 (−0.685)	−0.004 (−0.743)
$\Delta PolRate \cdot D^{Access}$				−0.201*** (−2.692)	−0.324*** (−5.644)	−0.284*** (−6.242)	−0.155* (−1.782)	−0.263*** (−4.261)	−0.222*** (−4.423)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$							−0.528*** (−3.986)	−0.604*** (−4.584)	−0.561*** (−5.885)
$\Delta repo^{GC}$ lagged	−0.302*** (−15.168)	−0.345*** (−18.622)	−0.337*** (−24.685)	−0.303*** (−15.259)	−0.340*** (−18.181)	−0.335*** (−24.388)	−0.303*** (−15.180)	−0.341*** (−18.237)	−0.335*** (−24.410)
N	12,219	22,863	35,082	12,219	22,863	35,082	12,219	22,863	35,082
R^2	0.253	0.143	0.180	0.254	0.150	0.185	0.257	0.153	0.187

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for core European countries separate for each and pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.8: ECB access: All countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON b/t	TN b/t	ON/TN b/t	ON b/t	TN b/t	ON/TN b/t	ON b/t	TN b/t	ON/TN b/t
$\Delta PolRate$	0.660*** (19.491)	0.304*** (15.542)	0.424*** (24.699)	0.708*** (10.666)	0.520*** (12.869)	0.589*** (16.774)	0.694*** (9.670)	0.484*** (11.494)	0.560*** (15.106)
D^{Dep}	0.033*** (2.675)	−0.020* (−1.775)	0.001 (0.143)				0.034*** (2.774)	−0.020* (−1.775)	0.002 (0.221)
$\Delta PolRate \cdot D^{Dep}$	−0.200** (−2.562)	0.122* (1.882)	0.011 (0.220)				0.169* (1.808)	0.525*** (5.546)	0.384*** (5.668)
D^{Access}				−0.002 (−0.302)	−0.004 (−0.726)	−0.003 (−0.755)	−0.002 (−0.273)	−0.004 (−0.674)	−0.003 (−0.709)
$\Delta PolRate \cdot D^{Access}$				−0.085 (−1.152)	−0.279*** (−6.199)	−0.223*** (−5.687)	−0.047 (−0.594)	−0.240*** (−5.104)	−0.184*** (−4.438)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$							−0.657*** (−5.109)	−0.595*** (−5.022)	−0.595*** (−6.733)
$\Delta repo^{GC}$ lagged	−0.324*** (−15.436)	−0.382*** (−25.063)	−0.372*** (−30.291)	−0.324*** (−15.482)	−0.381*** (−24.915)	−0.371*** (−30.133)	−0.324*** (−15.452)	−0.381*** (−24.929)	−0.371*** (−30.167)
N	21,894	36,289	58,183	21,894	36,289	58,183	21,894	36,289	58,183
R^2	0.248	0.140	0.174	0.248	0.145	0.177	0.250	0.147	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for all European countries separate for each and pooled across the term types ON and TN for the time-period 2010–2018.

Results for different fixed effect specifications

Table OA.2.9: ECB access: Germany, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.675***	0.684***	0.712***	0.725***	0.725***
	(8.781)	(9.301)	(9.197)	(8.733)	(8.709)
D^{Dep}	−0.047**	−0.047**	−0.027**	−0.032***	−0.021*
	(−2.338)	(−2.274)	(−2.068)	(−3.605)	(−1.795)
$\Delta PolRate \cdot D^{Dep}$	0.265**	0.269**	0.279**	0.313**	0.293**
	(2.082)	(2.350)	(2.225)	(2.358)	(2.228)
D^{Access}	−0.000	−0.002	0.003	0.002	0.003
	(−0.035)	(−0.147)	(0.265)	(0.155)	(0.339)
$\Delta PolRate \cdot D^{Access}$	−0.177**	−0.149*	−0.130	−0.138	−0.139
	(−2.100)	(−1.766)	(−1.456)	(−1.461)	(−1.468)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.719***	−0.686***	−0.665***	−0.591***	−0.583***
	(−4.970)	(−4.821)	(−4.400)	(−3.616)	(−3.608)
$\Delta repo^{GC}$ lagged	−0.332***	−0.321***	−0.307***	−0.298***	−0.299***
	(−14.151)	(−14.032)	(−12.483)	(−12.005)	(−12.072)
FE	Basket× Month× Term	Basket× Month	Basket× Year	Basket	Year
N	10,001	10,098	10,165	10,168	10,168
R^2	0.220	0.239	0.227	0.220	0.223

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.10: ECB access: Core countries, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.643***	0.672***	0.709***	0.716***	0.715***
	(14.261)	(15.044)	(15.028)	(14.735)	(14.721)
D^{Dep}	−0.032***	−0.027**	−0.019***	−0.018***	−0.015**
	(−2.922)	(−2.434)	(−2.594)	(−4.059)	(−2.243)
$\Delta PolRate \cdot D^{Dep}$	0.298***	0.293***	0.298***	0.326***	0.310***
	(3.968)	(4.140)	(3.908)	(4.127)	(3.966)
D^{Access}	−0.004	−0.004	−0.002	−0.003	−0.001
	(−0.743)	(−0.662)	(−0.331)	(−0.487)	(−0.156)
$\Delta PolRate \cdot D^{Access}$	−0.222***	−0.230***	−0.227***	−0.227***	−0.225***
	(−4.423)	(−4.565)	(−4.262)	(−4.162)	(−4.126)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.561***	−0.512***	−0.482***	−0.429***	−0.423***
	(−5.885)	(−5.599)	(−5.029)	(−4.262)	(−4.230)
$\Delta repo^{GC}$ lagged	−0.335***	−0.327***	−0.310***	−0.303***	−0.304***
	(−24.410)	(−23.978)	(−22.599)	(−22.093)	(−22.134)
FE	Basket× Month× Term	Basket× Month	Basket× Year	Basket	Year
N	35,082	35,376	35,624	35,631	35,631
R^2	0.187	0.199	0.192	0.188	0.190

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include GC repo transactions for core European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.11: ECB access: All countries, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.560^{***}	0.583^{***}	0.616^{***}	0.622^{***}	0.621^{***}
	(15.106)	(15.963)	(16.619)	(16.527)	(16.500)
D^{Dep}	0.002	0.005	−0.002	-0.011^{***}	−0.002
	(0.221)	(0.553)	(−0.311)	(−2.815)	(−0.530)
$\Delta PolRate \cdot D^{Dep}$	0.384^{***}	0.383^{***}	0.397^{***}	0.429^{***}	0.417^{***}
	(5.668)	(5.995)	(5.843)	(6.082)	(5.976)
D^{Access}	−0.003	−0.004	−0.003	−0.004	−0.003
	(−0.709)	(−0.816)	(−0.746)	(−1.009)	(−0.904)
$\Delta PolRate \cdot D^{Access}$	-0.184^{***}	-0.188^{***}	-0.190^{***}	-0.182^{***}	-0.180^{***}
	(−4.438)	(−4.586)	(−4.537)	(−4.259)	(−4.217)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	-0.595^{***}	-0.533^{***}	-0.495^{***}	-0.454^{***}	-0.444^{***}
	(−6.733)	(−6.303)	(−5.567)	(−4.889)	(−4.817)
$\Delta repo^{GC}$ lagged	-0.371^{***}	-0.363^{***}	-0.347^{***}	-0.342^{***}	-0.342^{***}
	(−30.167)	(−30.027)	(−28.923)	(−28.550)	(−28.577)
FE	Basket× Month× Term	Basket× Month	Basket× Year	Basket	Year
N	58,183	58,626	58,983	58,996	58,997
R^2	0.178	0.191	0.188	0.186	0.188

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include GC repo transactions for all European countries pooled across the term types ON and TN for the time-period 2010–2018.

Results for clustered standard errors

Table OA.2.12: ECB access: Germany

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.539*	0.717*	0.675*
	(7.367)	(10.556)	(9.705)
D^{Dep}	−0.046		−0.047
	(−4.366)		(−4.723)
$\Delta PolRate \cdot D^{Dep}$	−0.176		0.265
	(−0.631)		(3.538)
D^{Access}		−0.001	−0.000
		(−0.126)	(−0.060)
$\Delta PolRate \cdot D^{Access}$		−0.264**	−0.177*
		(−15.995)	(−12.534)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.719*
			(−11.802)
$\Delta repo^{GC}$ lagged	−0.332**	−0.332**	−0.332**
	(−34.857)	(−55.699)	(−31.902)
N	10,001	10,001	10,001
R^2	0.210	0.213	0.220

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates using clustered standard errors. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and standard errors accounting for clustering at the basket and access level. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.13: ECB access: Core countries

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.472*	0.683**	0.643**
	(6.571)	(16.968)	(17.549)
D^{Dep}	−0.032		−0.032
	(−3.318)		(−2.634)
$\Delta PolRate \cdot D^{Dep}$	−0.048		0.298*
	(−0.209)		(7.263)
D^{Access}		−0.005	−0.004
		(−2.577)	(−1.780)
$\Delta PolRate \cdot D^{Access}$		−0.284***	−0.222**
		(−74.521)	(−22.051)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.561**
			(−28.590)
$\Delta repo^{GC}$ lagged	−0.337**	−0.335**	−0.335**
	(−27.282)	(−52.065)	(−49.473)
N	35,082	35,082	35,082
R^2	0.180	0.185	0.187

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates using clustered standard errors. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and standard errors accounting for clustering at the basket and access level. Data include GC repo transactions for core European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.14: ECB access: All countries

	(1)	(2)	(3)
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	b/t	b/t	b/t
$\Delta PolRate$	0.424*	0.589**	0.560**
	(6.626)	(18.599)	(18.663)
D^{Dep}	0.001		0.002
	(0.079)		(0.107)
$\Delta PolRate \cdot D^{Dep}$	0.011		0.384
	(0.047)		(6.133)
D^{Access}		−0.003	−0.003
		(−2.754)	(−2.053)
$\Delta PolRate \cdot D^{Access}$		−0.223	−0.184
		(−6.139)	(−5.411)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$			−0.595**
			(−17.311)
$\Delta repo^{GC}$ lagged	−0.372**	−0.371**	−0.371**
	(−21.546)	(−21.317)	(−21.424)
N	58,183	58,183	58,183
R^2	0.174	0.177	0.178

The table reports the regression results examining the impact of access to the ECB's deposit facility on the pass-through of the monetary policy target rate into GC repo rates using clustered standard errors. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in the policy rate. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and standard errors accounting for clustering at the basket and access level. Data include GC repo transactions for all European countries pooled across the term types ON and TN for the time-period 2010–2018.

Results for different monetary policy target rates

Table OA.2.15: ECB access: Germany

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.675***	0.705***	0.480***	0.334***	0.179***	0.329***	0.723***
	(8.781)	(9.274)	(9.220)	(6.013)	(5.055)	(4.349)	(14.246)
D^{Dep}	−0.047**	−0.026**	−0.051**	−0.021	−0.029**	−0.029**	−0.041**
	(−2.338)	(−2.059)	(−2.520)	(−1.564)	(−2.061)	(−2.249)	(-2.108)
$\Delta PolRate \cdot D^{Dep}$	0.265**	0.253**	0.356***	0.268**	0.179**	0.363***	0.277**
	(2.082)	(2.086)	(4.003)	(2.571)	(2.196)	(3.249)	(2.320)
D^{Access}	−0.000	0.002	0.004	0.001	−0.004	0.001	−0.005
	(−0.035)	(0.183)	(0.339)	(0.120)	(−0.361)	(0.090)	(−0.482)
$\Delta PolRate \cdot D^{Access}$	−0.177**	−0.128	−0.117*	−0.165***	−0.072*	−0.046	−0.162***
	(−2.100)	(−1.474)	(−1.743)	(−2.702)	(−1.887)	(−0.516)	(−2.702)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.719***	−0.648***	−0.670***	−0.378***	−0.264***	−0.258*	−0.657***
	(−4.970)	(−4.425)	(−5.607)	(−3.377)	(−3.058)	(−1.740)	(−4.166)
$\Delta repo^{GC}$ lagged	−0.332***	−0.311***	−0.420***	−0.323***	−0.311***	−0.324***	−0.307***
	(−14.151)	(−12.972)	(−15.125)	(−12.711)	(−12.876)	(−12.113)	(−11.913)
N	10,001	10,158	9,952	9,778	9,758	10,078	10,060
R^2	0.220	0.231	0.187	0.124	0.114	0.144	0.297

The table reports the robustness results examining the impact of access to the ECB's deposit facility on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in different policy rates. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German GC repo transactions pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.16: ECB access: Core countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.643***	0.704***	0.440***	0.312***	0.135***	0.348***	0.691***
	(14.261)	(15.067)	(8.908)	(9.306)	(7.426)	(6.378)	(22.354)
D^{Dep}	−0.032***	−0.018**	−0.030***	−0.020**	−0.025***	−0.022***	−0.031***
	(−2.922)	(−2.488)	(−2.770)	(−2.575)	(−3.260)	(−2.961)	(−3.037)
$\Delta PolRate \cdot D^{Dep}$	0.298***	0.299***	0.375***	0.210***	0.198***	0.319***	0.303***
	(3.968)	(3.943)	(5.581)	(3.317)	(4.152)	(4.315)	(4.180)
D^{Access}	−0.004	−0.001	−0.005	−0.001	−0.006	−0.004	−0.007
	(−0.743)	(−0.192)	(−0.785)	(−0.231)	(−1.033)	(−0.619)	(−1.436)
$\Delta PolRate \cdot D^{Access}$	−0.222***	−0.226***	−0.122**	−0.186***	−0.059***	−0.117**	−0.203***
	(−4.423)	(−4.310)	(−2.094)	(−5.242)	(−2.947)	(−2.006)	(−5.592)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.561***	−0.497***	−0.417***	−0.240***	−0.231***	−0.233***	−0.363***
	(−5.885)	(−5.259)	(−4.766)	(−3.612)	(−4.533)	(−2.711)	(−3.383)
$\Delta repo^{GC}$ lagged	−0.335***	−0.313***	−0.401***	−0.318***	−0.305***	−0.318***	−0.303***
	(−24.410)	(−22.963)	(−26.606)	(−22.834)	(−22.875)	(−22.775)	(−23.424)
N	35,082	35,607	34,949	34,606	34,519	35,295	35,279
R^2	0.187	0.195	0.168	0.118	0.106	0.135	0.256

The table reports the robustness results examining the impact of access to the ECB's deposit facility on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in different policy rates. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for core European countries pooled across the term types ON and TN for the time-period 2010–2018.

Table OA.2.17: ECB access: All countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$	$\Delta repo^{GC}$
	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t	ON/TN b/t
$\Delta PolRate$	0.560***	0.612***	0.379***	0.250***	0.127***	0.262***	0.643***
	(15.106)	(16.587)	(10.586)	(10.923)	(10.831)	(6.977)	(24.770)
D^{Dep}	0.002	−0.002	0.003	−0.003	−0.007	−0.005	0.002
	(0.221)	(−0.354)	(0.340)	(−0.468)	(−1.055)	(−0.804)	(0.262)
$\Delta PolRate \cdot D^{Dep}$	0.384***	0.400***	0.396***	0.289***	0.210***	0.417***	0.283***
	(5.668)	(5.872)	(6.898)	(5.154)	(5.112)	(6.987)	(3.969)
D^{Access}	−0.003	−0.002	−0.003	−0.002	−0.004	−0.002	−0.005
	(−0.709)	(−0.509)	(−0.641)	(−0.447)	(−0.961)	(−0.535)	(−1.213)
$\Delta PolRate \cdot D^{Access}$	−0.184***	−0.193***	−0.112***	−0.142***	−0.052***	−0.102**	−0.178***
	(−4.438)	(−4.635)	(−2.677)	(−5.732)	(−4.004)	(−2.462)	(−5.804)
$\Delta PolRate \cdot D^{Access} \cdot D^{Dep}$	−0.595***	−0.500***	−0.362***	−0.283***	−0.231***	−0.200***	−0.291***
	(−6.733)	(−5.763)	(−4.753)	(−4.711)	(−5.198)	(−2.713)	(−2.846)
$\Delta repo^{GC}$ lagged	−0.371***	−0.350***	−0.416***	−0.354***	−0.346***	−0.345***	−0.343***
	(−30.167)	(−29.208)	(−30.883)	(−28.331)	(−27.758)	(−28.558)	(−28.889)
N	58,183	58,961	57,864	57,214	57,026	58,447	58,460
R^2	0.178	0.189	0.160	0.133	0.128	0.139	0.238

The table reports the robustness results examining the impact of access to the ECB's deposit facility on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the GC rate $\Delta repo^{GC}$. $\Delta PolRate$ denotes the change in different policy rates. D^{Dep} equals 1 if a country's average GC rate is below the deposit facility. D^{Access} equals 1 if a lending bank has access to the deposit facility. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include basket-month-term fixed effects and heteroscedasticity-robust standard errors. Data include GC repo transactions for all European countries pooled across the term types ON and TN for the time-period 2010–2018.

OA.3 Robustness results for asset eligibility

Results by region, pooled across term types

Table OA.3.1: Collateral eligibility: Germany

	(1)	(2)	(3)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	b/t	b/t	b/t
$\Delta PolRate$	0.106***	0.098***	0.109***
	(19.644)	(12.937)	(13.130)
D^{QE}	−0.016		−0.016
	(−1.462)		(−1.434)
$\Delta PolRate \cdot D^{QE}$	−0.150***		−0.120***
	(−15.837)		(−8.154)
$D^{Eligible}$		0.004	0.004
		(0.454)	(0.440)
$\Delta PolRate \cdot D^{Eligible}$		0.006	−0.005
		(0.537)	(−0.463)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.172***	−0.052***
		(−14.035)	(−2.737)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.364***
	(−20.719)	(−20.716)	(−20.719)
N	301,608	301,608	301,608
R^2	0.119	0.119	0.119

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.2: Collateral eligibility: Core countries

	(1)	(2)	(3)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	b/t	b/t	b/t
$\Delta PolRate$	0.105***	0.095***	0.103***
	(31.179)	(17.681)	(17.810)
D^{QE}	−0.008		−0.008
	(−1.187)		(−1.158)
$\Delta PolRate \cdot D^{QE}$	−0.126***		−0.104***
	(−19.814)		(−9.643)
$D^{Eligible}$		0.005	0.005
		(0.972)	(0.969)
$\Delta PolRate \cdot D^{Eligible}$		0.011	0.002
		(1.592)	(0.295)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.137***	−0.033**
		(−17.552)	(−2.453)
$\Delta repo^{Special}$ lagged	−0.357***	−0.357***	−0.357***
	(−39.267)	(−39.259)	(−39.264)
N	705,633	705,633	705,633
R^2	0.115	0.115	0.115

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for core European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.3: Collateral eligibility: All countries

	(1) $\Delta repo^{Special}$ b/t	(2) $\Delta repo^{Special}$ b/t	(3) $\Delta repo^{Special}$ b/t
$\Delta PolRate$	0.099***	0.094***	0.101***
	(30.205)	(18.394)	(18.358)
D^{QE}	−0.017*		−0.016*
	(−1.752)		(−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.108***		−0.089***
	(−17.339)		(−8.198)
$D^{Eligible}$		0.004	0.004
		(0.669)	(0.649)
$\Delta PolRate \cdot D^{Eligible}$		0.004	−0.004
		(0.562)	(−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.117***	−0.028**
		(−15.319)	(−2.119)
$\Delta repo^{Special}$ lagged	−0.362***	−0.362***	−0.362***
	(−51.918)	(−51.911)	(−51.915)
N	943,349	943,349	943,349
R^2	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.4: Collateral eligibility: Germany, core countries and all countries

		Germany			Core			All	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.106*** (19.644)	0.098*** (12.937)	0.109*** (13.130)	0.105*** (31.179)	0.095*** (17.681)	0.103*** (17.810)	0.099*** (30.205)	0.094*** (18.394)	0.101*** (18.358)
D^{QE}	−0.016 (−1.462)		−0.016 (−1.434)	−0.008 (−1.187)		−0.008 (−1.158)	−0.017* (−1.752)		−0.016* (−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.150*** (−15.837)		−0.120*** (−8.154)	−0.126*** (−19.814)		−0.104*** (−9.643)	−0.108*** (−17.339)		−0.089*** (−8.198)
$D^{Eligible}$		0.004 (0.454)	0.004 (0.440)		0.005 (0.972)	0.005 (0.969)		0.004 (0.669)	0.004 (0.649)
$\Delta PolRate \cdot D^{Eligible}$		0.006 (0.537)	−0.005 (−0.463)		0.011 (1.592)	0.002 (0.295)		0.004 (0.562)	−0.004 (−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.172*** (−14.035)	−0.052*** (−2.737)		−0.137*** (−17.552)	−0.033** (−2.453)		−0.117*** (−15.319)	−0.028** (−2.119)
$\Delta repo^{Special}$ lagged	−0.364*** (−20.719)	−0.364*** (−20.716)	−0.364*** (−20.719)	−0.357*** (−39.267)	−0.357*** (−39.259)	−0.357*** (−39.264)	−0.362*** (−51.918)	−0.362*** (−51.911)	−0.362*** (−51.915)
N	301,608	301,608	301,608	705,633	705,633	705,633	943,349	943,349	943,349
R^2	0.119	0.119	0.119	0.115	0.115	0.115	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for Germany, core European countries, and all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.5: Collateral eligibility: Core countries and all countries

		Core			All	
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.105***	0.095***	0.103***	0.099***	0.094***	0.101***
	(31.179)	(17.681)	(17.810)	(30.205)	(18.394)	(18.358)
D^{QE}	−0.008		−0.008	−0.017*		−0.016*
	(−1.187)		(−1.158)	(−1.752)		(−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.126***		−0.104***	−0.108***		−0.089***
	(−19.814)		(−9.643)	(−17.339)		(−8.198)
$D^{Eligible}$		0.005	0.005		0.004	0.004
		(0.972)	(0.969)		(0.669)	(0.649)
$\Delta PolRate \cdot D^{Eligible}$		0.011	0.002		0.004	−0.004
		(1.592)	(0.295)		(0.562)	(−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.137***	−0.033**		−0.117***	−0.028**
		(−17.552)	(−2.453)		(−15.319)	(−2.119)
$\Delta repo^{Special}$ lagged	−0.357***	−0.357***	−0.357***	−0.362***	−0.362***	−0.362***
	(−39.267)	(−39.259)	(−39.264)	(−51.918)	(−51.911)	(−51.915)
N	705,633	705,633	705,633	943,349	943,349	943,349
R^2	0.115	0.115	0.115	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for core European countries and all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Results by region and term type

Table OA.3.6: Collateral eligibility: Germany

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN	SN	TN/SN	TN	SN	TN/SN	TN	SN	TN/SN
	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t
$\Delta PolRate$	0.190***	0.061***	0.106***	0.171***	0.058***	0.098***	0.186***	0.066***	0.109***
	(17.269)	(11.084)	(19.644)	(11.689)	(6.992)	(12.937)	(11.598)	(7.315)	(13.130)
D^{QE}	−0.022	−0.010	−0.016				−0.022	−0.010	−0.016
	(−0.996)	(−0.877)	(−1.462)				(−0.995)	(−0.839)	(−1.434)
$\Delta PolRate \cdot D^{QE}$	−0.206***	−0.119***	−0.150***				−0.165***	−0.095***	−0.120***
	(−10.786)	(−12.683)	(−15.837)				(−5.586)	(−6.505)	(−8.154)
$D^{Eligible}$				−0.001	0.005	0.004	−0.001	0.005	0.004
				(−0.043)	(0.575)	(0.454)	(−0.051)	(0.568)	(0.440)
$\Delta PolRate \cdot D^{Eligible}$				0.023	−0.001	0.006	0.008	−0.010	−0.005
				(1.097)	(−0.127)	(0.537)	(0.356)	(−0.837)	(−0.463)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$				−0.235***	−0.138***	−0.172***	−0.070*	−0.043**	−0.052***
				(−9.456)	(−11.374)	(−14.035)	(−1.820)	(−2.299)	(−2.737)
$\Delta repo^{Special}$ lagged	−0.424***	−0.312***	−0.364***	−0.424***	−0.312***	−0.364***	−0.424***	−0.312***	−0.364***
	(−56.995)	(−9.357)	(−20.719)	(−56.981)	(−9.356)	(−20.716)	(−56.992)	(−9.357)	(−20.719)
N	106,105	195,503	301,608	106,105	195,503	301,608	106,105	195,503	301,608
R^2	0.159	0.084	0.119	0.159	0.084	0.119	0.159	0.084	0.119

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German special repo transactions separate for each and pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.7: Collateral eligibility: Core countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN	SN	TN/SN	TN	SN	TN/SN	TN	SN	TN/SN
	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t
$\Delta PolRate$	0.184***	0.063***	0.105***	0.147***	0.063***	0.095***	0.157***	0.071***	0.103***
	(26.371)	(18.168)	(31.179)	(14.900)	(10.447)	(17.681)	(14.724)	(10.779)	(17.810)
D^{QE}	−0.010	−0.006	−0.008				−0.010	−0.005	−0.008
	(−0.719)	(−0.802)	(−1.187)				(−0.709)	(−0.760)	(−1.158)
$\Delta PolRate \cdot D^{QE}$	−0.160***	−0.110***	−0.126***				−0.124***	−0.092***	−0.104***
	(−12.396)	(−17.603)	(−19.814)				(−5.922)	(−8.172)	(−9.643)
$D^{Eligible}$				0.000	0.008	0.005	0.000	0.008	0.005
				(0.013)	(1.179)	(0.972)	(0.007)	(1.181)	(0.969)
$\Delta PolRate \cdot D^{Eligible}$				0.055***	−0.004	0.011	0.044***	−0.011	0.002
				(4.088)	(−0.526)	(1.592)	(3.169)	(−1.472)	(0.295)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$				−0.182***	−0.120***	−0.137***	−0.058**	−0.028**	−0.033**
				(−11.145)	(−16.192)	(−17.552)	(−2.189)	(−2.095)	(−2.453)
$\Delta repo^{Special}$ lagged	−0.409***	−0.316***	−0.357***	−0.409***	−0.316***	−0.357***	−0.409***	−0.316***	−0.357***
	(−81.121)	(−19.471)	(−39.267)	(−81.084)	(−19.470)	(−39.259)	(−81.092)	(−19.472)	(−39.264)
N	238,165	467,468	705,633	238,165	467,468	705,633	238,165	467,468	705,633
R^2	0.146	0.088	0.115	0.146	0.008	0.115	0.146	0.088	0.115

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for core European countries separate for each and pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.8: Collateral eligibility: All countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN	SN	TN/SN	TN	SN	TN/SN	TN	SN	TN/SN
	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t	b/t
$\Delta PolRate$	0.174***	0.061***	0.099***	0.145***	0.062***	0.094***	0.153***	0.069***	0.101***
	(26.299)	(17.227)	(30.205)	(15.800)	(10.508)	(18.394)	(15.406)	(10.844)	(18.358)
D^{QE}	−0.021	−0.012	−0.017*				−0.021	−0.012	−0.016*
	(−1.046)	(−1.404)	(−1.752)				(−1.047)	(−1.375)	(−1.740)
$\Delta PolRate \cdot D^{QE}$	−0.126***	−0.105***	−0.108***				−0.094***	−0.088***	−0.089***
	(−10.342)	(−16.347)	(−17.339)				(−4.601)	(−7.479)	(−8.198)
$D^{Eligible}$				−0.007	0.009	0.004	−0.007	0.009	0.004
				(−0.658)	(1.374)	(0.669)	(−0.675)	(1.365)	(0.649)
$\Delta PolRate \cdot D^{Eligible}$				0.041***	−0.005	0.004	0.033**	−0.012	−0.004
				(3.259)	(−0.625)	(0.562)	(2.508)	(−1.545)	(−0.565)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$				−0.145***	−0.114***	−0.117***	−0.051**	−0.026*	−0.028**
				(−9.463)	(−14.766)	(−15.319)	(−1.995)	(−1.869)	(−2.119)
$\Delta repo^{Special}$ lagged	−0.412***	−0.324***	−0.362***	−0.412***	−0.324***	−0.362***	−0.412***	−0.324***	−0.362***
	(−95.132)	(−27.036)	(−51.918)	(−95.101)	(−27.036)	(−51.911)	(−95.110)	(−27.037)	(−51.915)
N	323,263	620,086	943,349	323,263	620,086	943,349	323,263	620,086	943,349
R^2	0.151	0.093	0.118	0.151	0.093	0.118	0.151	0.093	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries separate for each and pooled across the term types TN and SN for the time-period 2010–2018.

Results for different fixed effect specifications

Table OA.3.9: Collateral eligibility: Germany, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.109***	0.111***	0.117***	0.118***	0.119***
	(13.130)	(13.151)	(13.619)	(13.718)	(13.765)
D^{QE}	−0.016	−0.016	0.048***	0.013***	0.048***
	(−1.434)	(−1.428)	(9.022)	(5.858)	(9.408)
$\Delta PolRate \cdot D^{QE}$	−0.120***	−0.121***	−0.129***	−0.129***	−0.131***
	(−8.154)	(−8.170)	(−8.598)	(−8.558)	(−8.715)
$D^{Eligible}$	0.004	0.004	−0.010**	−0.002	−0.000
	(0.440)	(0.505)	(−2.344)	(−0.827)	(−0.017)
$\Delta PolRate \cdot D^{Eligible}$	−0.005	−0.006	−0.002	−0.003	−0.004
	(−0.463)	(−0.511)	(−0.219)	(−0.302)	(−0.348)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.052***	−0.053***	−0.053***	−0.051***	−0.052**
	(−2.737)	(−2.739)	(−2.711)	(−2.596)	(−2.642)
$\Delta repo^{Special}$ lagged	−0.364***	−0.360***	−0.350***	−0.349***	−0.349***
	(−20.719)	(−21.031)	(−20.941)	(−20.941)	(−20.950)
FE	ISIN× Month× Term	ISIN× Month	ISIN× Year	ISIN	Year
N	301,608	301,859	301,896	301,897	301,897
R^2	0.119	0.123	0.121	0.121	0.121

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; *t*-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.10: Collateral eligibility: Core countries, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.103***	0.106***	0.114***	0.115***	0.115***
	(17.810)	(18.194)	(19.593)	(19.711)	(19.745)
D^{QE}	−0.008	−0.008	0.045***	0.010***	0.045***
	(−1.158)	(−1.148)	(13.006)	(7.362)	(13.513)
$\Delta PolRate \cdot D^{QE}$	−0.104***	−0.107***	−0.119***	−0.119***	−0.121***
	(−9.643)	(−9.860)	(−10.855)	(−10.823)	(−11.030)
$D^{Eligible}$	0.005	0.005	−0.007**	−0.002	0.001
	(0.969)	(0.972)	(−2.470)	(−1.324)	(0.599)
$\Delta PolRate \cdot D^{Eligible}$	0.002	0.003	0.006	0.005	0.005
	(0.295)	(0.400)	(0.858)	(0.764)	(0.722)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.033**	−0.033**	−0.031**	−0.029**	−0.030**
	(−2.453)	(−2.426)	(−2.305)	(−2.096)	(−2.179)
$\Delta repo^{Special}$ lagged	−0.357***	−0.352***	−0.341***	−0.340***	−0.340***
	(−39.264)	(−39.715)	(−39.287)	(−39.274)	(−39.297)
FE	ISIN× Month× Term	ISIN× Month	ISIN× Year	ISIN	Year
N	705,633	706,207	706,252	706,255	706,255
R^2	0.115	0.119	0.116	0.116	0.116

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include special repo transactions for core European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.11: Collateral eligibility: All countries, different fixed effect specifications

	(1)	(2)	(3)	(4)	(5)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.101*** (18.358)	0.105*** (18.825)	0.113*** (20.418)	0.114*** (20.554)	0.114*** (20.584)
D^{QE}	−0.016* (−1.740)	−0.017* (−1.764)	0.038*** (10.253)	0.011*** (8.196)	0.039*** (11.222)
$\Delta PolRate \cdot D^{QE}$	−0.089*** (−8.198)	−0.092*** (−8.437)	−0.104*** (−9.547)	−0.104*** (−9.563)	−0.106*** (−9.737)
$D^{Eligible}$	0.004 (0.649)	0.004 (0.727)	−0.007*** (−2.867)	−0.001 (−0.652)	0.001 (0.611)
$\Delta PolRate \cdot D^{Eligible}$	−0.004 (−0.565)	−0.003 (−0.369)	0.001 (0.181)	0.001 (0.096)	0.000 (0.057)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.028** (−2.119)	−0.029** (−2.165)	−0.031** (−2.310)	−0.028** (−2.076)	−0.029** (−2.170)
$\Delta repo^{Special}$ lagged	−0.362*** (−51.915)	−0.356*** (−52.505)	−0.345*** (−51.939)	−0.344*** (−51.934)	−0.344*** (−51.964)
FE	ISIN× Month× Term	ISIN× Month	ISIN× Year	ISIN	Year
N	943,349	944,265	944,331	944,335	944,335
R^2	0.118	0.122	0.119	0.119	0.119

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the pass-through of the monetary policy target rate into special repo rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in the policy rate. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. The regressions include different fixed effect specifications and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Results for clustered standard errors

Table OA.3.12: Collateral eligibility: Germany

	(1)	(2)	(3)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	b/t	b/t	b/t
$\Delta PolRate$	0.106**	0.098**	0.109**
	(32.158)	(33.661)	(36.511)
D^{QE}	−0.016		−0.016
	(−0.832)		(−0.835)
$\Delta PolRate \cdot D^{QE}$	−0.150		−0.120**
	(−5.792)		(−20.932)
$D^{Eligible}$		0.004	0.004
		(0.400)	(0.400)
$\Delta PolRate \cdot D^{Eligible}$		0.006	−0.005
		(1.925)	(−1.309)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.172***	−0.052*
		(−175.810)	(−8.421)
$\Delta repo^{Special}$ lagged	−0.364**	−0.364**	−0.364**
	(−22.869)	(−22.935)	(−22.804)
N	301,608	301,608	301,608
R^2	0.119	0.119	0.119

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through using clustered standard errors. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and standard errors accounting for clustering at the ISIN and eligibility level. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.13: Collateral eligibility: Core countries

	(1)	(2)	(3)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	b/t	b/t	b/t
$\Delta PolRate$	0.105***	0.095***	0.103***
	(134.397)	(72.001)	(81.078)
D^{QE}	−0.008		−0.008
	(−0.716)		(−0.694)
$\Delta PolRate \cdot D^{QE}$	−0.126*		−0.104**
	(−8.472)		(−39.994)
$D^{Eligible}$		0.005	0.005
		(1.050)	(1.028)
$\Delta PolRate \cdot D^{Eligible}$		0.011*	0.002
		(7.979)	(1.168)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.137***	−0.033**
		(−195.384)	(−12.887)
$\Delta repo^{Special}$ lagged	−0.357**	−0.357**	−0.357**
	(−29.353)	(−29.473)	(−29.314)
N	705,633	705,633	705,633
R^2	0.115	0.115	0.115

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through using clustered standard errors. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and standard errors accounting for clustering at the ISIN and eligibility level. Data include special repo transactions for core European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.14: Collateral eligibility: All countries

	(1)	(2)	(3)
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	b/t	b/t	b/t
$\Delta PolRate$	0.099**	0.094***	0.101***
	(45.807)	(110.286)	(99.326)
D^{QE}	−0.017		−0.016
	(−0.666)		(−0.661)
$\Delta PolRate \cdot D^{QE}$	−0.108*		−0.089**
	(−8.733)		(−48.349)
$D^{Eligible}$		0.004	0.004
		(0.702)	(0.667)
$\Delta PolRate \cdot D^{Eligible}$		0.004	−0.004
		(3.383)	(−1.931)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$		−0.117***	−0.028**
		(−186.211)	(−31.726)
$\Delta repo^{Special}$ lagged	−0.362**	−0.362**	−0.362**
	(−43.257)	(−43.367)	(−43.092)
N	943,349	943,349	943,349
R^2	0.118	0.118	0.118

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through using clustered standard errors. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and standard errors accounting for clustering at the ISIN and eligibility level. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Results for different monetary policy target rates

Table OA.3.15: Collateral eligibility: Germany

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.109***	0.109***	0.105***	0.054***	0.046***	0.101***	0.117***
	(13.130)	(13.130)	(11.394)	(9.442)	(9.250)	(12.053)	(13.854)
D^{QE}	−0.016	−0.016	−0.040***	−0.028**	−0.031**	−0.039***	0.042***
	(−1.434)	(−1.421)	(−3.105)	(−2.303)	(−2.465)	(−3.456)	(3.461)
$\Delta PolRate \cdot D^{QE}$	−0.120***	−0.116***	−0.109***	−0.025***	−0.019***	−0.039**	0.406***
	(−8.154)	(−7.867)	(−9.346)	(−3.565)	(−2.984)	(−2.427)	(6.250)
$D^{Eligible}$	0.004	0.004	0.003	0.003	0.002	0.002	0.002
	(0.440)	(0.435)	(0.316)	(0.314)	(0.254)	(0.187)	(0.202)
$\Delta PolRate \cdot D^{Eligible}$	−0.005	−0.005	−0.000	0.015**	0.002	−0.022**	0.013
	(−0.463)	(−0.463)	(−0.015)	(1.987)	(0.355)	(−2.059)	(1.172)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.052***	−0.044**	−0.023	−0.031***	−0.017**	−0.023	−0.216***
	(−2.737)	(−2.289)	(−1.491)	(−3.346)	(−2.021)	(−1.086)	(−2.972)
$\Delta repo^{Special}$ lagged	−0.364***	−0.364***	−0.365***	−0.363***	−0.363***	−0.359***	−0.356***
	(−20.719)	(−20.719)	(−20.277)	(−19.856)	(−19.668)	(−20.195)	(−69.536)
N	301,608	301,608	299,889	290,153	289,058	298,718	303,446
R^2	0.119	0.119	0.120	0.119	0.120	0.116	0.119

The table reports the robustness results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include German special repo transactions pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.16: Collateral eligibility: Core countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t	TN/SN b/t
$\Delta PolRate$	0.103^{***}	0.103^{***}	0.099^{***}	0.055^{***}	0.041^{***}	0.074^{***}	0.115^{***}
	(17.810)	(17.810)	(15.179)	(13.493)	(11.908)	(12.705)	(20.365)
D^{QE}	−0.008	−0.008	-0.033^{***}	-0.023^{***}	-0.026^{***}	-0.032^{***}	0.060^{***}
	(−1.158)	(−1.140)	(−3.990)	(−2.845)	(−3.244)	(−4.581)	(7.534)
$\Delta PolRate \cdot D^{QE}$	-0.104^{***}	-0.097^{***}	-0.094^{***}	-0.037^{***}	-0.023^{***}	−0.001	0.463^{***}
	(−9.643)	(−8.995)	(−10.427)	(−7.136)	(−4.925)	(−0.049)	(9.028)
$D^{Eligible}$	0.005	0.005	0.006	0.004	0.003	0.004	0.001
	(0.969)	(0.959)	(1.003)	(0.688)	(0.612)	(0.629)	(0.246)
$\Delta PolRate \cdot D^{Eligible}$	0.002	0.002	0.017^{**}	0.005	0.001	0.028^{***}	0.025^{***}
	(0.295)	(0.295)	(2.108)	(1.112)	(0.270)	(3.810)	(3.586)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	-0.033^{**}	-0.028^{**}	-0.028^{**}	−0.010	−0.005	-0.026^{*}	-0.155^{***}
	(−2.453)	(−2.133)	(−2.517)	(−1.591)	(−0.937)	(−1.754)	(−2.706)
$\Delta repo^{Special}$ lagged	-0.357^{***}	-0.357^{***}	-0.359^{***}	-0.356^{***}	-0.356^{***}	-0.352^{***}	-0.354^{***}
	(−39.264)	(−39.264)	(−38.341)	(−37.516)	(−37.058)	(−38.194)	(−103.672)
N	705,633	705,633	701,859	681,324	678,897	699,266	709,927
R^2	0.115	0.115	0.117	0.114	0.115	0.113	0.119

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; *t*-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for core European countries pooled across the term types TN and SN for the time-period 2010–2018.

Table OA.3.17: Collateral eligibility: All countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	EONIA	€STR	euro LIBOR	zero OIS	zero EURIBOR	OIS 1W	GC Pooling
	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$	$\Delta repo^{Special}$
	TN/SN	TN/SN	TN/SN	TN/SN	TN/SN	TN/SN	TN/SN
	b/t	b/t	b/t	b/t	b/t	b/t	b/t
$\Delta PolRate$	0.101***	0.101***	0.092***	0.055***	0.040***	0.065***	0.105***
	(18.358)	(18.358)	(15.576)	(14.263)	(12.556)	(11.882)	(20.022)
D^{QE}	−0.016*	−0.016*	−0.039***	−0.031***	−0.034***	−0.040***	0.043***
	(−1.740)	(−1.729)	(−3.990)	(−3.185)	(−3.471)	(−4.399)	(4.016)
$\Delta PolRate \cdot D^{QE}$	−0.089***	−0.083***	−0.086***	−0.033***	−0.018***	0.030**	0.419***
	(−8.198)	(−7.669)	(−9.474)	(−6.308)	(−3.803)	(2.538)	(10.410)
$D^{Eligible}$	0.004	0.004	0.004	0.001	0.001	0.002	−0.001
	(0.649)	(0.642)	(0.685)	(0.218)	(0.124)	(0.298)	(−0.135)
$\Delta PolRate \cdot D^{Eligible}$	−0.004	−0.004	0.007	−0.003	−0.003	0.039***	0.027***
	(−0.565)	(−0.565)	(0.902)	(−0.634)	(−0.659)	(5.593)	(4.041)
$\Delta PolRate \cdot D^{Eligible} \cdot D^{QE}$	−0.028**	−0.024*	−0.005	−0.001	−0.002	−0.013	−0.108**
	(−2.119)	(−1.781)	(−0.439)	(−0.103)	(−0.287)	(−0.857)	(−2.427)
$\Delta repo^{Special}$ lagged	−0.362***	−0.362***	−0.363***	−0.360***	−0.360***	−0.358***	−0.359***
	(−51.915)	(−51.915)	(−50.806)	(−49.173)	(−48.554)	(−50.579)	(−113.820)
N	943,349	943,349	938,391	913,396	910,329	934,884	948,564
R^2	0.118	0.118	0.120	0.118	0.118	0.117	0.123

The table reports the regression results examining the impact of asset eligibility for quantitative easing on the monetary policy pass-through for alternative monetary policy target rates. The dependent variable is the change in the special repo rate $\Delta repo^{Special}$. $\Delta PolRate$ denotes the change in different policy rates. D^{QE} equals 1 during the PSPP. $D^{Eligible}$ equals 1 if a security is (hypothetically) eligible for purchase under the PSPP. ***, **, and * represent significance at a 1, 5, and 10% level, respectively; t-statistics are in parentheses. All regressions include ISIN-month-term fixed effects and heteroscedasticity-robust standard errors. Data include special repo transactions for all European countries pooled across the term types TN and SN for the time-period 2010–2018.

Chapter 3

Italy in the Eurozone

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Using a DSGE model with nominal wage rigidity, we investigate two scenarios for the Italian economy. The first considers sustained policy commitment to reform. The results indicate the possibility of 'growing out of bad initial conditions', if fiscal consolidation is combined with a program for bank recovery and for competitiveness and growth. The second scenario involves a strong asymmetric recession. It is likely to be very severe under the restrictions of the currency union. A benign exit from the Eurozone with stable investor expectations could substantially dampen the short-run impact. Stabilization is achieved by monetary expansion, combined with exchange rate depreciation. However, investor panic may lead to escalation. Capital market reactions would offset the benefits of monetary autonomy and much delay the recovery.

JEL Classification: E42, E44, E60, F30, F36, F45, G15, G21.

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3.1 Introduction

The global financial crisis revealed large imbalances in the Eurozone. Banks were highly leveraged and unable to absorb large shocks, requiring government support. With the increase in public debt, doubts emerged about the solvency of several member states, leading to substantially higher borrowing costs for those governments. Banks, which typically hold large amounts of domestic sovereign debt, and other investors faced the risk of sovereign default. In addition, some countries in the Eurozone periphery had gradually lost competitiveness in the pre-crisis boom during the early 2000s and have experienced stagnant growth thereafter. The latter significantly constrains the borrowing capacity of governments and hampers the role of the fiscal budget in stabilizing the economy during a recession. Instead of providing fiscal relief, governments may be forced to pursue a policy of fiscal consolidation. This reinforces the downturn and ultimately magnifies the share of non-performing loans thereby further weakening the banking sector.

Italy arguably comes close to the Eurozone trilemma of fiscal solvency issues, problems in the banking sector and stagnant growth. On all three fronts, the country starts from unfavorable initial conditions and is especially vulnerable to shocks. First, public debt is excessively high and accounts for 130 percent of GDP. The chronically high debt level is mainly a result of the 1980s and early 1990s. Between the late 1990s and 2008, it remained stable at around 100 percent of GDP. However, the financial crisis led to an increase in the public debt ratio by roughly 30 percentage points. Second, the Italian banking sector suffers from many non-performing loans. Their share increased from 6 to 16 percent of total loans between 2006 and 2013 (Schivardi et al., 2017). Since Italian banks were not severely hit by the first wave of the financial crisis due to their low exposure to the US subprime market, fiscal support with equity injections or the creation of bad banks was limited. These measures would have allowed banks to restructure non-performing loans. Instead, they kept those loans and continued to finance distressed borrowers. Another potential source of financial instability is that banks have traditionally held large amounts of domestic sovereign bonds, more than 11 percent of bank assets in 2017 according to ECB data. Third, the Italian economy suffers from sluggish growth and low productivity. In 2017, real GDP per capita was virtually the same as in 2000. An important reason for this pattern is stagnant or declining labor productivity since the 1990s, which contributed to rising unit labor costs and deteriorating competitiveness.

The paper formulates a dynamic stochastic general equilibrium (DSGE) model. We first simulate how sustained policy commitment to fiscal and banking reforms within the monetary union can help Italy overcome the bad initial conditions and converge to a new steady state. Subsequently, we compare the consequences and policy options in case of severe, asymmetric recession in Italy. We specifically consider three scenarios, namely, (i) continued membership within the Eurozone, (ii) a 'benign' exit from the Eurozone, and (iii) an 'escalating' exit. The exit introduces a flexible exchange rate between the Euro and the new currency (Lira) and allows for an autonomous monetary policy tailored to the needs of the Italian economy. These scenarios and our focus on events following a recession reflect the widely accepted view that money and exchange rates affect real economic activity in the short and medium run due to nominal rigidities but are largely neutral in long-run equilibrium. Given the uncertainty about how an exit from the Eurozone could be organized, we consider two distinct cases. The 'benign' scenario pictures the best case without severe short-run disruptions such as a widespread loss of confidence. In contrast, the 'escalating' scenario corresponds to the worst case. It introduces runs on Italian banks and a flight to safety with a large sell-off of Italian sovereign bonds. Short-run effects are much more damaging.

The paper develops a three-region DSGE model with money and nominal rigidities. It pictures Italy, the rest of the Eurozone and the rest of the world. The main focus is on Italy. While the other two regions are kept rather stylized, the model of the Italian economy includes a banking sector, a government, and a real sector and thereby captures three reinforcing driving forces of a crisis within the Eurozone. The regions are connected with trade in goods and capital flows. Nominal wage stickiness allows for real effects of monetary policy. Importantly, our analysis includes a regime change from a monetary union to a new currency with flexible exchange rates and renationalization of monetary policy making. The model is empirically implemented: The initial steady state is calibrated to match the Italian economy in the early 2000s prior to the crisis. Adding structural shocks to the model and using Bayesian estimation procedures allows us to track past performance and approximately replicate time series until 2017.

Our quantitative analysis yields three main results: First, we show that a 'reform package' consisting of tax- and expenditure based fiscal consolidation, a shift to productivity enhancing fiscal spending, tax incentives for investment, as well as labor market and banking reform could help Italy to overcome unfavorable initial conditions and gradually reach a new long-run equilibrium with higher income and consumption and lower public debt. Second, the short- and medium-term response of the Italian economy to an asymmetric recession markedly differs depending on whether the country continues to be part of the Eurozone or exits. An exit would allow Italy to conduct an independent monetary policy more tailored to the specific needs of its economy and to depreciate its new currency. Nominal rigidities are critical for this result as monetary expansion may immediately depreciate real wages, thereby increasing employment. In general, the recession reduces real variables like domestic output, employment and capital stock less strongly in the short but more strongly in the medium run if Italy exits compared to continued membership. Third, an escalating exit accompanied with investor panic would eliminate any such short-term gains from having access to a more flexible monetary policy and would magnify the recession. An important driver is the sudden increase in risk premia for banks and governments, which translates into higher borrowing costs and significantly lowers investment and the capital stock.

The existing literature on the Eurozone is large and predominantly relates to specific aspects of the crisis. The aim of the present paper is to capture vicious spirals and reinforcing feedback loops in a DSGE model and evaluate alternative policy scenarios. Specifically, it compares the recovery following a recession under continued membership in the monetary union with developments in two exit scenarios. Closest to our endeavor is the research by Gourinchas et al. (2017) and Chodorow-Reich et al. (2019) who suggest an open economy New Keynesian DSGE model to explain the evolution of the Greek economy during the crisis. Martin and Philippon (2017) develop a stylized two-country model to analyze the contrasting behavior of the periphery and core countries and to investigate macroprudential policies. They also include amplifying feedback mechanisms in reduced form. Gilchrist et al. (2018) introduce a DSGE model with two financially heterogeneous regions where financial frictions prevent price adjustments. Apart from differences in modeling, none of these papers considers an exit scenario implying a complete regime shift, that is, moving from fixed to flexible exchange rates and from common to national monetary policy. Part of this scenario resembles the break-up of currency pegs. Schmitt-Grohé and Uribe (2016), for example, show how downward wage rigidity combined with free capital mobility cause overborrowing in booms and unemployment during recessions, resembling key aspects of the Eurozone crisis.

The present paper emphasizes a trilemma of high public debt, weak banks, and deteriorating competitiveness (see Shambaugh, 2012). Our approach is motivated by the importance of these three reinforcing driving forces of the Eurozone crisis, which are well documented in empirical research: First, a systemic banking crisis entails severe macroeconomic and fiscal costs. Laeven and Valencia (2012) analyze a range of banking crises since 1970 and estimate a 32 percent median cumulative output loss relative to the pre-crisis trend over four years in advanced economies. A weakened banking sector tends to prolong the crisis. Under-capitalized banks continue to finance distressed firms because they cannot absorb the short-term restructuring costs. Schivardi et al. (2017) find that banks with a below-median capital ratio are more likely to lend to highly indebted, unproductive firms. A banking crisis typically leads to a massive increase in public debt. Reinhart and Rogoff (2013) suggest that government debt is on average 86 percent higher three years after a major banking crisis. On top of bailout costs, this figure accounts for stimulus packages and a shortfall of tax revenue. As the Irish experience has shown, a banking crisis can rapidly transform into a public debt crisis (e.g. Acharya et al., 2014). Second, a sovereign debt crisis undermines financial stability. European banks typically hold large amounts of domestic sovereign bonds (e.g. Acharya and Steffen, 2015; Altavilla et al., 2017; Ongena et al., 2016). Given this exposure, a public debt crisis leads to a massive contraction of private credit especially if banks' sovereign bond holdings are large and they are highly leveraged (Gennaioli et al., 2014). Bofondi et al. (2017) show that, during the sovereign debt crisis, domestic Italian banks reduced credit significantly more than foreign banks that operate in Italy. Related papers highlight that banks' sovereign bond purchases crowded out corporate lending, for example, Becker and Ivashina (2018) and Popov and Van Horen (2015).

Third, a lack of competitiveness can become an obstacle for economic growth and lead to persistent employment problems. Declining tax revenues magnify budget deficits and render fiscal consolidation more painful and less effective in stabilizing public debt. Furthermore, the share of non-performing loans tends to rise under such circumstances, making private defaults more frequent. The empirical literature on the macroeconomic determinants of non-performing loans emphasizes the role of growth and unemployment (e.g. Louzis et al., 2012; Salas and Saurina, 2002) or the specific impact of recessions (Quagliariello, 2007). A large stock of non-performing loans, in turn, hurts banks, weakens growth by constraining reallocation, and is a source of financial instability.

The remainder of this paper is organized as follows: Section 2 sets out the DSGE model. Section 3 reports on calibration and illustrates how the model tracks the performance of Italy since the introduction of the Euro. It then turns to the three recession scenarios, with and without Eurozone exit. Section 4 concludes.

3.2 The model

The monetary DSGE model includes three regions. The focus is on Italy. The rest of the Eurozone is modeled in much less detail but is sufficient to explain trade and capital flows. Italy and the Eurozone may run independent or common monetary policy, with fixed or flexible exchange rates. The rest of the world (RoW) is represented by export demand functions. Goods are differentiated by geographic origin, with the RoW good serving as numeraire. The presentation is meant to provide an overview.[2]

3.2.1 Production sector

Investment firms accumulate capital. *Monopolistic input firms* rent capital and hire labor to produce differentiated intermediate goods (inputs). Competitive *final goods producers* assemble intermediate inputs y_{vt} to produce a final good using the technology $Y_t^g = \left[\int_0^1 y_{vt}^{(\sigma_v - 1)/\sigma_v} dv\right]^{\sigma_v/(\sigma_v - 1)}$. Given aggregate demand Y_t^g, expenditure minimization results in demand for inputs and a final

[2] For a complete documentation, we refer to the Technical Appendix in Keuschnigg (2020).

goods price index P_t,

$$y_{v,t} = (P_t/p_{vt})^{\sigma_v} Y_t^g, \quad P_t = \left[\int_0^1 p_{vt}^{1-\sigma_v} dv\right]^{1/(1-\sigma_v)}, \quad P_t Y_t^g = \int_0^1 p_{vt} y_{vt} dv. \tag{3.1}$$

Aggregate spending is $P_t Y_t^g$, and the price elasticity of demand for components is $\sigma_v > 1$.

Input suppliers are specialized in a single variety v and use technology $y_{vt} = z_t k_{vt}^\alpha l_{vt}^{1-\alpha}$. They rent capital k_{vt} at a price w_t^K from investment firms, and employ labor l_{vt} at a uniform price w_t^L . Labor is a bundle of specialized services with unit cost w_t^L, see below. In a first stage, firms minimize cost per unit of output, giving $m_t^c = \min_{l_{vt},k_{vt}} w_t^L l_{vt} + w_t^K k_{vt}$ s.t. $y_{vt} = 1$. Since components y_{vt} are close substitutes, firms enjoy local monopoly power and earn $\chi_{vt}^m = \max_{p_{vt}} (p_{vt} - m_t^c) y_{vt}$. In a second stage, they set a profit maximizing price p_{vt} subject to the perceived demand elasticity in (3.1). Since all firms face identical factor prices, production is symmetric. The price is a mark up over marginal costs,

$$p_t = \frac{\sigma_v}{\sigma_v - 1} \cdot m_t^c, \quad \chi_t^m = (p_t - m_t^c) Y_t^g. \tag{3.2}$$

Due to symmetry, $p_t = P_t$ and $y_t = Y_t^g$. Aggregate monopoly profit is χ_t^m.

By linear homogeneity, factor use is linear in output and must exhaust factor supply, $K_{t-1} = k_t^u Y_t^g$ and $L_t = l_t^u Y_t^g$. The unit isoquant $1 = z_t (k_t^u)^\alpha (l_t^u)^{1-\alpha}$ implies final output

$$Y_t^g = z_t K_{t-1}^\alpha L_t^{1-\alpha}, \quad z_t = (1-\rho^z)\bar{z}_t + \rho^z z_{t-1} + \varepsilon_t^z, \tag{3.3}$$

where z_t is a standard productivity shock and $\bar{z}_t$ is specified in (3.24) below.

Total costs are $m_t^c Y_t^g = w_t^L L_t + w_t^K K_{t-1}$. Noting (3.2), the value of final output is competitive earnings of labor and capital, augmented by monopoly profits,

$$P_t Y_t^g = w_t^L L_t + w_t^K K_{t-1} + \chi_t^m. \tag{3.4}$$

Finally, employment is a CES composite $L_t = \left[\int_0^1 L_{j,t}^{(\sigma_l-1)/\sigma_l} dj\right]^{\sigma_l/(\sigma_l-1)}$ of differentiated services $L_{j,t}$ supplied by specialized individuals. Firms face wages $w_{j,t}$ set by households and, to minimize labor costs, adjust the use of labor services according to

$$L_{j,t} = \left(w_t^L / w_{j,t}\right)^{\sigma_l} L_t, \quad w_t^L = \left[\int_0^1 w_{j,t}^{1-\sigma_l} dj\right]^{1/(1-\sigma_l)}. \tag{3.5}$$

Total costs are $w_t^L L_t = \int_0^1 w_{j,t} L_{j,t} dj$ and w_t^L is a nominal wage index.

3.2.2 Household sector

Households supply labor, consume goods, and demand real money balances. Households of region i consume final goods C_t^{ij}. The index $j \in \{i, e, o\}$ refers the origin country. We think of Italy i (home), the rest of the Eurozone e, and other countries o (RoW). In most cases, we suppress the index i so that $C_t = C_t^{ii}$ is demand for home goods, and C_t^{ie} and C_t^{io} are imports. Assuming that final goods are differentiated by origin, households consume a basket $\bar{C}_t = \left[\sum_j \left(s^j\right)^{1/\sigma_r} \left(C_t^{ij}\right)^{(\sigma_r-1)/\sigma_r}\right]^{\sigma_r/(\sigma_r-1)}$, and optimally demand

$$C_t^{ij} = s^j \left(\bar{P}_t / P_t^{ij}\right)^{\sigma_r} \bar{C}_t, \quad \bar{P}_t = \left[\sum_j s^j \left(P_t^{ij}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}, \tag{3.6}$$

where $\bar{P}_t$ is the price index and minimum spending is $\sum_j P_t^{ij} C_t^{ij} = \bar{P}_t \bar{C}_t$. Exchange rates relate import prices in domestic currency to foreign producer prices in foreign currency,

$$P_t^{ie} = e_t^{ie} \cdot P_t^e, \quad P_t^{io} = e_t^{io} \cdot P^o. \tag{3.7}$$

Suppose i (Italy) uses Lire, e uses Euros and o Dollars. Exchange rates convert 1 Euro and 1 Dollar into e_t^{ie} and e_t^{io} Lire. Lira prices for imports are P_t^{ie} and P_t^{io} where foreign prices P_t^e and $P^o = 1$ (numeraire) are in foreign currency. The inverse rate converts 1 Lira into $1/e_t^{ie}$ Euros and $1/e_t^{io}$ Dollars. By transitivity, the Euro Dollar exchange rate is $e_t^{eo} \equiv e_t^{io}/e_t^{ie}$. When Italy is part of the Euro Area, the exchange rate $e_t^{ie} = 1$ is fixed.

The household is an extended family with individuals $j \in [0, 1]$, each offering labor services $N_{j,t}$. Household size is H, and $N_{j,t}$ is labor supply per capita. Type j is a monopolist over her specialized services and sets a wage $w_{j,t}$. Once wage and labor supply are optimally determined, the family pools all income.

Preferences for consumption, labor supply and *real* money balances $\bar{M}_t$ are

$$V_t^h = E_t \sum_{s=0}^{\infty} \beta^s u\left(\bar{C}_{t+s}, \bar{M}_{t+s}, \{N_{j,t+s}\} H\right). \tag{3.8}$$

Preferences are homothetic and separable. Instantaneous utility is

$$u_t = \frac{X_t^{1-\sigma_c}}{1-\sigma_c} - \phi_t \cdot \frac{\int_0^1 N_{j,t}^{1+\eta} H dj}{1+\eta}, \quad X_t = \left[s_c \bar{C}_t^{1-\sigma_m} + (1-s_c) \bar{M}_t^{1-\sigma_m}\right]^{1/(1-\sigma_m)}. \tag{3.9}$$

The process $\phi_t = \left(1-\rho^\phi\right)\bar{\phi} + \rho^\phi \phi_{t-1} + \varepsilon_t^\phi$ introduces fluctuations in labor supply and converges to $\bar{\phi}$ in the absence of shocks. Changing the taste parameter $\bar{\phi}$ captures, in reduced form, 'institutional' changes affecting the willingness to work.

Labor earnings derive from differentiated services $N_{j,t}$ at wages $w_{j,t}$. Insurance within the family perfectly smooths income risk. The family cares only about total earnings. Households pay a wage income tax at rate τ_t and a consumption tax at rate τ_t^c, and are able to reduce tax liability by T_t^l (see the fiscal budget). They collect dividends χ_t and χ_t^b from firms and banks, respectively, and receive transfers from social spending E_t and seignorage T_t^M. Income from bank deposits S_t^d includes interest plus repayment of deposits, net of any new savings. Net earnings on government debt holdings are $\left(1-\tilde{s}^b\right) S_t^G$. We assume that households directly hold a share $1-\tilde{s}^b$ of government debt, and banks hold the rest. Residual savings in bonds is subject to the nominal budget constraint

$$\begin{aligned} A_t/(1+i_t) &= A_{t-1} + \int_0^1 (1-\tau_t) w_{j,t} N_{j,t} H dj + E_t + T_t^l + \chi_t + \chi_t^b \\ &+ S_t^d + \left(1-\tilde{s}^b\right) S_t^G + (M_{t-1} - M_t) + T_t^M - (1+\tau_t^c) \bar{P}_t \bar{C}_t. \end{aligned} \tag{3.10}$$

All variables are measured at the beginning of period, except for stocks M_t and A_t which are dated at the end. Nominal money holdings are M_{t-1} at the beginning of period t, giving real money balances $M_{t-1}/\bar{P}_t \equiv \bar{M}_{t-1}$. Finally, the inflation rate π_t must also account for changes in commodity tax rates. Real and nominal interest rates, r_t and i_t, are related by the Fisher equation

$$1+i_t = (1+r_t)(1+\pi_t), \quad 1+\pi_t = \frac{\left(1+\tau_{t+1}^c\right)\bar{P}_{t+1}}{(1+\tau_t^c)\bar{P}_t}. \tag{3.11}$$

In period t, the family maximizes expected utility in (3.8-3.9) by choosing consumption, real money balances, and a wage w_t^* for the fraction of individuals receiving a new wage setting opportunity. With details set out in the separate Technical Appendix, optimal consumption growth follows a standard Euler equation

$$u_{C,t} = \beta E_t (1 + r_t) \cdot u_{C,t+1}, \quad \frac{u_{M,t}}{u_{C,t}} = \frac{i_t}{\left(1 + \tau_{t+1}^c\right)(1 + r_t)}. \tag{3.12}$$

Marginal utilities are defined as $u_{C,t} \equiv du_t/d\bar{C}_t$ and $u_{M,t} \equiv du_t/d\bar{M}_t$.[3] A higher real interest tilts consumption to the future, implying larger savings today. The tangency condition for money implies that money demand is a fraction of consumption, $\bar{M}_t = m_t \bar{C}_t$,[4] where the desired money consumption ratio m_t is declining in nominal interest. Money demand depends on the opportunity cost, the return that could have been obtained if it were invested in the market at a rate i_t, or $i_t/(1 + r_t)$ in present value.

Turning to wage setting and labor supply, individual j faces demand $L_{j,t}$ for her labor type as in (3.5). Being a monopolist, $N_{j,t}H = L_{j,t}$, she sets a wage to exploit market power. Being one among many close substitutes, she takes the wage index w_t^L and aggregate demand L_t as given which implies a perceived demand elasticity σ_l. To account for wage rigidity, we assume that, in any period t, only a *random selection* of workers, a fraction $1 - \omega$, can optimally set wages (see, e.g., Galí, 2015), $w_{t,t} = w_t^*$. The remaining fraction ω is stuck with a wage set in the past, $w_{t-i,t} = w_{t-i}^*$. Consequently, wages are heterogeneous, and agents satisfy labor demand at the relevant wage.

In general, the households' required compensation for labor effort is equal to the marginal rate of substitution $MRS_{j,t} = -u_{N_{j,t}}/u_{C,t}$.[5] Being endowed with unique skills in performing specialized tasks, individuals enjoy limited market power and would set a wage so that the real wage is equal to a mark-up over $MRS_{j,t}$, an individual's competitive valuation of marginal effort, if wages

[3]Given functional forms, $u_{C,t} = s_c x_t^{\sigma_m - \sigma_c}/\bar{C}_t^{\sigma_c}$ and $u_{M,t} = (1 - s_c)\, x_t^{\sigma_m - \sigma_c}/\left(m_t^{\sigma_m} \bar{C}_t^{\sigma_c}\right)$ where x_t is given by $x_t = \left[s_c + (1 - s_c)\, m_t^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$.

[4]Given the specification of utility, the ratio is $m_t = \left(\frac{1-s_c}{s_c} \frac{(1+\tau_{t+1}^c)(1+r_t)}{i_t}\right)^{1/\sigma_m}$.

[5]Given functional forms, $MRS_{j,t} = -u_{N_{j,t}}/u_{C,t} = \phi \cdot N_{j,t}^{\eta} \bar{C}_t^{\sigma_c}/\left(s_c x_t^{\sigma_m - \sigma_c}\right)$. Again, a detailed derivation of wage setting is offered in the Technical Appendix.

were flexible. In a stationary state, new and old wages as well as the marginal valuations are all the same, so that wage setting collapses to the very same static solution,

$$\frac{(1-\tau)\, w^*}{(1+\tau^c)\, \bar{P}} = \frac{\sigma_l}{\sigma_l - 1} \cdot MRS. \tag{3.13}$$

However, given wage stickiness, households are locked into the currently set wage until the next wage setting opportunity arrives. The new wage determines not only current, but also future earnings resulting from labor demand at that wage. Wage setting thus becomes forward looking, replacing the right hand side of (3.13) by a present value of marginal valuations. Wage setting today equates the current real wage with an average of present and future valuations $MRS_{t,t+i}$, discounted with the real interest, and weighted by the probabilities that the wage in period $t+i$ is still unchanged. Wage stickiness implies that the real wage does not move one to one with variations in marginal rates of substitution. Upon aggregating the household sector, sticky wages cause a slow adjustment of the wage index that determines labor demand of firms and unit costs,

$$w_t^L = \left[(1-\omega) \cdot w_{t,t}^{1-\sigma_l} + \omega \cdot \left(w_{t-1}^L \right)^{1-\sigma_l} \right]^{1/(1-\sigma_l)}. \tag{3.14}$$

3.2.3 Investment and private debt

Investment firms own intermediate goods producers, accumulate capital stock, and rent back services on an 'internal capital market', charging a competitive price w_t^K. Noting (3.4), revenues are $w_t^K K_{t-1} + \chi_t^m = P_t Y_t^g - w_t^L L_t$. Firms invest to accumulate the capital stock, $K_t = I_t + (1-\delta) K_{t-1}$, where δ is the depreciation rate. Investment I_t requires a basket of final goods $\bar{Z}_t = I_t + \frac{\psi}{2} K_{t-1} \left(I_t / K_{t-1} - \delta \right)^2$. New capital goods, including installation costs, consist of both domestic and imported final goods and are composed in the same way as in (3.6). Investment spending is thus $\bar{P}_t \bar{Z}_t$. Finally, the required return on equity is $i_t^k = \theta_t^k i_t$. Compared to a safe benchmark interest i_t, households demand an equity premium $\theta_t^k = \left(1-\rho^\theta\right) \bar{\theta}^k + \rho^\theta \theta_{t-1}^k + \varepsilon_t^k$ that fluctuates around $\bar{\theta}^k \geq 1$.

Firms finance investment with retained earnings and bank credit. In the beginning of the period, they repay loans S_t^l, giving outstanding debt of $B_{t-1}^l - S_t^l$. Noting interest payments $i_t^l \left(B_{t-1}^l - S_t^l \right)$, external debt amounts to $B_t^l =$

$B_{t-1}^l - S_t^l + i_t^l \left(B_{t-1}^l - S_t^l\right)$ at the end of the period, or $B_t^l / \left(1 + i_t^l\right) = B_{t-1}^l - S_t^l$. Subtracting wages, investment, debt service and taxes from total earnings leaves dividends equal to

$$\chi_t = P_t Y_t^g - w_t^L L_t - \bar{P}_t \bar{Z}_t - S_t^l - \tau_t T_t^k, \tag{3.15}$$

where $T_t^k = P_t Y_t^g - w_t^L L_t - t^z \bar{P}_t \bar{Z}_t - i_t^l \left(B_{t-1}^l - S_t^l\right) / \left(1 + i_t^k\right)$ is the business tax base. Firms may deduct an investment tax credit at rate t^z and interest on debt (discounted to the beginning of period, using the firm's discount rate i_t^k). For simplicity, we lump together corporate and personal taxes on capital income which gets taxed with the overall income tax rate τ_t. Note finally that the cash-flow $P_t Y_t^g - w_t^L L_t = w_t^K K_{t-1} + \chi_t^m$ stems from a competitive return to capital plus monopoly profits, see (3.4).

A firm's debt capacity is limited and constrains the use of debt. We assume that debt is restricted to a fixed fraction b^l of the replacement cost of preexisting capital,

$$B_t^l / \left(1 + i_t^l\right) = b^l \cdot \left(1 + i_t^k\right) \left(1 - t^z \tau_t\right) \bar{P}_t K_{t-1}, \tag{3.16}$$

where private investment cost is reduced by a factor $1 - t^z \tau_t$ by the tax subsidy.

Firm value V_t is dated at the beginning of period. Using $V_t = V\left(K_{t-1}, B_{t-1}^l\right)$, value maximization $V_t = \max_{I_t} \chi_t + V_{t+1} / \left(1 + i_t^k\right)$ gives optimal investment and new debt. The *net* investment rate $x_t^I \equiv I_t / K_{t-1} - \delta$ is determined by

$$x_t^I = \left(Q_t - 1\right) / \psi, \quad Q_t \equiv \frac{\lambda_{t+1}^K / \left(1 + i_t^k\right)}{\left(1 - t^z \tau_t\right) \bar{P}_t}. \tag{3.17}$$

Tobin's Q_t is the shadow price or market value $E_t \lambda_{t+1}^K / \left(1 + i_t^k\right)$ per unit of capital, divided by the tax adjusted acquisition cost of capital $\left(1 - t^z \tau_t\right) \bar{P}_t$. End of period debt follows from (3.16) and determines repayment S_t^l to banks.

In a steady state, $I = \delta K$ and $Q = 1$. The user cost of capital is then a weighted average of the cost of equity and debt, using the debt ratio b^l as a weight,

$$w^K = \left[\frac{\delta}{1 - \tau} + \frac{i^k}{1 - \tau} \cdot \left(1 - b^l\right) + i^l \cdot b^l\right] \left(1 - t^z \tau\right) \bar{P}. \tag{3.18}$$

A unit of capital effectively costs $\left(1 - \tau^z \tau\right) \bar{P}$, to be financed with debt and equity. The tax inflates the cost of equity $i^k / \left(1 - \tau\right)$, but not the cost of debt

i^l, since interest on debt is tax deductible. Replacement investment is fully equity financed, and hence bears a tax adjusted cost of depreciation equal to $\delta^K/(1-\tau)$.

3.2.4 Fiscal policy

The government inherits debt B^G_{t-1}, raises tax revenue T_t, spends on productive services P_tG_t and on social transfers E_t, and potentially pays subsidies T^b_t to stabilize banks (see below). The fiscal constraint restricts issuing new gross debt B^G_t at a price $1/(1+i^g_t)$,

$$B^G_t/(1+i^g_t) = B^G_{t-1} - S^G_t, \quad S^G_t = T_t - P_tG_t - E_t - T^b_t. \tag{3.19}$$

Sovereign risk is reflected in an interest premium on sovereign bonds, $i^g_t = \theta^g_t \cdot i_t$. The premium is assumed to follow an autoregressive process $\theta^g_t = 1-\rho^g + \rho^g\theta^g_{t-1} + \varepsilon^g_t$ that converges to $\theta^g = 1$ in the long run. Shocks reflect investor panic (or a safe haven effect if $\theta^g_t < 1$). As a result, the interest rate must rise to induce investors to hold on to stocks, leading to increasing costs of government debt service.

Taxing wages and profits at rate τ_t and consumption at rate τ^c_t yields revenue

$$T_t = \tau_t \cdot w^L_t L_t + \tau_t \cdot T^k_t + \tau^c_t \cdot \bar{P}_t\bar{C}_t - T^l_t, \quad T^l_t = \left(1-\rho^T\right)\bar{t}^l P_tY_t + \rho^T T^l_{t-1} + \varepsilon^T_t. \tag{3.20}$$

Reflecting the efficiency of tax collection, we allow revenues to shrink due to base erosion, leading to revenue losses T^l_t. The tax yield is reduced by $\bar{t}^l$ percent of GDP in the long run. The larger such tax losses, the higher tax rates must be. This magnifies distortions and slows down growth. To satisfy the fiscal constraint, we scale tax rates $\tau_t = t^s_t\tau_0$ and $\tau^c_t = t^s_t\tau^c_0$ by a common factor t^s_t starting from initial values.

To prevent unstable debt, the government must pursue a consolidation policy. We specify a policy rule for the 'structural' part $\tilde{S}^G_t$ of the primary surplus which excludes any surprise expenditures or windfall gains. Indeed, the Maastricht rules impose restrictions on the structural rather than the actual deficit, and also specify a long-run debt to GDP ratio $\bar{b}^g = B^G/(PY)$. The parameter γ^g determines how fast debt is reduced (or increased) to reach the long-run target. The consolidation rule thus specifies a structural surplus

$$\tilde{S}_t^G = \left(1 - \frac{\gamma^g}{1+i_t^g}\right) B_{t-1}^G - \frac{1-\gamma^g}{1+i_t^g} \bar{b}^g P_t Y_t. \tag{3.21}$$

In the absence of fiscal shocks, $B_t^G / (1+i_t^g) = B_{t-1}^G - \tilde{S}_t^G$. Debt is exclusively driven by the target surplus. With $\gamma^g < 1$, debt follows a stable path

$$B_t^G = \gamma^g \cdot B_{t-1}^G + (1-\gamma^g) \cdot \bar{b}^g P_t Y_t. \tag{3.22}$$

The stabilization rule makes debt converge to $B^G = \bar{b}^g PY$, equal to $\bar{b}^g$ percent of GDP. The actual surplus may deviate from the structural surplus due to unexpected shocks. Spending policies and required tax revenues T_t are

$$\begin{aligned} P_t G_t &= \bar{g} \cdot P_t Y_t - \xi^g \cdot \tilde{S}_t^G + \varepsilon_t^G, \\ E_t &= \bar{e} \cdot w_t^L L_t - \xi^e \cdot \tilde{S}_t^G + \varepsilon_t^E, \\ T_t &= \bar{g} \cdot P_t Y_t + \bar{e} \cdot w_t^L L_t + (1-\xi^g-\xi^e) \cdot \tilde{S}_t^G. \end{aligned} \tag{3.23}$$

Productive spending consists of a normal level $\bar{g} P_t Y_t$, reduced by spending cuts to finance a share ξ^g of the required surplus. Social spending reflects a replacement rate $\bar{e}$ of wage earnings, and spending cuts must contribute a share ξ^e to fiscal consolidation. The required tax revenue T_t covers the structural part of public spending, $\bar{g} P_t Y_t + \bar{e} w_t^L L_t$, plus tax increases equal to $(1-\xi^g-\xi^e)\, \tilde{S}_t^G$, needed to reduce public debt. Tax rates are set such that revenue (3.20) matches this target level. Spending shocks ε_t^G and ε_t^E as well as unexpected subsidies to banks T_t^b are not immediately financed with taxes but raise next period's debt and are consolidated only later on. To see how unconsolidated shocks affect fiscal debt dynamics, substitute the policy rules (3.23) into the primary surplus (3.19) and get $S_t^G = \tilde{S}_t^G - \varepsilon_t^G - \varepsilon_t^E - T_t^b$. Unexpected spending reduces the actual primary surplus and raises debt before is gets consolidated in future periods.

The policy parameters ξ^e and ξ^g determine whether consolidation is tax or expenditure based. If ξ^e and ξ^g are low, budget consolidation is mostly tax based. High values indicate budget consolidation with spending cuts. These parameters thus connect to research on the effectiveness of tax- versus spending-based consolidation (e.g. Alesina et al., 2015). Higher tax rates discourage labor supply and investment and slow down growth. Spending cuts involve their own costs. For example, cuts in social spending might be good for growth but involve unfavorable distributional effects. Cutting productive spending tends to impair private sector productivity. In the spirit of Barro (1990), we assume that a higher stock of infrastructure K_t^G shifts factor productivity by $\bar{z}_t$ in (3.3),

$$K_t^G = G_t + (1 - \delta^g) K_{t-1}^G, \quad \bar{z}_t = z_0 \left(K_t^G / \bar{K}^G\right)^{\sigma^z}. \tag{3.24}$$

3.2.5 Banking sector

Banks provide credit B_t^l to (investment) firms and B_t^g to the government. The government issues debt B_t^G in total, of which $B_t^g = \tilde{s}^b B_t^G$ is acquired by banks, and the rest by investors (private households). In holding a fixed share $\tilde{s}^b$ of bonds, banks receive interest and repayment S_t^G in proportion. The remainder is paid to households, see (3.10). Outstanding business loans and sovereign bond holdings thus evolve as

$$B_t^l / \left(1 + i_t^l\right) = B_{t-1}^l - S_t^l, \quad B_t^g / \left(1 + i_t^g\right) = B_{t-1}^g - \tilde{s}^b S_t^G. \tag{3.25}$$

In line with prior literature (e.g., Kollmann et al., 2011), we capture loan risks by private defaults of borrowers that diminish banks' earnings. We introduce a share s_t^l of non-performing loans. When a default occurs, banks extract liquidation values $1 - \ell$ which are available for new lending to other firms.[6] The relationship in (3.25) lists the liabilities of (surviving) firms, while credit losses $d_t^l B_{t-1}^l$ reflect real costs that diminish bank earnings S_t^l. Losses are proportional to the share of non-performing loans,

$$d_t^l = \ell \cdot s_t^l, \quad T_t^b = t_t^b d_t^l B_{t-1}. \tag{3.26}$$

To keep up lending in a crisis and to mitigate the bank's losses, the government may provide some support T_t^b. The latter is equal to a fraction t_t^b of total losses.[7]

[6] Keuschnigg and Kogler (2020) provide microfoundations for the process of credit reallocation.

[7] More specifically, public support stems from asset purchases similar to the troubled asset relief program (TARP) of the U.S. during the financial crisis. The government buys a fraction t_t^b of the loan portfolio and pays the face value of one, giving a volume $t_t^b B_{t-1}^l$. After absorbing losses $T_t^b = t_t^b d_t^l B_{t-1}$, it sells back 'cleaned' assets at a depreciated value $\left(1 - d_t^l\right) t_t^b B_{t-1}^l$. The net transfer to banks is T_t^b.

Banks are funded with deposits and equity. Given repayment S_t^d and interest, the stock of deposits D_t follows

$$D_t / \left(1 + i_t^d\right) = D_{t-1} - S_t^d. \tag{3.27}$$

Depositors and equity holders require a risk premium compared to the safe benchmark rate such that deposit rate and return on equity satisfy

$$\begin{aligned} i_t^d &= \theta_t^d \cdot i_t, \quad \theta_t^d = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^d + \varepsilon_t^d, \\ i_t^b &= \theta_t^b \cdot i_t, \quad \theta_t^b = \left(1 - \rho^\theta\right) \bar{\theta}^b + \rho^\theta \theta_{t-1}^b + \varepsilon_t^b. \end{aligned} \tag{3.28}$$

While bank equity requires a permanent premium $\bar{\theta}^b \geq 1$, the deposit rate is normally equal to the safe benchmark rate. During a crisis, however, a loss of confidence may lead to prohibitive interest costs leading to a sudden stop in deposit funding. We capture such panic-driven shocks by including a risk premium on deposits, which is absent in normal times ($\theta_t^d \to 1$ without any shocks).

Relating *net* inflows and outflows of funds, the bank's budget constraint gives dividends to equity holders (households)[8]

$$\chi_t^b = S_t^l + \tilde{s}^b S_t^G - S_t^d - \left(1 - t_t^b\right) d_t^l B_{t-1}^l. \tag{3.29}$$

The banking sector's balance sheet requires that total assets equal deposits and equity,

$$\frac{B_t^l}{1 + i_t^l} + \frac{B_t^g}{1 + i_t^g} = \frac{D_t}{1 + i_t^d} + \frac{E_t^b}{1 + i_t^b}. \tag{3.30}$$

Banks are subject to capital requirements, which define minimum regulatory capital as a fraction of risk-weighted assets. Banks therefore have to raise total equity equal to κ^B percent of business loans plus κ^G percent of sovereign bonds. In line with the preferential treatment of government debt, which is deemed to be safe in the Basel accords, we assume $\kappa^G < \kappa^B$. Given that equity is much more expensive than deposits, banks tend to economize on the use of equity and raise no more than $\frac{E_t^b}{1+i_t^b} = \kappa^B \frac{B_t^l}{1+i_t^l} + \kappa^G \frac{B_t^g}{1+i_t^g}$. Substituting into the balance

[8] For example, the gross inflow from deposit funding is $D_t / \left(1 + i_t^d\right)$, while the gross outflow is the repayment of the stock D_{t-1}. The *net* outflow is $S_t^d = D_{t-1} - D_t / \left(1 + i_t^d\right)$ and reduces dividends.

sheet determines the volume of deposits

$$\frac{D_t}{1+i_t^d} = \left(1-\kappa^B\right)\frac{B_t^l}{1+i_t^l} + \left(1-\kappa^G\right)\frac{B_t^g}{1+i_t^g}. \tag{3.31}$$

In addition to holding a share of total government debt, banks choose net deposit funding S_t^d and net business lending S_t^l. Referring to the Technical Appendix for details, value maximization subject to financing constraints results in loan pricing

$$1+i_t^l = \frac{\kappa^B\cdot\left(1+i_t^b\right)+\left(1-\kappa^B\right)\cdot\left(1+i_t^d\right)}{1-\left(1-t_{t+1}^b\right)d_{t+1}^l}. \tag{3.32}$$

The loan rate i_t^l is a mark-up over the cost of capital which is a weighted average of deposit interest and the cost of equity. The mark-up factor reflects default risk and expected depreciation of bad loans as discussed in (3.26) above. Government support with a subsidy t_t^b reduces the markup, leading to lower loan rates. After all, the program aims at preventing a surge in loan rates that would block investment of firms.

To close the feedback loop between banks and the real economy, we relate the share of bad loans to macroeconomic fundamentals and assume an autoregressive process

$$s_t^l = \left(1-\rho^{sl}\right)s_0^l\cdot\left(\bar{Y}_t/Y_t\right)^{\sigma^{sl}} + \rho^{sl}s_{t-1}^l + \varepsilon_t^{sl}, \quad t_t^b = \rho^{sl}t_{t-1}^b + \varepsilon_t^{tb}. \tag{3.33}$$

When output Y_t falls short of potential output $\bar{Y}_t$, the share of bad loans shifts up with elasticity σ^{sl}. The subsidy rate on bad loans follows a policy process as specified in the second equation. The program is activated only if the share of non-performing loans s_t^l is very high. When the program is terminated, the subsidy rate vanishes with speed ρ^{sl}.

3.2.6 General equilibrium

We analyze fluctuations around a steady state with constant money supply and zero inflation. To introduce monetary policy, we specify a policy rule as in

Ascari and Ropele (2013) and Sargent and Surico (2011),

$$M_t^s = (1-\rho^m)\,\phi^m \bar{Y}_{t-1} \cdot \frac{\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y}}{(1+\pi_t)^{\psi_\pi}} + \rho^m M_{t-1}^s + \varepsilon_t^m, \quad T_t^M = M_t^s - M_{t-1}^s. \tag{3.34}$$

Trend output is smoothed over the business cycle according to $\bar{Y}_t = \delta^m Y_t + (1-\delta^m)\,\bar{Y}_{t-1}$. With a smaller rate δ^m, trend output depends less heavily on current output realizations. Money supply consists of a trend and a cyclical component. The trend component $\phi^m \bar{Y}_{t-1}$ accommodates a permanent increase in output. The cyclical part is meant to dampen fluctuations and depends on parameters ψ_y and ψ_π. If current output is below trend, $Y_t < \bar{Y}_{t-1}$, money supply scales up by a factor $\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y} > 1$, while the opposite happens in a boom. Similarly, if actual inflation exceeds the trend rate ($\pi_t > 0$), money supply is scaled down by $1/\left(1+\pi_t\right)^{\psi_\pi} < 0$.

An autonomous monetary policy regime creates exchange rate risk. If an Eurozone saver invests 1 Euro at home, she earns gross interest $1+i_t^e$. If she invests 1 Euro in the Italian bond, she gets e_t^{ie} Lire at the beginning of period which grow by $1+i_t$ and are converted back at a rate $1/e_{t+1}^{ie}$, giving end of period wealth equal to $(1+i_t)\,e_t^{ie}/e_{t+1}^{ie}$. Standard interest rate parity prevents arbitrage. However, when there is country risk, investors request a premium θ_t. Modified interest rate parity then requires

$$(1+i_t)\,e_t^{ie}/e_{t+1}^{ie} = (1+i_t^e)\,\theta_t. \tag{3.35}$$

The return of the Italian bond in Euros must exceed the domestic return $1+i_t^e$ by a factor of θ_t. When the country's debt ratio rises, investors start to worry about solvency and ask for a higher premium. The reverse case may be associated with a safe haven effect. Following Schmitt-Grohé and Uribe (2003), we postulate

$$\theta\left(b_t^f\right) = 1 + \gamma\left(e^{b_t^f - \bar{b}^f} - 1\right), \quad b_t^f \equiv B_t^f / \left(P_t Y_t\right). \tag{3.36}$$

In a steady state, exchange rates are constant and $i = i^e = 1/\beta$, to support stationary consumption. The country premium must disappear, $\theta\left(b^f\right) = 1$ which requires $b_t^f = \bar{b}^f$. The model thus explains fluctuations around a stationary foreign debt to GDP ratio. The debt sensitivity of the country premium assures stability of savings in an open economy.

The trade balance TB_t is equal to the value of exports minus imports. Exports reflect import demand of other regions as specified in the next subsection. In focusing on the interactions within the Euro Area, we assume that foreign debt is exclusively held by Eurozone investors. Foreign debt B_t^f, denominated in domestic currency, grows by

$$B_t^f / (1 + i_t) = B_{t-1}^f - TB_t, \quad TB_t = P_t E_t^x - P_t^{ie} \left(C_t^{ie} + Z_t^{ie} \right) - P_t^{io} \left(C_t^{io} + Z_t^{io} \right). \tag{3.37}$$

Since loans B_t^l are in nominal terms, real credit losses are $d_t^l B_t^l / P_t$. Subtracting from gross output Y_t^g as listed in (3.3) gives net output or real GDP, $Y_t = Y_t^g - d_t^l B_{t-1}^l / P_t$. Market clearing conditions for output, asset and money markets are,[9]

$$Y_t = C_t + G_t + Z_t + E_t^x, \quad A_t = -B_t^f, \quad \bar{M}_t = M_t^s / \bar{P}_{t+1}. \tag{3.38}$$

Demand for home goods stems from consumption, public spending, investment and exports. Households own firms and banks and, accordingly, receive dividends as in (3.10). They also hold deposits, leading to a net income flow S_t^d equal to interest minus savings in new deposits as demanded by banks. Therefore, A_t is the residual stock of savings which must be equal to net foreign assets if B_t^f is negative. Alternatively, the country is a net debtor. Finally, the private sector chooses real money balances which must be equal to money supply, $\bar{M}_t = M_t^s / \bar{P}_{t+1}$. One of the conditions is redundant by Walras' Law.

3.2.7 Eurozone and rest of the world

Given our focus on Italy, we propose a minimal model of the rest of the Eurozone but rich enough to analyze Italy's policy alternatives in the Euro Area. We therefore entirely abstract from fiscal policy, banking and supply side details, and replace production of final goods by an autoregressive process for Eurozone GDP,

$$Y_t^e = \left(1 - \rho^{Y,e}\right) Y_0^e + \rho^{Y,e} Y_{t-1}^e + \varepsilon_t^{Y,e}. \tag{3.39}$$

[9]There is no separate condition for labor market clearing since each household type j is a 'local' monopolist and serves the entire market.

Preferences are similar to (3.8-3.9), except for fixed labor supply. Being endowed with an income stream $P_t^e Y_t^e$, households choose intertemporal consumption and money demand. The real interest rate determines consumption growth and savings as in the Euler equation (3.12), and demand for real money balances is $\bar{M}_t^e = m_t^e \bar{C}_t^e$. By the same principles as in (3.6), households allocate spending on home goods and imports,

$$\bar{P}_t^e \bar{C}_t^e = P_t^e C_t^e + P_t^{ei} C_t^{ei} + P_t^{eo} C_t^{eo}, \tag{3.40}$$

where $P_t^{ei} = P_t^i / e_t^{ie}$ and $P_t^{eo} = P^o e_t^{eo}$ are local demand prices of final goods from Italy and rest of the world, denominated in Euros. Goods demand is parallel to (3.6). Given the trade balance $TB_t^e = P_t^e E_t^{x,e} - P_t^{ei} C_t^{ei} - P_t^{eo} C_t^{eo}$, the current account is the mirror image of (3.37). Net foreign debt of Italy corresponds to net foreign assets of the Eurozone. In parallel to (3.38), market clearing in the EZ economy requires $Y_t^e = C_t^e + E_t^{x,e}$, $A_t^e = -B_t^e$, and $\bar{M}_t^e = M_t^{s,e} / \bar{P}_{t+1}^e$. Supply stems from the output process above. Demand consists of consumption demand and exports only. In an autonomous regime, the money supply rule is parallel to (3.34). One of the three conditions is redundant by Walras' Law.

The Rest of the World consists of other countries (indexed by o) and is even simpler. The final good serves as the *numeraire*, i.e., we abstract from monetary policy in RoW and normalize the local price to $P^o = 1$. Income and demand are exogenous. RoW is represented only by import demand functions for Italian and EZ exports to RoW,

$$C_t^{oi} = s^{oi} \cdot \left(e_t^{io} / P_t\right)^{\sigma_r}, \quad C_t^{oe} = s^{oe} \cdot \left(e_t^{eo} / P_t^e\right)^{\sigma_r}. \tag{3.41}$$

Now all export demands are specified. Italian exports $E_t^x = C_t^{ei} + C_t^{oi}$ reflect import demand from the Eurozone and RoW. Exports of the Eurozone and of RoW to Italy reflect Italian imports for both consumption and investment needs, giving $E_t^{x,e} = C_t^{ie} + Z_t^{ie} + C_t^{oe}$ and $E_t^{x,o} = C_t^{io} + Z_t^{io} + C_t^{eo}$. Since we abstract from capital flows relating to RoW, trade of that region must be balanced, $TB_t^o = P^o E_t^{x,o} - P_t^{oe} C_t^{oe} - P_t^{oi} C_t^{oi} = 0$. Finally, by Walras' Law, $TB_t + e_t^{ie} TB_t^e + e_t^{io} TB_t^o = 0$. In the world economy, the sum of trade balances, after converting them into the same currency (e.g. Lire), must add up to zero.

3.2.8 Currency union

In a *currency union*, there is only one monetary policy subject to one money market clearing, and the internal exchange rate is fixed at $e^{ie} = 1$. Money supply is based on the state of the whole union which is a weighted average of the two regions. We use weights $s^Y = PY/(PY + P^e Y^e)$ and $1 - s^Y$ equal to the calibrated shares in total Eurozone GDP of Italy and the rest. We define a 'price index' $\bar{P}_t^u$ and get

$$Y_t^u \equiv (P_t Y_t + P_t^e Y_t^e) / \bar{P}_t^u, \quad \bar{P}_t^u \equiv s^Y \bar{P}_t + \left(1 - s^Y\right) \bar{P}_t^e. \tag{3.42}$$

Accordingly, the Euro Area wide inflation is $1 + \pi_t^u \equiv \bar{P}_{t+1}^u / \bar{P}_t^u$, while local inflation reflects the changes in local price indices. In money market equilibrium, central money supply must accommodate the sum of money demands in both regions, $M^{s,u} = \bar{P}\bar{M} + \bar{P}^e \bar{M}^e$. The common monetary policy rule includes trend and countercyclical components as before,

$$M_t^{s,u} = (1 - \rho^m)\, \phi^{m,u} \bar{Y}_{t-1}^u \cdot \frac{\left(\bar{Y}_{t-1}^u / Y_t^u\right)^{\psi_y}}{\left(1 + \pi_t^u\right)^{\psi_\pi}} + \rho^m M_{t-1}^{s,u} + \varepsilon_t^{m,u}. \tag{3.43}$$

We allocate total money supply to each region to accommodate local money demand.

We solve the model for two alternative regimes. In the monetary union, the internal exchange rate is fixed ($e^{ie} = 1$), and monetary policy is centralized. Total money supply is governed by the policy rule (3.43) and must accommodate the sum of regional money demands. For a very small member state with little weight in total Euro Area wide GDP and inflation, monetary policy is effectively exogenous. Common monetary policy serves as our base case. Alternatively, in the autonomous regime, money markets are separate. Monetary policy is decentralized to target local conditions, and the internal exchange rate e_t^{ie} becomes fully flexible. Exit from the Eurozone reflects a regime change from common to separate policies.

3.3 Quantitative analysis

3.3.1 Model calibration and estimation

We calibrate a stationary state and estimate selected parameters and shock processes to track past economic performance. To reflect conditions in the early phase of the Eurozone, we use an average of the period 2001:1-2006:4 of detrended quarterly data. The focus is on Italy. After de-trending, growth and inflation rates are zero. Model solutions are thus interpreted as deviations from long-run rates. We normalize Italian GDP to 100 so that all macro data are conveniently interpreted in percent of GDP. We infer relative country size from Eurostat and Worldbank data. Italy produced 18% of EA's GDP, while EA's GDP amounted to 17% of world GDP.

Table 1 reports key parameters and data. By OECD data, EA sovereign bonds paid an annual rate of roughly 4%, largely the same in all member states. The prototype safe asset is long-term US Treasury bills which paid on average of 2% per anno. We assume that all assets yield the same risk adjusted return equal to 0.75% quarterly, corresponding to 3% per anno. The discount factor β is set to support stationarity in consumption. A typical equity premium from Eurostat data yields a required return on equity capital of 3% (12% p.a.). The loan rate of interest for private credit is a weighted average of bank funding costs and, thus, amounts to 1.45%, or roughly 5.8% p.a.

Based on evidence in Keane and Rogerson (2012) and Chetty et al. (2011), we set $\eta = 2$, corresponding to a Frisch labor supply elasticity of 1/2. The intertemporal substitution elasticity is 2/3, implying $\sigma^c = 1.5$, which is a typical value as in Smets and Wouters (2003, 2005), for example. The interest sensitivity of money demand depends on the substitution elasticity between consumption and real money balances, equal to 3 as in Walsh (2017, p.49-52 and 72). The price sensitivity of trade flows depends on the Armington elasticity of substitution between goods of different country origin. Evidence in Adolfson et al. (2007) and Obstfeld and Rogoff (2000) gives $\sigma^r = 5$. To match mark-up data, we fix the elasticity of variety substitution at $\sigma^v = 6$, implying a mark-up factor of 1.2 (Schmitt-Grohé and Uribe, 2005). Finally, we follow Galí (2015, p.177) and set the substitution elasticity for labor varieties equal to $\sigma_l = 4.5$ and the degree of wage stickiness to $\omega = 0.8$. This is broadly consistent with Schmitt-Grohé and Uribe (2005) who rely on wage stickiness between 0.64 and 0.87 and with Erceg et al. (2000) who use a value of 0.75.

Key Parameters and Data		
Interest rates:		
i	0.75%	risk adjusted interest rate
i^k, i^b	3%	required return on equity
i^l	1.45%	loan rate of interest
Household sector:		
$1/\eta$	0.5	Frisch labor supply elasticity
$1/\sigma^c$	2/3	intertemporal Substitution elasticity
σ^m	3	substitution elasticity consumption / money
σ^r	5	substitution elasticity goods by region
σ^v	6	substitution elasticity differentiated products
σ^l	4.5	substitution elasticity labor varieties
ω	0.8	rate of wage adjustment
Production and banking sector:		
α	0.25	capital income share
δ	0.03	capital depreciation rate
b^l	0.6	debt asset ratio firms
κ^B	0.11	equity ratio business credits
κ^G	0.03	equity ratio sovereign bonds
s^l	0.06	non performing loan share
$1-\ell$	0.925	recovery rate of liquidated credit
σ^{sl}	13.3	output elasticity of bad loan share
Dynamics:		
b^f	0.22	net foreign debt
γ	0.0124	interest sensitivity w.r.t. foreign debt
ψ	5	adjustment cost to investment
ρ	0.95	persistence of cyclical shocks

Table 3.1: Key Parameters and Data

Regarding transitional dynamics, a widely used parameter value for adjustment costs to investment is $\psi = 5$, in line with Smets and Wouters (2003) who estimate a confidence interval between 5.1 and 8.9. We set the prior of the autoregressive coefficients of business cycle shocks equal to $\rho = 0.95$, with the estimated values ranging from 0.9 to 0.94 (see Appendix). Estimations for the Euro Area suggest values between 0.85 and 0.95 (Smets and Wouters, 2003; Gerali et al., 2010).

Turning to production, we set the capital share in value added to $\alpha = 0.25$. Adding monopolistic profits then comes close to OECD data on the income share of capital. The depreciation rate is $\delta = 0.03$, or 12% annually. Demand for bank credit follows from a fixed debt asset ratio $b^l = 0.6$, based on Eurostat data of a debt-to-asset ratio of 63% for EA non-financial firms. Italian banks had an equity ratio κ^B of 11%, leaving a buffer of 3% in excess of the minimum regulatory capital ratio of 8% for corporate credit. In line with Basel II accords, we set the regulatory weight for sovereign bonds to zero and set κ^G equal to the voluntary buffer. Already in the early 2000's, Italy's non-performing loan (NPL) share amounted to 6.6%, substantially above the share of 2.5% in the EA, and multiplied by roughly 2.7 since then. The loss rate on non-performing loans amounts to 30% annually, or $l = 7.5\%$ per quarter, reflecting estimates for total recovery rates between 50 and 85%.[10] The NPL share is sensitive to output fluctuations. By (33), the (long-run) semi-elasticity in a steady state is $ds^l = -s^l\sigma^{sl} \cdot dY/Y$. We postulate that a recession with an output loss of 5% ($dY/Y = -.05$) changes the NPL share by 4 percentage points ($ds^l = .04$) which requires $\sigma^{sl} = (.04/.05)/s^l \approx 13.3$.[11]

Finally, net foreign debt amounts to 21.6% of GDP, reflecting liabilities to foreigners. The parameter γ captures how an increase in net foreign indebtedness translates into a higher country premium and raises domestic interest rates. We normalize the country premium to zero at this (steady state) level, requiring $\theta = 1$ in (36). We then calibrate γ such that an increase in the debt to GDP ratio by 20 percentage points raises the interest rate by 25 basis points (1 pc annually).[12] Turning to trade flows, Italy imported 23% of GDP and exported 21%, according to Eurostat data. Of all imports, 47% were sourced from the EA and 53% from RoW. On the export side, 47% of all exports went to the EA and 53% to RoW. Using export data from RoW to all individual EA countries (except Italy), one can determine EA's import share as 19% of GDP, of which 12% stemmed from Italy and 88% from RoW.

[10] Acharya et al. (2007) report a mean loan recovery rate of 81% from a sample of non-financial US corporations over 1982-1999. Grunert and Weber (2009) find a 73% retrieval rate for German firms while Caselli et al. (2008) estimate a rate of only 48% for Italian SMEs.

[11] Nkusu (2011) finds that a 2.7 percent shock to GDP growth causes NPLs to increase by 1.7 percentage points within 4 years in an advanced economy. His analysis also shows that this relationship is highly non-linear. Larger shocks to GDP growth will lead to substantially larger responses in NPL rates.

[12] Specifically, we define $(1 + i_t)\, e^e_t/e^e_{t+1} \equiv 1 + \tilde{\imath}_t$ in (35) and use (36) to calculate the slope $d\tilde{\imath}_t/db^f_t = (1 + i^e)\,\gamma$ where $e^{b^f - \bar{b}^f} = 1$ in a steady state. Replicating the quantitative response thus requires $d\tilde{\imath}_t/db^f_t = (1 + i^e)\,\gamma = .0025/.2$. Noting $i^e = i = .0075$, we find the parameter $\gamma = .0124$.

Policy Parameters		
Fiscal policy:		
$\bar{b}^g$	105%	fiscal debt to GDP target
γ^g	0.97	fiscal consolidation speed
$\bar{g}$	15%	public consumption spending to GDP
σ^z	0.25	productivity effect public infrastructure
ξ^g	0.2	consolidation share productive spending
ξ^e	0.1	consolidation share social spending
Monetary policy:		
m	1.3	money consumption ratio
ψ_π	2	sensitivity of money supply to inflation
ψ_y	1	sensitivity of money supply to output gap

Table 3.2: Policy Parameters

Table 2 reports parameter values that govern fiscal and monetary policy as well as transitional dynamics. By OECD data, the Italian debt to GDP ratio was 105% in 2006 ($\bar{b}^g = 1.05$) which compares to a much lower ratio of 61% in EA without Italy in 2006, and has grown since then to about 130% of GDP (see next subsection). Banks (and other financial institutions) hold around 35% of national public debt in Italy, giving $\tilde{s}^b = 0.35$. The parameter γ^g determines the speed of fiscal consolidation and the convergence of public debt towards the target ratio $\bar{b}^g$. The value $\gamma^g = 0.97$ implies a half-life of debt adjustment of 23 quarters, or less than six years. We assume that 70% of consolidation results from tax increases and 30% from spending cuts. One third are cuts in social spending ($\xi^e = 0.1$), and two thirds are cuts in productive spending ($\xi^g = 0.2$). Social spending absorbs 18.5% of GDP which is 30% of gross wage income ($\bar{e} = 0.295$). Public consumption in Italy amounts to 14.6% of GDP ($\bar{g} = .15$). Adding debt service gives a total expenditure share of 44.3% of GDP.

Following Barro (1990), we allow for a positive productivity effect of productive public spending where $\sigma^z = 0.25$ is consistent with typical estimates of the output effect.[13] In calibrating money demand, we set the money con-

[13] Colombier (2009) finds that an increase in public spending on transport infrastructure, water systems and education by 1 percentage point raises the per capita growth rate of real GDP by 0.5 percentage points. The estimate of Bleaney et al. (2001) is somewhat lower at 0.3 percentage points. In our model, growth relates to long-run level effects. In (24), the long-run effect on factor productivity is $\hat{z} = \sigma^z \hat{G}$, where stationarity implies $z = \bar{z}$ and

sumption ratio to $m = 1.3$. Regarding monetary policy, we postulate a money supply rule, but allow for discretionary intervention in times of crisis. Ascari and Ropele (2013) have estimated the sensitivities of money supply to changes in the price level and the output gap and report values between 1 and 3 for ψ_π and a range of 0 to 1 for ψ_y.

3.3.2 Tracking past performance

Calibration results in a deterministic steady state reflecting the conditions at the start of the monetary union in early 2000. We now use the model to track the evolution of the Italian economy since then, and Euro Area GDP. Since the model requires stationary data, we use a Kalman implementation of the one-sided HP filter for detrending output data. The Kalman filter includes a zero constant which allows us to scale the series to fluctuate around a normalized output value. We also remove seasonal trends in wages. Prior to 2014, the share of non-performing loans is reported with annual frequency only. We obtain quarterly data by linear interpolation of annual values.

The most commonly used estimation method adds structural shocks to the model (Smets and Wouters, 2003, 2007; Rabanal and Rubio-Ramírez, 2005) in order to estimate the parameters influencing model dynamics and to calibrate those affecting the steady state. Starting from this steady state, we use Bayesian estimation procedures and let the model determine the shock processes to replicate key time series from 2000 to 2018. Specifically, we estimate shocks to factor productivity ϕ_t^Y, bad loan share s_t^l, risk premia on sovereign bonds θ_t^g and deposits θ_t^d, as well as government consumption G_t and social spending E_t in Italy. Furthermore, we include a shock process to the Eurozone GDP Y_t^e into our estimation. With seven endogenously determined shocks, the model replicates exactly, without error, seven selected time series as part of the stochastic general equilibrium solution. Motivated by the earlier discussion of past economic performance in Italy, we track the wage index w_t, the GDP share of fiscal debt $B_t^G/(P_tY_t)$ and government consumption $G_t/(P_tY_t)$, the bad loan share s_t^l, interest rates i_t^d and i_t^g on deposits and fiscal debt in Italy,

---

$G = \delta^g K^G$. Assuming user cost and employment are constant, technology $Y^g = zK^\alpha L^{1-\alpha}$ implies $\hat{Y}^g = \hat{z} + \alpha\hat{K}$ while Y_K^g constant implies $\hat{Y}_K^g = \hat{z} - (1-\alpha)\hat{K} = 0$. Combining, the long-run output effect is $\hat{Y}^g = \frac{1}{1-\alpha}\hat{z} = \frac{\sigma^z}{1-\alpha}\hat{G}$. With $\alpha = .25$ and $\sigma^z = .25$, the output elasticity of productive spending is $.25/.75 = 0.33$, well within the range of typical estimates.

as well as output in the Eurozone Y_t^e.

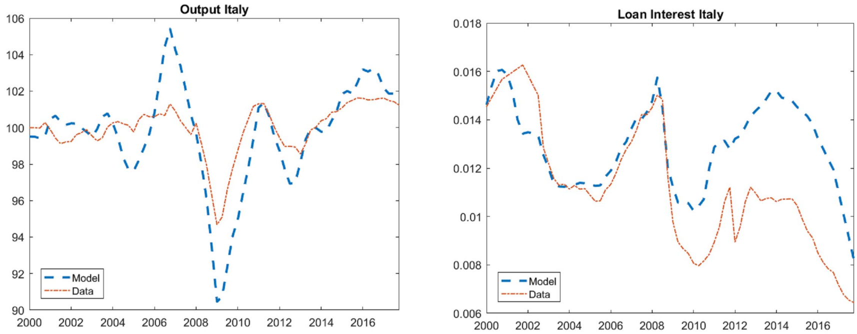

Figure 3.1: Simulated and Actual Time Series

Given a relatively small selection of 'targeted' variables, the model cannot exactly replicate but only approximate more or less closely the remaining data. Figure 1 compares actual and simulated gross output and the loan rate of interest in Italy since the start of the currency union. As a result of de-trending, the Figure shows fluctuations around a trend. The approximation appears reasonable. The relatively favorable performance prior to the crisis led to output substantially moving above trend. The sharp recession starting in 2008 resulted in a large drop in output. The subsequent periods have seen a moderate recovery over the past ten years. By and large, the loan rate of interest followed a downward trend, although with a period of rising rates prior to the start of the crisis.

In addition to the shocks, we have also estimated a number of structural parameters. Appendix B describes the estimation procedure in more detail, including our assumptions on priors and the resulting posterior distributions of estimated parameters in Table A1.

3.3.3 Sustained reform

Our rich structural model of Italy as part of the Eurozone allows for an analysis of many policy options. Although the model is quite detailed, we can only paint a broad picture. Starting from unfavorable initial conditions, we explore the potential consequences of (i) sustained reform within the Eurozone with a long-term policy commitment; and (ii) exit from the Eurozone, triggered by a severe asymmetric recession. The starting point of the analysis is an unfavorable stationary equilibrium as portrayed in Table 3.

The model is calibrated to reflect the situation at the start of the Eurozone and some key model parameters are estimated to track the development since then. Today, Italy appears to be stuck in a bad equilibrium and confronts a 'trilemma' of excessive government debt, a vulnerable banking sector and stagnant growth. The last column of Table 3 illustrates a constructed steady state that can rationalize the state of the Italian economy today in several key variables (FSS). The numbers partly reflect a cumulative negative causation of the three drivers of the Eurozone crisis that were discussed, for example, by Shambaugh (2012). Public debt is about 130% of GDP, compared to 105% twenty years earlier, with no clear tendency for reversal. Given the growth in government spending resulting from a larger debt burden and an assumed increase in social spending of about 3% of GDP,[14] the effective income tax rate is 3.5 points higher,[15] thereby discouraging employment and investment. To stabilize debt, the government must initiate fiscal consolidation which, by assumption, is based 70% on tax increases, 20% on cuts in productive spending and 10% in social spending (which partly offsets the initial increase). Importantly, the cuts in productive spending imply deteriorating public services and infrastructure which endogenously transmits into stagnant factor productivity.

On top of that, the banking sector remains vulnerable with a high share of bad loans which forces banks to raise the loan rate. A higher cost of credit, a higher tax burden and a deteriorating infrastructure all contribute to a slowdown of investment and growth. In this bad equilibrium, the model implies a capital stock 17% lower than at the start of Eurozone membership. Higher labor taxes and lower real wages on account of declining productivity discourage labor supply and employment as well which is 2% lower. The decline in real wages of about 6% comes close to observed trends (ILO (International Labour Organization), 2018). Reduced factor inputs and declining productivity imply a 10% reduction of the output level and an 8% loss in private consumption.[16]

[14]By Eurostat data, social spending increased from 19% in the early 2000s to more than 22% in 2018.

[15]The OECD tax database reports an all-in average personal income tax rate at the average wage for a single worker without children of 31.4%, up from 28.5% in 2001.

[16]The last two lines of Table 3 result from a model with international capital flows and infinitely lived agents. In the long-run, domestic interest is tied to foreign interest rates, see (3.36). The net foreign asset position must thus be a constant fraction of GDP, with possibly

Symbols	Names	ISS	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.0500	1.3000
s_l	Bad Loan Share Banks	0.0600	0.1500
Y	Real GDP	0.0000	-10%
K	Capital Stock	0.0000	-17%
L	Employment	0.0000	-2%
Cbar	Private Consumption	0.0000	-8%
w/Pbar	Real Wage	0.0000	-6%
z	Factor Productivity	1.0700	1.0428
tau	Income Tax Rate	0.3000	0.3337
i	Ann.Domestic Interest	0.0300	0.0300
B_f/PY	Net Foreign Debt/GDP	0.2200	0.2200

Remark: ISS stationary state at start of Eurozone.
FSS stationary state in bad equilibrium.

Table 3.3: A bad stationary equilibrium

These developments render Italy in a vulnerable position. As a member of the Eurozone, it lacks monetary policy instruments that could be targeted to the national economy to dampen the impact of asymmetric shocks. It also lacks important adjustment mechanisms such as exchange rate flexibility. As a consequence of the trilemma discussed above, the ability of fiscal policy, banks and the real sector to absorb shocks and dampen business cycle fluctuations is limited, leading to larger recessions and making it more vulnerable to a loss of confidence on financial markets. We first discuss key reforms that could potentially reverse the unfavorable trends and increase the gains from Eurozone membership. A comprehensive reform agenda for sustained recovery requires to address all three fronts of the economic trilemma. The reform scenario thus involves three separate packages.

- The first pillar is fiscal reform: We reduce the long-term debt target to the level at the start of Eurozone membership equal to 105% of GDP ($\bar{b}^g = 1.05$) which initiates tax- and expenditure-based consolidation as described in (3.22-3.23). Past experience shows that fiscal consolidation is predominantly tax based. To reconcile fiscal consolidation with growth, we instantaneously raise investment tax credits (increasing the expensing rate t^z from .1 to .5) to reduce the effective tax on investment.
- The second pillar aims at reversing stagnant productivity growth. Specifically, we raise the share $\bar{g}$ of productive fiscal spending (e.g., basic re-

large deviations in transitory periods.

search, schools, judicial system, hard infrastructure) by 2% of GDP. This endogenously transmits into slowly accumulating productivity gains, see (3.24) and (3.2). To boost competitiveness, we also mimic internal devaluation and reduce the taste parameter $\bar{\phi}$ by 5% which initiates a delayed reduction of ϕ_t as in (3.9), thereby stimulating employment and inducing households to accept somewhat lower wages.[17]

- The third pillar addresses the non-performing loans problem to stimulate lending at lower interest rates, see (3.32-3.33). Specifically, we analyze the consequences of banks reducing the share of bad loans to the level at the start of the Eurozone ($s_t^l \to \bar{s}^l$, from 15% to 6%). This decrease is supported by the recovery of the economy driven by sustained reforms. The government provides some support and subsidizes the currently high credit losses at a rate t^b, starting with 50% and phasing out with the reduction in bad loans.

Comprehensive reform requires long-term commitment and involves a long time-horizon for the gains to become effective. Private and public capital accumulation and fiscal consolidation are slow processes. The figures below show the adjustment process over 400 quarters or 100 years. Table 4 reports key indicators, starting from a bad equilibrium (column ISS) as portrayed in Table 3 and reaching a new final steady state (column FSS). Column 'Col40', for example, lists the changes 40 quarters or 10 years after the start of reform program. The dark shaded rows report absolute numbers, the light shaded rows give percent changes relative to the base case equilibrium.

The reform is designed for the country 'to grow out of high debt levels'. Adjustment is driven by several strong growth stimuli, consisting of a large, instantaneous increase in investment tax credits, a productivity-enhancing program of improving public infrastructure, 'internal devaluation' by inducing households to accept somewhat lower wages, and a bank recovery program to assure lower rates of interest. The total reform plan initiates strong and sustained accumulation of private and public capital stocks and boosts productivity and

[17]A lower ϕ_t directly reduces the marginal rate of substitution between work and consumption which determines the required consumption and wage to compensate for extra work, see (3.13) and footnote 4. In a more refined labor market model, such reform could reduce the bargaining strength of unions, remove obstacles to labor market participation etc. An alternative would be fiscal devaluation by shifting the tax burden from wage to consumption taxes (which are already rather high in Italy).

competitiveness. The early adjustment phase reflects intertemporal substitution in labor supply. Households are willing to work more in the beginning when income and consumption levels are low, while they work less in the future when consumption is expected to be high.[18] Furthermore, the instantaneous increase in employment by more than 4% in the first quarters also reflects the internal devaluation, making households willing to work more even though taxes are higher initially and wages increase only with delay. The initial rise in GDP rests on employment gains and is of roughly equal size. The increase in GDP mainly accommodates a strong investment boom and leaves little room for private consumption and exports. Consumption is only 1% higher after five years or 20 quarters, and exports even decline by 2% in the short-run before export growth sets in. Over time, the GDP expansion increasingly relies on capital accumulation while the initial employment gains fade out. Household incomes increasingly stem from growth in real wages rather than more employment. Private consumption recovers only with considerable delay.

Ultimately, GDP is 17% higher than in the bad equilibrium. The long-run income gains exclusively rest on capital accumulation and improved factor productivity as employment remains rather constant and even slightly declines in the long run. Consumption follows the increase in aggregate output only with substantial delay but finally exceeds low initial levels in the bad equilibrium by about 11%. Rising exports, although setting in only after more than two years, reflect improved international competitiveness.

Strong growth is achieved in spite of fiscal consolidation, which requires higher consumption and income taxes. In isolation, the latter would discourage labor supply but the larger investment tax credit more than compensates for the higher tax rates, substantially reduces the cost of capital, and boosts investment. Tax rates almost instantaneously rise by 3 percentage points to generate the revenue needed for sustained debt reduction but they roughly stay constant thereafter. Income and consumption growth swells the tax base and generates more revenue. Furthermore, the sustained reduction in the debt to GDP ratio on account of strong income growth partly reduces the need for fur-

[18] In other words, low consumption today implies a low marginal rate of substitution (MRS) between leisure and consumption so that households require little compensation for an extra unit of work and are willing to expand labor supply at low wages. As sustained growth increases the MRS in line with rising wages and consumption, households increasingly cut back on labor supply in the future.

Symbols	Names	ISS	Col4	Col8	Col20	Col40	Col80	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.3000	1.2365	1.2379	1.2079	1.1340	1.0582	1.0500
s_l	Bad Loan Share Banks	0.1500	0.1359	0.1197	0.0849	0.0548	0.0397	0.0600
Y	Real GDP	0.0000	4%	5%	7%	10%	14%	17%
K	Capital Stock	0.0000	4%	9%	15%	20%	30%	39%
L	Employment	0.0000	4%	3%	1%	1%	1%	-1%
Cbar	Private Consumption	0.0000	0%	0%	1%	4%	8%	11%
Ex_e	Exports to Rest of EZ	0.0000	-2%	-1%	3%	6%	8%	9%
Ex_o	Exports to RoW	0.0000	-2%	0%	3%	5%	7%	9%
K_G	Public Capital Stock	0.0000	2%	3%	8%	15%	24%	34%
w/Pbar	Real Wage	0.0000	1%	2%	4%	7%	12%	16%
z	Factor Productivity	1.0428	1.0433	1.0451	1.0539	1.0703	1.0953	1.1216
tau	Income Tax Rate	0.3337	0.3609	0.3615	0.3625	0.3620	0.3606	0.3612
i	Ann.Domestic Interest	0.0300	0.0308	0.0317	0.0353	0.0372	0.0339	0.0300
i_g	Ann.Gov.Debt Interest	0.0300	0.0308	0.0317	0.0353	0.0372	0.0339	0.0300
i_l	Ann.Loan Interest	0.0859	0.0636	0.0646	0.0667	0.0645	0.0570	0.0582
e_io	Euro/Dollar Exch.Rate	0.9943	1.0036	1.0014	0.9970	0.9952	0.9977	1.0062
B_F/PY	Net Foreign Debt/GDP	0.2200	0.2802	0.3485	0.4132	0.3430	0.2619	0.2200

Remarks: ISS stationary state in bad equilibrium. FSS stationary state in reform scenario.

Table 3.4: Reform within the Eurozone

ther revenue increasing measures. Social entitlements are largely determined by a constant replacement rate of wage earnings as in (3.23) and contribute relatively little to budget consolidation. The simulation shows a reduction in social spending of less than half a percent of GDP. We conclude that a program of national recovery can be designed to be largely neutral in terms of intra-generational fairness but must involve substantial redistribution across present and future generations.[19]

Table 4 also illustrates a strong decline in interest rates for business loans, down from about 8.6% in the initial situation to about 5.8% annually in the long-term. A major part is due to the fiscal subsidy which temporarily subsidizes credit losses of banks and is priced into lower loan rates. The subsidy is phased out along with the reduction in the share of bad loans. The debt ratio of firms is about 60% of assets. The reduction in bank lending rates therefore substantially reduces the cost of capital and boosts investment, which is the main purpose of the measure in the first place. Finally, the investment-led recovery in the early adjustment phase is financed to a large extent with foreign debt. Net foreign debt is relatively low at the outset, equal to 22% of GDP.

[19] A model of infinitely lived families doesn't lend itself to discuss fairness across generations. Future research should use an overlapping generations model to explore intergenerational effects.

Italy is thus in a relatively good position to resort to foreign funding of domestic investment. Within five years, the foreign debt almost doubles to 41% of GDP before again rapidly declining. Within the same period, the national interest rate rises by almost one percentage points as investors require a somewhat higher premium due to the rising debt to GDP ratio. Funding costs of government, banks and firms increase in line and decline thereafter.

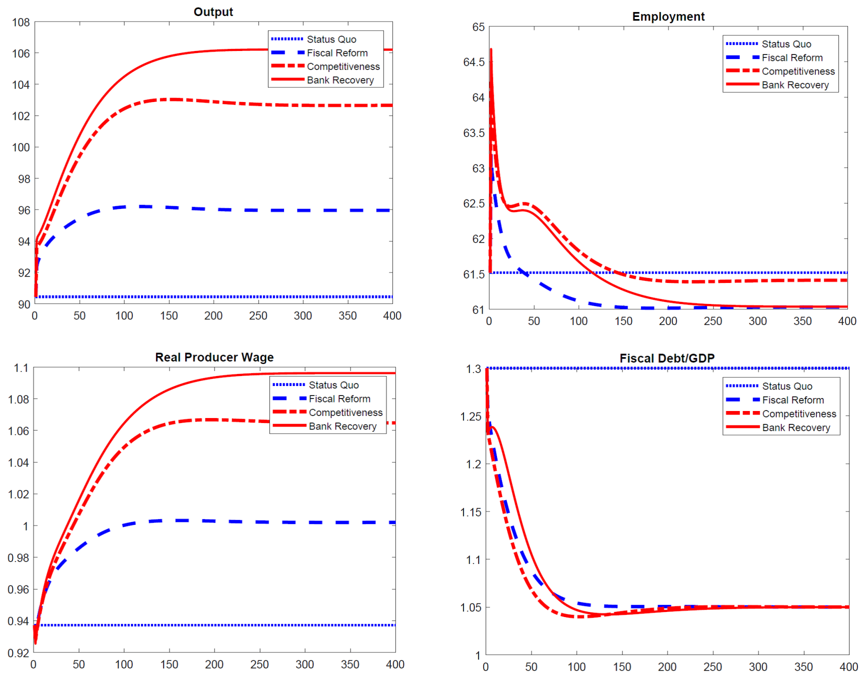

Figure 3.2: Reform within the Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

Figure 2 illustrates dynamic adjustment and separates the effects of the three pillars of the reform plan. The decomposition is cumulative, that is, the competitiveness program is added to the fiscal package, and bank recovery comes on top of the other parts. Fiscal reform stabilizes the debt to GDP ratio. Consolidation is mostly tax based and immediately raises tax rates across the board (income and consumption taxes) by more than three percentage points.

To avoid distortions, a strategy of 'growing out of debt' must thus combine consolidation with powerful investment incentives. Model simulations draw an encouraging picture of growth-friendly fiscal consolidation. The direct effect is a sustained reduction of the debt to GDP ratio after a small decline in the first quarters. This is partly due to strong growth induced by tax incentives. The output gains correspond to about 6 percentage points of GDP,[20] and the index of real producer wages recovers to the level at the start of the Eurozone. As discussed above, labor supply responses shift employment from the future to the present and speed up current recovery.

The program that aims at enhancing competitiveness and growth includes internal devaluation to encourage employment and an increase in productive government spending. The growth effect is powerful, adding another 5 percentage points of GDP in the long run which substantially stems from employment gains. Engineering an internal devaluation realistically takes considerable time. We mimic this by slowly phasing in labor supply incentives with the autoregressive process stated in (3.9). The employment gains (relative to the fiscal scenario) thus materialize with some delay. The budget cost of productive spending increases tax rates by about 2 percentage points across the board (not shown). Apart from transitional dynamics, the consolidation policy in (3.22) allows the nominal debt level to increase in proportion to nominal income gains where the proportionality factor corresponds to the new target level of 105% of GDP. For this reason, the effect on the debt to GDP ratio is almost not visible in the early adjustment phase, while induced growth in later periods speeds up the debt reduction.

Finally, the bank recovery program, by reducing the cost of credit and stimulating demand driven bank lending, adds about 2 additional percentage points of GDP in the long run. The effects kick in with some delay, since induced investment takes time to build up productive capacity, and because the reduction in bad loans is a prolonged process as well. Since we treat temporary bank subsidies as not being part of the 'structural deficit' subject to fiscal consolidation, they fully go into additional debt before they are consolidated in later periods. The bank subsidies thus slow down the reduction in the sovereign

[20]The effect appears large but studies of fundamental tax reform yield even larger effects. Altig et al. (2001), for example, simulate output gains up to 9% from a comprehensive tax reform in the U.S. that among other measures includes full expensing of new investment.

debt to gdp ratio in the early adjustment phase.

3.3.4 Recession and exit

Scenarios: The preceding section paints an encouraging picture about how structural reform and fiscal consolidation could help to escape the current stagnation. An uncompromising policy commitment over more than a decade could yield substantial productivity gains, revive growth and achieve a remarkable reduction in the public debt to GDP ratio. However, is political commitment realistic? Could the reform process be interrupted by another severe crisis? Given the difficulties of securing lasting political support and the current economic vulnerabilities, we explore an alternative scenario. How can the country cope with a severe asymmetric recession when exchange rate adjustment is not possible and monetary policy cannot target the specific situation in a single member country? Whether intentional or forced, an exit from the Eurozone and the introduction of an own currency (Lira) might become a possibility. To which extent could the country reduce the costs of a severe recession by pursuing autonomous monetary policy and allowing for exchange rate flexibility? Given the complexity of the problem, our analysis can be no more than a crude approximation of possible developments. We focus on three scenarios.

- Asymmetric recession with continued Eurozone membership: Italy is hit by a combination of severe economic shocks, lasting for six quarters, while other regions are unaffected. Disutility of labor supply is exogenously increased by 10% over the period, implying that workers reduce labor supply and/or request higher wages. In addition, factor productivity is exogenously reduced by -2%, and the share of bad loans rises by 10% (from 15% to 16.5%). Apart from these exogenous changes, the emerging output gap endogenously adds to the share of bad loans as in (3.33), and factor productivity partly responds to changes in productive fiscal spending.

- Benign exit: Italy is hit by the same recession which instantaneously triggers exit from the Eurozone. The Euro Lira exchange rate is flexible, and monetary policy is autonomously chosen. We assume that the national central bank aggressively responds to the output gap by expanding money supply, and thus raises the sensitivity to the output gap from 1 to

5 (see ψ_y Table 1). The exit is benign in the sense that it does not lead to investor panic and speculative capital flight.

- Escalating exit: Mimicking investor panic, we raise the interest premium on government bonds and bank deposits as well as equity of firms and banks by a factor of 2. The sudden increase in 'risk premia' reflects funding shocks that require high interest to secure at least a reduced level of funding. These shocks last for two quarters and then phase out with the autoregressive process.

We emphasize two implications of the model to prepare intuition for the results. First, we treat the recession with and without Eurozone exit is a purely temporary event which may have quite dramatic short- and medium-run effects but is inconsequential for the long run. After the recession ends, the shock variables revert back to initial values in line with the estimated autoregressive processes. In the same vein, monetary policy may have substantial effects in the short but is neutral in the long run. Since we abstract from any permanent changes in structural parameters, the economy reverts to the same bad stationary equilibrium. Second, whenever the economy is in a steady state and no shock occurs, and whenever national monetary policy fully replicates centralized policy making, an unanticipated exit is completely neutral. Any effect on the exchange rate can only result from asymmetric shocks and from differences in monetary policy between Italy and the Eurozone. We thus expect in our scenarios rather modest changes in exchange rates even after an exit. Figures 3 and 4 decompose the cumulative effects of the three scenarios and illustrate transitional dynamics for key economic indicators. Table 5 reports more detailed information of the total effect (scenario 3, escalating exit).

Recession Within Eurozone: The dashed lines in Figures 3-4 refer to the impact of a deep asymmetric recession in Italy. Neither the internal exchange rate nor monetary policy can adjust. Our assumption is that monetary policy is conditional on average economic performance in the total Euro area and cannot separately address the recession in Italy. Given several large negative shocks, the recession is bound to be very severe and involves an instantaneous output loss of about five percentage points. This loss accumulates to a maximum of six percentage points within eight quarters when shocks start to fade out and economic recovery sets in.

The recession feeds on several sources: The cost of capital is linked to interest rates, which tend to rise rather than fall in the absence of monetary intervention. The output price instantaneously rises due to a negative productivity shock and weakens competitiveness relative to trading partners, thereby eroding exports as well. Given nominal wage stickiness, the price increase somewhat reduces the real producer wage to stabilize employment. However, the negative labor supply shock counteracts this effect so that employment, all in all, drops by 4 percent relative to the bad stationary state. The large emerging output gap substantially raises the share of non-performing loans from already high 15% to 22% within 4 years. This forces banks to raise loan interest rates by about 2.4 percentage points annually, from 8.6 to 11% over the same period such that firm investment substantially falls.

By construction, centralized monetary policy cannot target the specific situation in Italy and remains rather passive. Fiscal policy is constrained by a high level of debt and cannot run into a substantial deficit, thereby preventing automatic fiscal stabilization to a large degree. The model does not allow for a deviation from the consolidation rule as described in Section 2.4, so that the government must slightly tighten the fiscal stance to prevent a substantial increase in public debt. Our model simulation thus emphasizes that a Eurozone member state with excessive public debt, little competitiveness and a vulnerable banking sector is bound to experience more severe recessions than other member states if they were subject to the same shocks.

Benign Exit: This scenario mimicks a 'benign exit' without panic driven investor reactions. We consider the same shocks as before but now the internal exchange rate is fully flexible, and monetary policy is autonomous and can help cushion the recession. We assume that the national central bank aggressively expands money supply and liquidity to counter the deep recession. We thus raise the sensitivity of money supply to the output gap from 1 to 5. The aggressive monetary expansion leads to a sudden and unanticipated increase in the price level. The real value of outstanding nominal debt is depreciated.

More importantly, given sticky nominal wages, monetary policy is able to engineer an immediate reduction in real wages, much faster than in the first scenario. Real wage cuts lead to substantial employment gains before the recession deepens. Given the immediate losses in real wages and consumption, households respond by expanding labor supply today when consumption is low,

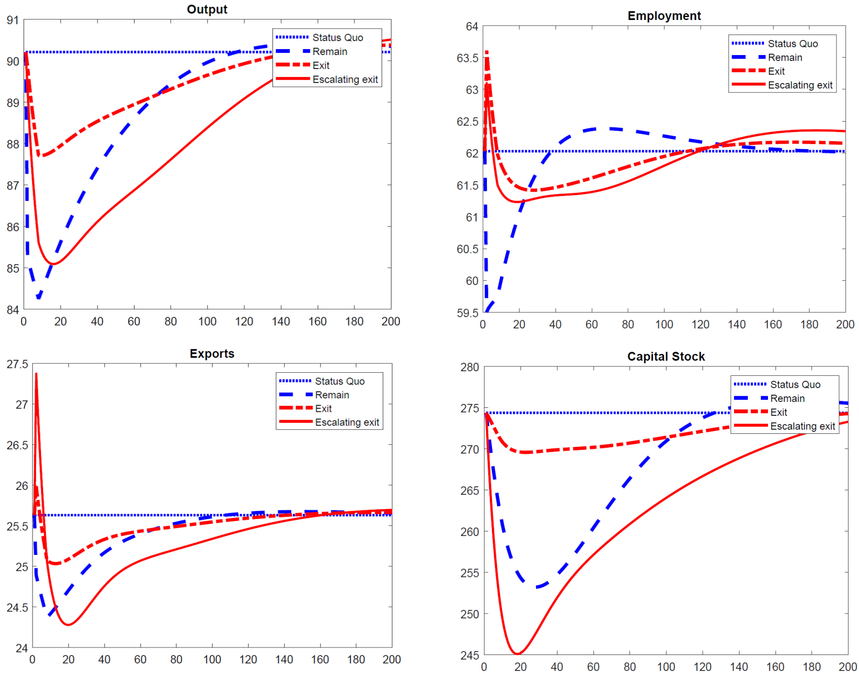

Figure 3.3: Recession and Exit from Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

and reduce it later on when real wages and consumption recover again. The initial employment response prevents a massive reduction in output. The real wage reduction more than halves the output loss in the early adjustment period. On the demand side, the decline in investment and consumption is much less dramatic, and exports largely keep up as the sudden increase in domestic producer prices goes in line with an immediate depreciation of the Lire. This restores competitiveness in international markets, facilitates a moderate initial increase in exports and contributes to the reduction in output losses. Given the more benign nature of the recession in the exit scenario, the share of bad loans rises much less dramatically, so that banks can abstain from charging much higher loan rates and thereby squeezing credit demand.

The recession becomes increasingly worse as soon as employment gains disappear and investment cuts erode the capital stock. Although the negative

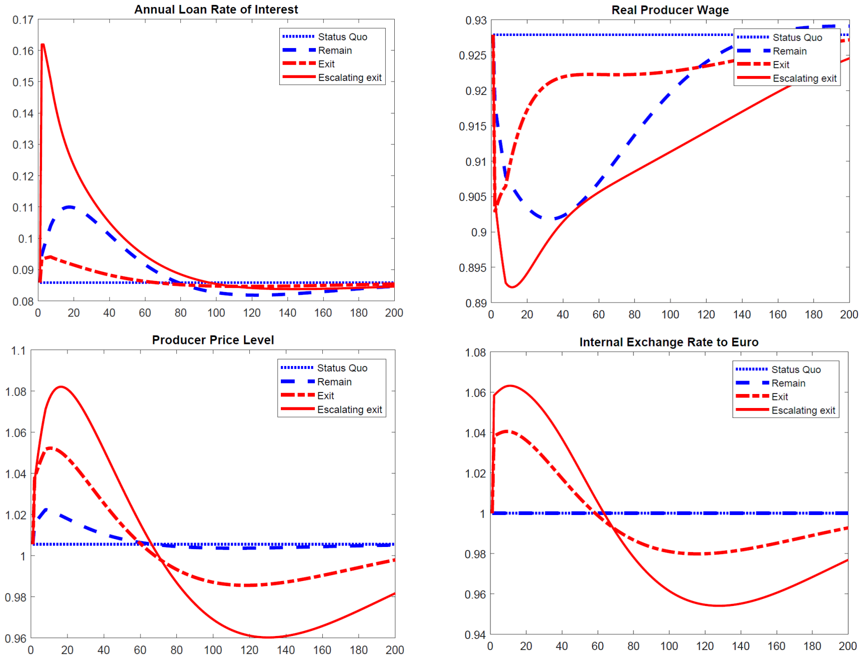

Figure 3.4: Recession and Exit from Eurozone

The horizontal axis shows the quarters after the start of the policy scenario. The vertical axis denotes the value of the respective variable.

shocks fade out after eight quarters, their detrimental effects persist and make the recovery slower. A striking feature of the adjustment is that the same recession within the currency union is much more devastating in the early phase compared to a benign exit, but recovery is faster thereafter. The pattern is most dramatic in the time paths of real wages and employment. The monetary expansion shifts forward in time the real wage reduction so that real wages are lower today but higher thereafter. In consequence, employment first rises but is subsequently lower over a long time span which delays the recovery in employment, capital stock and output. The ability of monetary policy to stabilize the economy may thus reduce output and income losses over a prolonged early period but not uniformly so.

Escalating Exit: Since the economy starts from a vulnerable position, an exit could trigger a general loss of confidence and even panic-driven capital

Symbols	Names	ISS	Per_2	Per_4	Per_8	Per_20	Per_40	Per_80	FSS
B_G/PY	Fiscal Debt/GDP Ratio	1.3000	1.2754	1.2827	1.2895	1.2891	1.3108	1.3364	1.3000
s_l	Bad Loan Share Banks	0.1500	0.1659	0.1702	0.1859	0.2154	0.2040	0.1569	0.1500
Y	Real GDP	0.0000	-1%	-3%	-5%	-6%	-5%	-3%	0%
K	Capital Stock	0.0000	-2%	-4%	-8%	-11%	-8%	-5%	0%
L	Employment	0.0000	2%	1%	-1%	-1%	-1%	-1%	0%
Cbar	Private Consumption	0.0000	-1%	-1%	-2%	-3%	-4%	-3%	0%
Ex_e	Exports to Rest of EZ	0.0000	7%	3%	-2%	-5%	-3%	-2%	0%
Ex_o	Exports to RoW	0.0000	6%	3%	-2%	-5%	-3%	-2%	0%
K_G	Public Capital Stock	0.0000	0%	0%	-1%	-3%	-4%	-4%	0%
w/P	Producer Real Wage	0.0000	-1%	-1%	-3%	-4%	-3%	-2%	0%
w/Pbar	Consumer Real Wage	0.0000	-1%	-2%	-3%	-3%	-3%	-2%	0%
z	Factor Productivity	1.0237	1.0023	1.0022	1.0016	1.0115	1.0135	1.0134	1.0237
tau	Income Tax Rate	0.2935	0.3071	0.3055	0.3012	0.2954	0.2954	0.2958	0.2935
P	Producer Prices	1.0055	1.0361	1.0499	1.0710	1.0803	1.0510	0.9870	1.0055
Pbar	Consumer Price Index	1.0016	1.0363	1.0477	1.0651	1.0721	1.0444	0.9820	1.0016
gi	Ann.Inflation Rate	0.0000	0.0218	0.0166	0.0063	-0.0030	-0.0066	-0.0046	0.0000
i	Ann.Domestic Interest	0.0300	0.0329	0.0322	0.0293	0.0232	0.0229	0.0280	0.0300
i_d	Ann.Deposit Interest	0.0300	0.0986	0.0943	0.0782	0.0483	0.0349	0.0315	0.0300
i_g	Ann.Gov.Debt Interest	0.0300	0.0986	0.0943	0.0782	0.0483	0.0349	0.0315	0.0300
i_k	Ann.Return on Equity	0.1200	0.1973	0.1910	0.1662	0.1180	0.1037	0.1155	0.1200
i_l	Ann.Loan Interest	0.0859	0.1618	0.1591	0.1469	0.1228	0.1048	0.0885	0.0859
e_ie	Lire/Euro Exch.Rate	1.0000	1.0582	1.0599	1.0624	1.0593	1.0366	0.9783	1.0000
e_eo	Euro/Dollar Exch.Rate	0.9942	1.0369	1.0437	1.0541	1.0572	1.0322	0.9727	0.9942
B_f/PY	Net Foreign Debt/GDP	0.2200	0.1707	0.1035	0.0431	0.1160	0.2705	0.2713	0.2200

Remarks: ISS stationary state in bad equilibrium. FSS steady state in exit scenario.

Table 3.5: Recession and Exit from Eurozone

flight. An unanticipated inflation shock and a corresponding devaluation of the Lira implies a one-time reduction of wealth. We picture the loss of confidence by a sudden increase in risk-premia on government bonds and bank deposits as well as equity of banks and firms. Interest rates on fiscal bonds and deposits essentially triple in the first two quarters of the recession and then revert back to normal levels with some delay. The solid lines in Figures 3-4 and Table 5 illustrate the dynamic adjustment.

Banks pass the increased cost of deposit as well as equity funding onto firms. The resulting increase in the loan rates of interest reflects a weighted average of deposit and equity funding costs and leads to a severe credit crunch. Compared to a benign exit, the funding stop caused by the sudden jump in capital costs severely impairs investment and leads to a much larger decline in the capital stock. The escalating scenario thus magnifies the recession in the early adjustment phase. The decline in economic activity endogenously swells the share of non-performing loans that reaches a maximum of almost 22% after 25 quarters, up from 15% in the bad initial equilibrium. The resulting credit losses endogenously force banks to raise loan rates even more which substantially delays the decline of credit costs and prolongs the recession.

The aggressive monetary policy response to the emerging output gap implies a substantially larger increase in the domestic price level and magnifies the depreciation of the Lira. With sticky nominal wages, the resulting real wage reduction is not only much larger but also persists over a long time span. The real wage cuts still result in a moderate employment gain in the very first quarters but smaller than before. Exports initially rise even more on account of a larger depreciation. However, export demand cannot make up for reduced investment and consumer demand. The sudden increase in sovereign funding costs constrains fiscal policy, which can thus not contribute to the stabilization of the economy. Overall, an escalating exit with a general loss of confidence and rising funding costs not only leads to a much sharper recession in the early adjustment period, but also substantially delays the economic recovery.

3.4 Conclusions

In a currency union, the internal exchange rate is fixed. Monetary policy is no longer available to stabilize the business cycle in a single member country but focuses on the average state of the entire union. Important adjustment mechanisms are missing. To compensate for the loss of monetary autonomy as a tool of macroeconomic stabilization, an individual member country must instead rely on fiscal policy and on automatic fiscal stabilizers. These instruments require low public debt, however. Banks can only help absorb shocks if endowed with sufficient equity and if lending activity rests on a low share of non-performing loans. Finally, a competitive and innovative economy is also more resilient and can better absorb macroeconomic fluctuations without creating large employment losses. In contrast, a recession can set off a vicious cycle if these conditions are not met, driven by mutual contagion between an overly indebted sovereign, a vulnerable banking sector, and an uncompetitive real economy.

Today, the Italian economy appears to be in a vulnerable position with respect to all three focal points. Using a New Keynesian DSGE model with nominal wage rigidity that pictures Italy and the rest of the Eurozone, this paper analyzed two broad alternatives for economic policy. The first scenario considered the possibility of sustained reform within the Eurozone, involving strong policy commitment over several decades. The results indicate the possibility of 'growing out of currently unfavorable initial conditions', provided that sustained fiscal consolidation is combined with bank recovery and a program for competitiveness and growth. On the other hand, a strong asymmetric recession could interrupt any attempt at reform and move the economy 'off track'. In a second scenario, we considered the possible developments in a severe asymmetric recession. We report three main insights. First, an asymmetric recession within the Eurozone is likely to be very severe, given the absence of typical shock absorbers. Second, a benign exit from the Eurozone with stable investor expectations could substantially dampen the negative short-run impact of a recession. On the negative side, the economy takes significantly longer to recover. Stabilization is achieved by an aggressive monetary expansion, combined with exchange rate depreciation to restore international competitiveness. However, 'stable investor expectations' after an exit might be rather unrealistic, given the large vulnerabilities. Third, investor panic may lead to an escalating exit with funding stops due to sudden jumps in risk premia, which magnify private and public borrowing costs, thereby further depressing investment and constraining fiscal policy. Unfavorable capital market reactions tend to offset the advantages of monetary autonomy. Such an exit scenario makes the recession as deep as under continued membership, while considerably delaying the full recovery.

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Appendix

A.1 Estimation

Following standard procedures in DSGE research, we add shocks to the model and apply Bayesian estimation techniques. Table A1 provides an overview of estimated shocks together with some structural parameters and reports our prior assumptions together with the resulting posterior distributions.

We have harmonized the priors for the standard deviation of the shock processes by assuming an inverse-gamma distribution (Gerali et al., 2010) with mean 0.1 and standard deviation of 2. An exception is the shock process for total income in the Eurozone for which we set a mean of 2 and a standard deviation of 0.5. Since persistence of the AR(1) processes is restricted in the 0-1 range, the parameters are assumed to be beta distributed with mean 0.95 and standard deviation 0.01. For other parameters, we use calibrated values as the mean, see Table 2. We estimate σ^{sl} with a mean of 13.33, a value that associates an output loss of 5% with an increase in the NPL share by 4 percentage points. For the elasticity between productivity and government spending, σ^{z}, we consider a mean of 0.2. This implies a 2 percentage point increase in factor productivity after a 10% increase in government spending. The shares of government budget consolidation attributed to productive government spending and social spending ξ_g and ξ_e, are set to a prior of 0.2 and 0.1, respectively. The prior for the parameter of investment adjustment costs, ψ is set to 5, while the prior for the fiscal adjustment speed γ_g is set at 0.97.

The last three columns of Table A1 show the means and confidence intervals of the posterior distributions as obtained by the Metropolis Hastings algorithm. We used 5 chains, each with 25,000 draws which ensures convergence of the sampling algorithm. Shock persistence is estimated to be quite high. Autocorrelation coefficients range from 0.93 (for the business cycle) to 0.97 for the risk premia. All other parameters are estimated to a value close to our prior assumptions. Figure 5 shows prior (gray curves) and posterior distributions (black curves) of the estimated parameters. The vertical dashed lines indicate the estimated posterior mode.[21]

[21] The mode is the most frequently computed value. It does not coincide with the mean for non-normal (non-symmetric) distributions and not necessarily with the peak of the posterior distribution.

Table A1: Prior and Posterior Distributions

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev	10%	Mean	90%
Autocor. risk premia	ρ^{th}	Beta	0.95	0.01	0.9559	0.9643	0.9723
Autocor. NPL shock	ρ^{sl}	Beta	0.95	0.01	0.9472	0.9578	0.9723
Autocor. revenue losses	ρ^{T}	Beta	0.95	0.01	0.9359	0.9495	0.9621
Autocor. business cycle	ρ	Beta	0.95	0.01	0.9086	0.9246	0.9399
Sensitivity NPL rate	σ^{sl}	Normal	13.33	1	11.8759	13.1615	14.4511
Sensitivity Productivity	σ^{z}	Inv.Gamma	0.25	0.001	0.2487	0.2500	0.2513
Fiscal adjustment speed	γ^{g}	Normal	0.97	0.001	0.9693	0.9705	0.9718
Investment adj. costs	ψ	Normal	5	0.01	4.9877	5.0010	5.0143
Consolidation share G	ξ^{g}	Normal	0.2	0.001	0.1987	0.2000	0.2014
Consolidation share E	ξ^{e}	Normal	0.1	0.001	0.0987	0.1000	0.1013
SD productivity shock IT	$\tilde{\sigma^{z}}$	Inv.Gamma	0.1	2	0.0113	0.0126	0.0141
SD income shock EZ	$\sigma^{\tilde{y}e}$	Inv.Gamma	0.1	2	1.9722	2.2017	2.4494
SD deposit shock	$\tilde{\sigma^{d}}$	Inv.Gamma	0.1	2	0.0803	0.0826	0.0920
SD gov. interest shock	$\tilde{\sigma^{g}}$	Inv.Gamma	0.1	2	0.0739	0.0826	0.0920
SD gov. spending shock	$\tilde{\sigma^{G}}$	Inv.Gamma	0.1	2	0.4648	0.5178	0.5746
SD social spending shock	$\tilde{\sigma^{E}}$	Inv.Gamma	0.1	2	1.1067	1.2374	1.3739
SD NPL shock	$\tilde{\sigma^{sl}}$	Inv.Gamma	0.1	2	0.0095	0.0106	0.0118

The smaller variance of the posterior indicates that the data appear to be informative of the persistence of shock processes. Figure 6 plots estimated standard deviations. They are relatively large for the shocks to Eurozone income, deposits, government interest rate, and both types of government expenditures. By contrast, the estimated standard deviations of the productivity shock and the non-performing loans shock are rather small. The model seemingly does not rely much on these shocks to explain fluctuations.

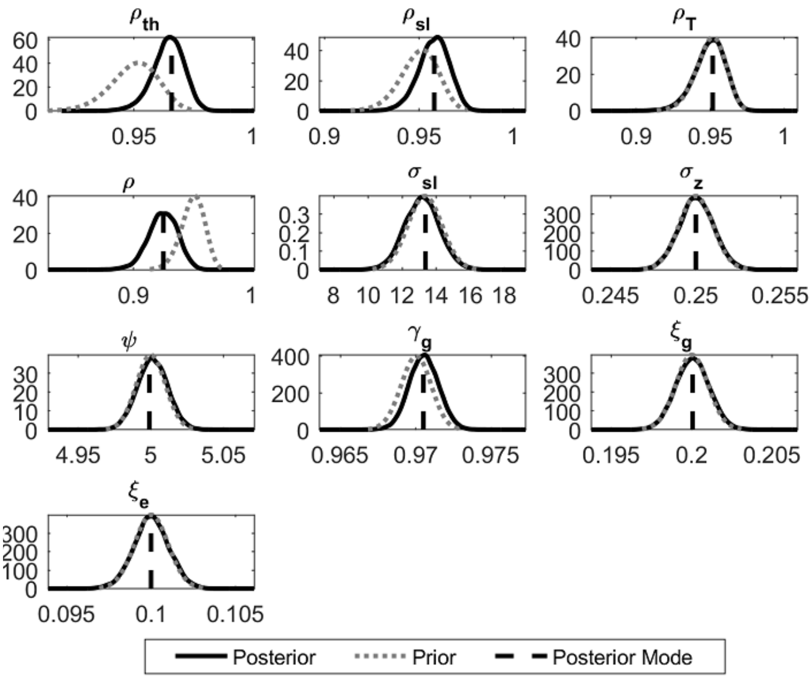

Figure A.1.1: Standard Deviations of Priors and Posteriors

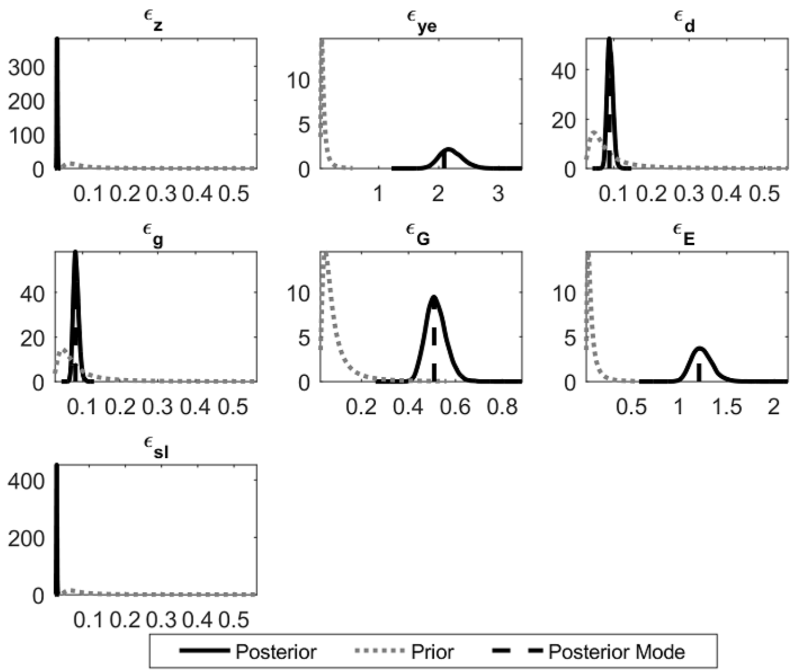

Figure A.1.2: Standard Deviations of Priors and Posteriors

A.2 Model representation in Dynare

1. $z_t = (1-\rho)\,\bar{z}\left(K_t^G/\bar{K}^G\right)^{\sigma^z} + \rho z_{t-1} + \varepsilon_t^z$, productivity shocks, **ITALY**
2. $\tau_t = t_t^s \tau_0$, tax rate scaling for budged balance
3. $\tau_t^c = t_t^s \tau_0^c$,
4. $P_t^{ie} = e_t^{ie} P_t^e$, import prices
5. $P_t^{io} = e_t^{io} P^o$,
6. $\bar{P}_t = \left[s^{ii}\left(P_t\right)^{1-\sigma_r} + s^{ie}\left(P_t^{ie}\right)^{1-\sigma_r} + s^{io}\left(P_t^{io}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}$, price index
7. $b_t^f = B_t^f / \left(P_t Y_t\right)$, foreign debt to GDP ratio
8. $\theta_t = \left(1-\rho^f\right)\left[1+\gamma\left(e^{b_t^f - \bar{b}^f} - 1\right)\right] + \rho^f \theta_{t-1} + \varepsilon_t^\theta$, country risk premium
9. $1 + i_t = \left(1 + i_t^e\right)\theta_t e_{t+1}^{ie}/e_t^{ie}$, interest parity
10. $1 + \pi_t = \left(1 + \tau_{t+1}^c\right)\bar{P}_{t+1}/\left(\left(1+\tau_t^c\right)\bar{P}_t\right)$,
11. $1 + r_t = \left(1 + i_t\right)/\left(1 + \pi_t\right)$,
12. $\theta_t^g = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^g + \varepsilon_t^g$, government interest shock
13. $\theta_t^d = 1 - \rho^\theta + \rho^\theta \theta_{t-1}^d + \varepsilon_t^d$, deposit shock
14. $\theta_t^b = \left(1-\rho^\theta\right)\bar{\theta}^b + \rho^\theta \theta_{t-1}^b + \varepsilon_t^b$, equity premium shocks
15. $\theta_t^k = \left(1-\rho^\theta\right)\bar{\theta}^k + \rho^\theta \theta_{t-1}^k + \varepsilon_t^k$,
16. $i_t^g = \theta_t^g i_t$, interest premium
17. $i_t^d = \theta_t^d i_t$,
18. $i_t^b = \theta_t^b i_t$,
19. $i_t^k = \theta_t^k i_t$,
20. $u_{C,t} = \beta\left(1 + r_t\right)\cdot u_{C,t+1}$, Euler equation
21. $m_t = \left[\left(1 - s_c\right)\left(1 + \tau_{t+1}^c\right)\left(1 + r_t\right)/\left(s_c i_t\right)\right]^{1/\sigma_m}$, money consumption ratio
22. $x_t = \left[s_c + \left(1 - s_c\right) {m_t}^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$,
23. $\bar{C}_t = \left(s_c x_t^{\sigma_m - \sigma_c}/u_{C,t}\right)^{1/\sigma_c}$,
24. $\bar{M}_t = m_t \cdot \bar{C}_t$, money demand
25. $\left(w_t^L\right)^{1-\sigma_l} = \left(1-\omega\right)\left(w_t^*\right)^{1-\sigma_l} + \omega\left(w_{t-1}^L\right)^{1-\sigma_l}$, wage index
26. $N_{t,t} = \left(w_t^L/w_t^*\right)^{\sigma_l} L_t/H$, per capita
27. $N_{t-1,t} = \left(w_t^L/w_{t-1}^*\right)^{\sigma_l} L_t/H$, vintage $t-1$ at date t
28. $\phi_t = (1-\rho)\,\bar{\phi} + \rho\phi_{t-1} + \varepsilon_t^\phi$,

29. $MRS_{t,t} = \phi_t N_{t,t}^{\eta} \bar{C}_t^{\sigma_c} / \left(s_c x_t^{\sigma_m - \sigma_c}\right)$,

30. $\frac{1-\tau_t}{1+\tau_t^c} \frac{w_t^*}{\bar{P}_t} = \frac{\sigma_l}{\sigma_l - 1} MRS_{t,t} + \left(w_t^* / N_{t,t}\right) \omega \mu_{t+1}^w / \left(1 + r_t\right)$, new wage setting

31. $\mu_t^w = -\left[\frac{1-\tau_t}{1+\tau_t^c} \frac{w_{t-1}^*}{\bar{P}_t} - \frac{\sigma_l}{\sigma_l - 1} \left(w_t^* / w_{t-1}^*\right)^{\eta \sigma_l} MRS_{t,t}\right] N_{t-1,t} / w_{t-1}^* + \omega \mu_{t+1}^w / \left(1 + r_t\right)$,

32. $m_t^c = P_t \cdot \left(\sigma_v - 1\right) / \sigma_v$, markup pricing

33. $\tilde{k}_t = K_{t-1} / L_t$,

34. $w_t^L = (1 - \alpha) m_t^c z_t \tilde{k}_t^{\alpha}$, factor prices

35. $w_t^K = \alpha m_t^c z_t / \tilde{k}_t^{1-\alpha}$,

36. $Q_t = \left(\lambda_{t+1}^K / \left(1 + i_t^k\right)\right) / \left(\left(1 - t^z \tau_t\right) \bar{P}_t\right)$, INVESTMENT

37. $K_t = \left(1 + \left(Q_t - 1\right) / \psi\right) K_{t-1}$,

38. $I_t = K_t - (1 - \delta) K_{t-1}$,

39. $\bar{Z}_t = I_t + \frac{\psi}{2} K_{t-1} \left(I_t / K_{t-1} - \delta\right)^2$, adjustment costs

40. $\bar{Z}_{K,t} = -\frac{\psi}{2} \left(I_t / K_{t-1} + \delta\right) \left(I_t / K_{t-1} - \delta\right)$,

41. $s_t^l = \left(1 - \rho^{sl}\right) \bar{s}^l \left(\bar{Y}_t / Y_t\right)^{\sigma^{sl}} + \rho^{sl} s_{t-1}^l + \varepsilon_t^{sl}$, NPL share

42. $d_t^l = l s_t^l$,

43. $t_t^b = \rho^{sl} t_{t-1}^b + \varepsilon_t^{tb}$, subsidy rate bank rescue

44. $1 + i_t^l = \left(\kappa^B \left(1 + i_t^b\right) + \left(1 - \kappa^B\right) \left(1 + i_t^d\right)\right) / \left(1 - \left(1 - t_{t+1}^b\right) d_{t+1}^l\right)$,

45. $\lambda_t^K = \left(1 - \tau_t\right) w_t^K + \left[\left(i_t^k - \left(1 - \tau_t\right) i_t^l\right) b^l - \bar{Z}_{K,t}\right] \left(1 - t^z \tau_t\right) \bar{P}_t + (1 - \delta) \lambda_{t+1}^K / \left(1 + i_t^k\right)$,

46. $B_t^l / \left(1 + i_t^l\right) = b^l \left(1 + i_t^k\right) \left(1 - t^z \tau_t\right) \bar{P}_t K_{t-1}$, debt capacity

47. $S_t^l = B_{t-1}^l - B_t^l / \left(1 + i_t^l\right)$,

48. $Y_t^g = z_t \tilde{k}_t^{\alpha} L_t$, gross output

49. $Y_t = Y_t^g - d_t^l B_{t-1}^l / P_t$, GDP

50. $\bar{Y}_t = \delta^m Y_t + \left(1 - \delta^m\right) \bar{Y}_{t-1}$, potential output

51. $\chi_t^m = \left(P_t - m_t^c\right) Y_t^g$,

52. $T_t^k = P_t Y_t^g - w_t^L L_t - t^z \bar{P}_t \bar{Z}_t - i_t^l \left(B_{t-1}^l - S_t^l\right) / \left(1 + i_t^k\right)$,

53. $\chi_t = P_t Y_t^g - w_t^L L_t - \bar{P}_t \bar{Z}_t - S_t^l - \tau_t T_t^k$,

54. $V_t = \chi_t + V_{t+1} / \left(1 + i_t^k\right)$,

55. $\tilde{S}_t^G = \left(1 - \gamma^g / \left(1 + i_t^g\right)\right) B_{t-1}^G - \left(\left(1 - \gamma^g\right) / \left(1 + i_t^g\right)\right) \bar{b}^g P_t Y_t$, FISCAL POLICY

56. $P_t G_t = \bar{g} \cdot P_t Y_t - \xi^g \cdot \tilde{S}_t^G + \varepsilon_t^G$,

57. $E_t = \bar{e} \cdot w_t^L L_t - \xi^e \cdot \tilde{S}_t^G + \varepsilon_t^E$,

58. $T_t = \bar{g} \cdot P_t Y_t + \bar{e} \cdot w_t^L L_t + (1 - \xi^g - \xi^e) \tilde{S}_t^G$, required tax revenue

59. $T_t^l = \left(1 - \rho^T\right) \bar{t}^l P_t Y_t + \rho^T T_{t-1}^l + \varepsilon_t^T$, tax base erosion

60. $T_t = \tau_t \cdot w_t^L L_t + \tau_t \cdot T_t^k + \tau_t^c \cdot \bar{P}_t \bar{C}_t - T_t^l$, budget balance

61. $K_t^G = G_t + (1 - \delta^g) K_{t-1}^G$,

62. $d_t^g = \rho^{dg} d_{t-1}^g + \varepsilon_t^{dg}$, unexpected default

63. $S_t^G = \tilde{S}_t^G - \varepsilon_t^G - \varepsilon_t^E - t_t^b d_t^l B_{t-1}^l + d_t^g B_{t-1}^G$,

64. $B_t^G / (1 + i_t^g) = B_{t-1}^G - S_t^G$,

65. $E_t^b / \left(1 + i_t^b\right) = \kappa^B B_t^l / \left(1 + i_t^l\right) + \kappa^G \tilde{s}^b B_t^G / (1 + i_t^g)$, bank equity

66. $D_t / \left(1 + i_t^d\right) = \left(1 - \kappa^B\right) B_t^l / \left(1 + i_t^l\right) + \left(1 - \kappa^G\right) \tilde{s}^b B_t^G / (1 + i_t^g)$, deposits

67. $S_t^d = D_{t-1} - D_t / \left(1 + i_t^d\right)$,

68. $\chi_t^b = S_t^l + \tilde{s}^b S_t^G - S_t^d - \left(1 - t_t^b\right) d_t^l B_{t-1}^l$,

69. $Y_t^e = (1 - \rho) Y_0^e + \rho Y_{t-1}^e + \varepsilon_t^{Y,e}$, **EUROZONE**

70. $\bar{Y}_t^e = \delta^m Y_t^e + (1 - \delta^m) \bar{Y}_{t-1}^e$, potential output

71. $e_t^{eo} = e_t^{io} / e_t^{ie}$,

72. $P_t^{ei} = P_t / e_t^{ie}$, import prices

73. $P_t^{eo} = P^o e_t^{eo}$,

74. $\bar{P}_t^e = \left[s^{ee} \left(P_t^e\right)^{1-\sigma_r} + s^{ei} \left(P_t^{ei}\right)^{1-\sigma_r} + s^{eo} \left(P_t^{eo}\right)^{1-\sigma_r}\right]^{1/(1-\sigma_r)}$, price index

75. $1 + \pi_t^e = \bar{P}_{t+1}^e / \bar{P}_t^e$,

76. $1 + r_t^e = (1 + i_t^e) / (1 + \pi_t^e)$,

77. $u_{C,t}^e = \beta (1 + r_t^e) \cdot u_{C,t+1}^e$, Euler equation

78. $m_t^e = \left[(1 - s_c)(1 + r_t^e) / (s_c i_t^e)\right]^{1/\sigma_m}$, money consumption ratio

79. $x_t^e = \left[s_c + (1 - s_c) (m_t^e)^{1-\sigma_m}\right]^{1/(1-\sigma_m)}$,

80. $\bar{C}_t^e = \left(s_c (x_t^e)^{\sigma_m - \sigma_c} / u_{C,t}^e\right)^{1/\sigma_c}$,

81. $\bar{M}_t^e = m_t^e \cdot \bar{C}_t^e$, money demand

82. $C_t^{oi} = s^{oi} \left(e_t^{io} / P_t\right)^{\sigma_r}$, **TRADE FLOWS**

83. $C_t^{oe} = s^{oe} \left(e_t^{eo} / P_t^e\right)^{\sigma_r}$, export demand functions

84. $C_t = s^{ii} \left(\bar{P}_t / P_t\right)^{\sigma_r} \bar{C}_t$, demand structure

85. $C_t^{ie} = s^{ie} \left(\bar{P}_t / P_t^{ie}\right)^{\sigma_r} \bar{C}_t$,

86. $C_t^{io} = s^{io} \left(\bar{P}_t / P_t^{io}\right)^{\sigma_r} \bar{C}_t$,

87. $Z_t = s^{ii}\left(\bar{P}_t/P_t\right)^{\sigma_r}\bar{Z}_t,$

88. $Z_t^{ie} = s^{ie}\left(\bar{P}_t/P_t^{ie}\right)^{\sigma_r}\bar{Z}_t,$

89. $Z_t^{io} = s^{io}\left(\bar{P}_t/P_t^{io}\right)^{\sigma_r}\bar{Z}_t,$

90. $C_t^{e} = s^{ee}\left(\bar{P}_t^{e}/P_t^{e}\right)^{\sigma_r}\bar{C}_t^{e},$

91. $C_t^{ei} = s^{ei}\left(\bar{P}_t/P_t^{ei}\right)^{\sigma_r}\bar{C}_t^{e},$

92. $C_t^{eo} = s^{eo}\left(\bar{P}_t/P_t^{eo}\right)^{\sigma_r}\bar{C}_t^{e},$

93. $E_t^{x} = C_t^{ei} + C_t^{oi}$, exports

94. $E_t^{x,e} = C_t^{ie} + Z_t^{ie} + C_t^{oe},$

95. $E_t^{x,o} = C_t^{io} + Z_t^{io} + C_t^{eo},$

96. $TB_t = P_t E_t^{x} - P_t^{ie}\left(C_t^{ie} + Z_t^{ie}\right) - P_t^{io}\left(C_t^{io} + Z_t^{io}\right)$, trade balance

97. $TB_t^{e} = P_t^{e} E_t^{x,e} - P_t^{ei} C_t^{ei} - P_t^{eo} C_t^{eo},$

98. $TB_t^{o} = P^{o} E_t^{x,o} - C_t^{oi} P_t/e_t^{io} - C_t^{oe} P_t^{e}/e_t^{eo},$

99. $Y_t = C_t + Z_t + G_t + E_t^{x}$, output market clearing

100. $B_t^{f} = (1+i_t)\left(B_{t-1}^{f} - TB_t\right),$

101. $B_t^{e} = -B_t^{f}/e_t^{ie},$

102. $\zeta_t = (1-\tau_t)\, w_t^{L} L_t + E_t + T_t^{l} + \chi_t + \chi_t^{b} + S_t^{d} + \left(1-\tilde{s}^{b}\right) S_t^{G} - (1+\tau_t^{c})\,\bar{P}_t \bar{C}_t - TB_t,$

103. $Y_t^{e} = C_t^{e} + E_t^{x,e},$

104. $\zeta_t^{e} = P_t^{e} Y_t^{e} - \bar{P}_t^{e} \bar{C}_t^{e} - TB_t^{e},$

105. $TB_t^{o} = 0,$

106. $\bar{P}_t^{u} \equiv s^{Y}\bar{P}_t + \left(1-s^{Y}\right)\bar{P}_t^{e}$, **MONETARY POLICY**

107. $1+\pi_t^{u} \equiv \bar{P}_{t+1}^{u}/\bar{P}_t^{u}$, EZ inflation

108. $Y_t^{u} \equiv \left(P_t Y_t + P_t^{e} Y_t^{e}\right)/\bar{P}_t^{u}$, EZ output

109. $\bar{Y}_t^{u} = \delta^{m} Y_t^{u} + (1-\delta^{m})\,\bar{Y}_{t-1}^{u},$

110. $M_t^{s,u} = (1-\rho^{m})\,\phi^{m,u}\bar{Y}_{t-1}^{u}\frac{\left(\bar{Y}_{t-1}^{u}/Y_t^{u}\right)^{\psi_y}}{\left(1+\pi_t^{u}\right)^{\psi_\pi}} + \rho^{m} M_{t-1}^{s,u} + \varepsilon_t^{m,u},$

111. $M_t^{s} = EZ\cdot\bar{P}_{t+1}\bar{M}_t + (1-EZ)\cdot\left((1-\rho^{m})\,\phi^{m}\bar{Y}_{t-1}\frac{\left(\bar{Y}_{t-1}/Y_t\right)^{\psi_y}}{(1+\pi_t)^{\psi_\pi}} + \rho^{m} M_{t-1}^{s} + \varepsilon_t^{m}\right),$

112. $M_t^{s,e} = EZ\cdot\bar{P}_{t+1}^{e}\bar{M}_t^{e} + (1-EZ)\cdot\left((1-\rho^{m})\,\phi^{m,e}\bar{Y}_{t-1}^{e}\cdot\frac{\left(\bar{Y}_{t-1}^{e}/Y_t^{e}\right)^{\psi_y}}{\left(1+\pi_t^{e}\right)^{\psi_\pi}} + \rho^{m} M_{t-1}^{s,e} + \varepsilon_t^{m,e}\right),$

113. $0 = EZ\cdot\left(\bar{P}_{t+1}\bar{M}_t + \bar{P}_{t+1}^{e}\bar{M}_t^{e} - M_t^{s,u}\right) + (1-EZ)\cdot\left(\bar{P}_{t+1}\bar{M}_t - M_t^{s}\right)$, market clearing

114. $0 = EZ\cdot\left(e_t^{ie} - 1\right) + (1-EZ)\cdot\left(\bar{P}_{t+1}^{e}\bar{M}_t^{e} - M_t^{s,e}\right).$

Model Statistics: Expected variables are indexed by $t+1$, predetermined ones by $t-1$.

- 114 equations for 114 endogenous variables: z, K^G, t^s, τ, τ^c, e^{ie}, e^{io}, P, P^e, P^{ie},[10] P^{io}, $\bar{P}$, B^f, Y, b^f, θ, i, i^e, π, r,[20] θ^g, θ^d, θ^b, θ^k, i^d, i^g, i^k, i^b, u_C, m,[30] x, $\bar{C}$, $\bar{M}$, w^L, w^*, N, N_1, L, ϕ, MRS,[40] μ^w, m^c, K, $\tilde{k}$, w^K, Q, λ^K, I, $\bar{Z}$, $\bar{Z}_K$,[50] $\bar{Y}$, s^l, d^l, t^b, i^l, B^l, S^l, Y^g, χ^m, T^k,[60] χ, V, $\tilde{S}^G$, B^G, G, E, T, T^l, d^g, S^G,[70] E^b, D, S^d, χ^b, Y^e, $\bar{Y}^e$, e^{eo}, P^{ei}, P^{eo}, $\bar{P}^e$,[80] π^e, r^e, u^e_C, m^e, x^e, $\bar{C}^e$, $\bar{M}^e$, C^{oi}, C^{oe}, C,[90] C^{ie}, C^{io}, Z, Z^{ie}, Z^{io}, C^e, C^{ei}, C^{eo}, E^x, $E^{x,e}$,[100] $E^{x,o}$, TB, TB^e, TB^o, B^e, ζ, ζ^e, $\bar{P}^u$, π^u, Y^u,[110] $\bar{Y}^u$, $M^{s,u}$, M^s, $M^{s,e}$.[114]

- 17 exogenous variables: ε^z, ε^θ, ε^g, ε^d, ε^b, ε^k, ε^ϕ, ε^{sl}, ε^{tb}, ε^G,[10] ε^E, ε^T, ε^{dg}, $\varepsilon^{Y,e}$, ε^m, $\varepsilon^{m,e}$, $\varepsilon^{m,u}$.[17]

- 64 parameters: ρ, $\bar{z}$, $\bar{K}^G$, σ^z, τ_0, τ^c_0, P^o, s^{ii}, s^{ie}, s^{io},[10] σ_r, γ, $\bar{b}^f$, ρ^f, ρ^θ, $\bar{\theta}^k$, $\bar{\theta}^b$, β, s_c, σ_m,[20] σ_c, σ_l, ω, H, $\bar{\phi}$, η, σ_v, α, t^z, ψ,[30] δ, $\bar{s}^l$, ρ^{sl}, σ^{sl}, l, κ^B, κ^G, b^l, δ^m, γ^g,[40] $\bar{b}^g$, $\bar{g}$, $\bar{e}$, ξ^g, ξ^e, ρ^T, $\bar{t}^l$, δ^g, ρ^{dg}, $\tilde{s}^b$,[50] Y^e_0, s^{ee}, s^{ei}, s^{eo}, s^{oi}, s^{oe}, s^Y, ρ^m, $\phi^{m,u}$, ψ_y,[60] ψ_π, EZ, ϕ^m, $\phi^{m,e}$.[64]

- 26 predetermined variables: z_{t-1}, θ_{t-1}, θ^g_{t-1}, θ^d_{t-1}, θ^b_{t-1}, θ^b_{t-1}, w^L_{t-1}, w^*_{t-1}, ϕ_{t-1}, K_{t-1},[10] s^l_{t-1}, t^b_{t-1}, B^l_{t-1}, $\bar{Y}_{t-1}$, B^G_{t-1}, T^l_{t-1}, K^G_{t-1}, d^g_{t-1}, D_{t-1}, Y^e_{t-1},[20] $\bar{Y}^e_{t-1}$, B^f_{t-1}, $\bar{Y}^u_{t-1}$, $M^{s,u}_{t-1}$, M^s_{t-1}, $M^{s,e}_{t-1}$.[26]

- 12 expected variables: e^{ie}_{t+1}, $\bar{P}_{t+1}$, τ^c_{t+1}, $u_{C,t+1}$, μ^w_{t+1}, λ^K_{t+1}, t^b_{t+1}, d^l_{t+1}, V_{t+1}, $\bar{P}^e_{t+1}$,[10] $u^e_{C,t+1}$, $\bar{P}^u_{t+1}$.

Curriculum Vitae

Born on February 10, 1991 in Lindlar, Germany.

Education

PhD	University of St. Gallen, Economics and Finance Thesis supervisor: Prof. Keuschnigg Dissertation title: Essays on the European financial market structure and the monetary union	expected 2022
	University of Maryland, Department of Economics Fellow of the Swiss National Science Foundation Hosted by Prof. Kalemli-Özcan	10/2019 - 08/2021
M.A.	University of St. Gallen, Economics (5.61/6.00) Received Jöhr Prize for the best Master's degree Thesis title: Securities lending and the economy – the ECB's newest monetary policy tool in a stylized equilibrium model	03/2017
B.A.	University of St. Gallen, Economics (5.45/6.00)	03/2014

Work Experience

University of St. Gallen, St. Gallen Research assistant to Prof. Keuschnigg	10/2016 to 07/2019, and 09/2021-11/2021
University of St. Gallen, St. Gallen Instructor of weekly exercises (Economics A & B)	09/2017 to 07/2019
Inter-American Development Bank, Washington D.C. Consultant in the Research Department	02/2016 to 06/2016

Conference Participation

2022 Presentations: RCEA Conference, 29th Finance Forum, FMA Conference, World Finance Conference (scheduled).

2021 Presentations: American Economic Association Annual Meeting, ECB-RFS Macro-Finance Conference, Annual Congress of the Swiss Society of Economics and Statistics, University of St. Gallen PhD Seminar, SFI Research Days, World Finance Conference, Annual Conference of the Money, Macro, Finance Society, SNB Research Conference, 16th Central Bank Conference on the Microstructure of Financial Markets.