Heterogeneous Banks and Quantitative Easing: the Portfolio Rebalancing Effect

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Abstract

This paper examines the transmission of Quantitative Easing through the portfolio rebalancing channel. In response to yield reductions on securities targeted by the central bank's purchases, banks actively rebalance their asset portfolios by increasing credit supply. The analysis is centered upon the Fed's large-scale asset purchases undertaken following the outbreak of the Covid-19 pandemic. First, an event-study methodology shows significant declines in the returns of U.S. Treasuries and agency MBS coinciding with the Fed's announcements, with the largest effects observed on longer-term securities. Second, a difference-in-differences design, based on intermediaries' baseline exposure to targeted securities, reveals a strong shift toward loan creation driven by an expansion in commercial loans. Finally, a theoretical framework featuring banks with heterogeneous risk preferences is introduced to rationalize an asset reallocation motive toward credit supply following a QE-induced decline in interest rates.

1 Introduction

Following the outbreak of Covid-19, several central banks around the world announced and subsequently implemented large-scale purchases of mostly, but not exclusively, government securities. These actions were undertaken to counteract the economic instability brought by the pandemic, with the Fed's declared objective of supporting the flow of credit to households and businesses. These unconventional monetary policy measures, widely referred to as Quantitative Easing (QE), saw their first full-scale implementation in response to the Financial Crisis of 2008-2009. A large body of literature from that period documents the effectiveness of the Fed's interventions in stabilizing financial markets - in particular, for mortgage-backed securities (MBS) - and lowering long-term interest rates[1].

Despite a broad consensus on its efficacy, a heated debate emerged in the following years over the channels through which QE operates. In an iconic discussion at the Brookings Institution in 2014, the former Fed Chairman Ben Bernanke declared: "The problem with QE is it works in practice, but it doesn't work in theory." The different mechanisms carried forward to explain the transmission of QE to the real economy can be divided into two categories. Some argue that large-scale asset purchases (LSAPs) stimulate economic activity by creating broad money in the form of new deposits, while others emphasize the lowering of long-term interest rates as the primary force driving recovery. The first argument hinges on part of the securities targeted by the central bank being acquired from non-depository financial institutions (e.g., hedge funds). Through the passive intermediation of the banking system, these transactions lead to a corresponding increase in private-sector holdings of bank deposits. The second perspective, instead, relies on the imperfect substitutability between financial assets and central bank reserves to link the draining of targeted securities from financial markets with a decline in their yield. Vayanos and Vila (2021) show that, if

[1] See, as one of the most notable examples, Krishnamurthy and Vissing-Jorgensen (2011).

investors have preferences for specific maturities, QE interventions targeting long-term assets generate sizable reductions in long-term interest rates through a decrease in term premium.

In this paper, I build on this second viewpoint to examine one transmission mechanism of QE, the portfolio rebalancing channel, by analyzing how the market effects of LSAPs interact with the banking system. Beyond the creation of deposits by banks acting as direct counterparts in the central bank's asset acquisitions, the yield movements resulting from these transactions may trigger broader second-round effects. Faced with a compression in the returns of the targeted securities, intermediaries holding these financial assets may adjust their asset portfolios in search of more profitable opportunities. If this rebalancing process is directed towards an expansion in credit extension to the private sector, then QE would support economic recovery through increased bank lending.

Notably, these portfolio adjustments go beyond the mechanical consequences of LSAPs. First, by operating through the market impact of QE on the targeted securities, this reallocation motive also encompasses financial intermediaries not directly involved in the central bank's transactions. Second, even for those institutions exchanging these assets for reserves, the rebalancing force is far from being purely automatic. Although QE mechanically reduces banks' holdings of the targeted securities, the fact that this, in turn, leads to higher loan creation is clearly not obvious, as banks have a wide array of alternative investment opportunities - from riskier fixed-income securities to equities and derivatives. Thus, whether the portfolio rebalancing channel amplifies the real effects of QE is ultimately an empirical question.

This inquiry centers on the most recent episode of QE interventions in the U.S., namely two statements made by the Federal Open Market Committee (FOMC) in March 2020 regarding large-scale purchases of U.S. Treasuries and agency MBS. The first step of the analysis is to determine the impact of the Fed's announcements on interest rates. Leveraging a high-frequency identification strategy to account for the confounding effects of the pandemic, I measure yield movements of the targeted securities within a 1-day window around each event date. This approach reveals significant yield and price fluctuations: a cumulative reduction of approximately 40 basis points in long-term Treasury yields and a price increase of about 2.5% for agency MBS. Remarkably, in contrast, the return on the 1-year Treasury underwent only small and statistically insignificant changes. This result supports the view that central banks use LSAPs to lower long-term interest rates, with the ultimate goal of stimulating private spending and investment.

Next, the paper examines U.S. banks' responses to these interest rate reductions, providing evidence of the portfolio rebalancing effect. By exploiting heterogeneity in pre-intervention holdings of the targeted securities, I estimate a dose-response difference-in-differences regression model using administrative data on U.S. banks from Call Reports. This specification compares changes in lending across financial institutions with varying exposure to these monetary policy measures. Two alternative treatment definitions are employed. The first, less refined approach considers the share of an intermediary's total assets allocated to U.S. Treasuries or agency MBS at baseline. To better capture a rebalancing toward loan creation, the continuous treatment variable is alternatively defined by focusing exclusively on the long-term share of these securities. As revealed by the high-frequency analysis, these financial assets experienced the most significant yield declines and, thus, any yield-induced portfolio rebalancing is expected to be more pronounced under this second treatment definition. The results presented below fully support this prediction: when considering banks' exposure to the entirety of the targeted securities, I detect only a weak and statistically insignificant shift toward private-sector credit. Under the long-term treatment, instead, a strong and statistically significant rebalancing force is uncovered: a one standard deviation increase in baseline exposure to long-term U.S. Treasuries or agency MBS led banks, on average, to invest an additional 3.2% of total assets in private-sector loans. Thus, despite the general contraction in lending activities that followed the outbreak of the pandemic, financial institutions with a larger share of assets in the securities targeted by the Fed increased their supply of credit in relative terms.

As a further step, I also examine the direction of the increase in bank credit. Documenting near-zero effects for real estate and consumer loans, this decomposition shows that the estimated portfolio rebalancing effect is almost entirely driven by commercial loans. Overall, these empirical findings demonstrate that the Fed's announcements of LSAPs successfully met its declared intent: acting through the banking system, these measures sustained the flow of credit particularly to U.S. firms, which faced a sudden exacerbation of their liquidity needs due to the lockdowns.

After illustrating this transmission channel empirically, the paper presents a theoretical framework that rationalizes the observed portfolio adjustments in response to a QE shock. In a simple model economy with a banking sector, a continuum of financial institutions intermediates funds between a representative household and a final good producer. Each bank solves a portfolio formation problem by allocating its resources - consisting of equity and household deposits - between risky private-sector loans and a safe asset. To define the optimal portfolio composition, intermediaries maximize mean-variance preferences, with a bank-specific risk aversion parameter, ϕ^i, capturing heterogeneity in risk attitudes. Taking the deposit rate as given, I show that the economy's equilibrium is governed by a relation that defines a cutoff in the risk aversion distribution, distinguishing levered from non-levered banks, and a simple capital aggregation equation.

To examine a yield-induced portfolio rebalancing within the calibrated framework, a QE shock is modeled as a reduction in the return on the safe asset. For an appropriate comparison of banks' portfolio adjustments between the model and the data, the general contraction in loan creation brought about by Covid-19 needs to be accounted for. Since this force is driven by factors beyond the scope of the model, I demean the changes in asset shares in both the theoretical and empirical environments, effectively controlling for the "fixed effects" of the pandemic period. In its simplicity, the model is fairly effective in replicating the observed cross-section of portfolio rebalances. The financial institutions most prone to risk-taking increased loan extension - relative to the average change in portfolio shares - and, as the degree of risk aversion decreases, the magnitude of the adjustment diminishes almost linearly.

1.1 Related Literature

This work naturally connects to the strand of economic research that examines the market effects of large-scale asset purchase programs. In the years following the Great Recession, several papers showed that these unconventional monetary policy measures led to substantial declines in various interest rates. Investigating the first two rounds of the Fed's QE intervention from 2008 to 2011, Krishnamurthy and Vissing-Jorgensen (2011) found sizable declines in nominal interest rates for targeted long-term securities, as well as for a set of private financial instruments. Based on different event-study analyses, similar conclusions were also supported by Gagnon et al. (2011) and Swanson (2011)[2]. Rather than focusing on market fluctuations around QE announcements, D'Amico and King (2013) estimated the impact of the implementation of the Fed's purchases: interestingly, while these transactions did lead to additional yield declines for targeted securities, the effects were significantly smaller than those observed on announcement dates. The following analysis of the portfolio rebalancing forces arising from LSAPs will focus exclusively on the yield effects induced by FOMC statements, abstracting from any market impact related to the actual central bank purchases. The findings in D'Amico and King (2013) suggest that this approximation still enables capturing the greater part of the interest rate declines stemming from QE.

With the new surge of LSAPs at the onset of the Covid-19 pandemic, this literature attracted a renewed interest. Examining the Fed's and the ECB's actions, several studies

[2]The latter exploited the vast purchase of long-term Treasuries conducted by the Fed in the context of Operation Twist to estimate the potential effects of QE2.

have documented significant reductions in interest rates due to these recent QE interventions and, more generally, highlighted how these measures remain effective in stabilizing financial markets (see, among others, Cortes et al. (2022), Gilchrist et al. (2024), Rebucci et al. (2022), and Haddad et al. (2021)).

Despite the significant attention devoted to the market effects of the asset purchases of 2020, a rather limited literature explored how these forces affected the banking system and, in particular, its lending activities. This paper aims to contribute to this area of research.

For this reason, this work is also closely related to contributions that investigate the transmission of Quantitative Easing through the financial system. A few papers analyzed banks' balance sheet adjustments in response to the LSAPs put in action during the Great Recession. Kandrac and Schlusche (2021) employed an IV identification based on a regulatory change with effects on financial institutions' reserves holdings to show a sizable positive impact of QE on loan creation. Similar findings were also observed by Rodnyansky and Darmouni (2017) and Paludkiewicz (2021).

In highlighting a lending stimulus, these papers argue for different mechanisms. Kandrac and Schlusche (2021) impute the expansion in credit to the accumulation of reserves generated by the central bank's purchases, whereas Paludkiewicz (2021) examines a yield-induced asset portfolio adjustment. Notably, forces acting through the market effects of the asset purchases are likely to generate a stronger transmission of QE than mechanisms working purely through the acquisitions of reserves: by influencing the lending behavior of banks not directly involved in the transactions, the former amplifies the credit creation effects of a given expansion of the central bank's balance sheet. The portfolio rebalancing effect, that will be discussed in detail below, falls within this category. In addition, recent work has shown that the increase in central bank reserves that follows LSAPs may, conversely, have adverse effects on loan creation: by estimating a structural model of the U.S. banking system, Diamond et al. (2024) reveal that the reserve injections due to the QE interventions between 2008 and

2017 led to a crowding-out of bank lending. Complementing the analysis in this paper, this finding suggests that any credit expansion associated with QE must instead be sought in the second-round effects of central bank purchases.

Lastly, my work is also linked to the literature incorporating a banking system within macroeconomic models[3]. The latest developments in this field place growing emphasis on the relevance of banks' heterogeneity in driving aggregate outcomes, with Boissay et al. (2016), Begenau and Landvoigt (2022), and Coimbra and Rey (2024) being among the most significant contributions. As will be thoroughly explained, the model in Coimbra and Rey (2024) constitutes the main reference for the theoretical framework proposed below. The authors consider financial intermediaries that face heterogeneous Value-at-Risk constraints, and solve a portfolio problem involving a safe and a risky asset. Despite a different modeling approach for bank heterogeneity, which results in distinct implications for the equilibrium distribution of portfolios, my work shares with this paper a focus on the interaction between financial institutions' risk-taking and monetary policy.

The rest of the paper is organized as follows. Section 2 presents evidence on the effects of the Fed's QE announcements on selected interest rates through an event study design. Section 3 shows how U.S. financial institutions responded by adjusting their asset composition and increasing credit supply. Section 4 proposes a theoretical framework with heterogeneous banks that matches the observed portfolio rebalances following a QE shock. Section 5 concludes.

2 The Effects of QE Announcements

The first step of the analysis is to document how announcements of LSAPs affect the market returns of securities targeted by the central bank.

[3]This rather active area of research finds its foundational contributions in Bernanke et al. (1999), Gertler and Kiyotaki (2010), and Gertler and Karadi (2011), among others.

Focusing on QE interventions undertaken in the US during the pandemic period, two statements made by the Federal Open Market Committee will be examined: on March 15, 2020, the Fed announced it would acquire at least $500 billion in Treasury securities and $200 billion in government-guaranteed mortgage-backed securities over the coming months. Subsequently, on March 23, 2020, the FOMC made these purchases open-ended, stating that it would buy securities "in the amounts needed to support smooth market functioning and effective transmission of monetary policy to broader financial conditions." These measures were adopted in a period of substantial turmoil, when updates from health authorities on the spread of the virus and announcements of lockdowns or other policy interventions led to large fluctuations in financial markets. To isolate the effect of QE on interest rates from these external forces, I employ a high-frequency identification strategy and measure changes in selected rates within a narrow window around QE announcements. By focusing on a short enough timeframe, potential confounding factors can be ruled out.

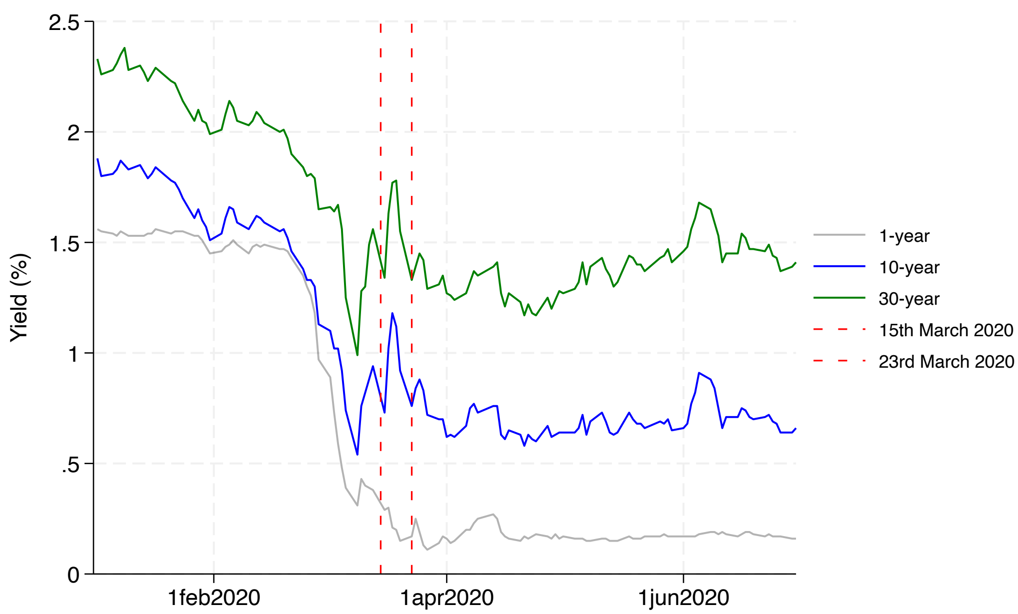
Given the event set described above, a crucial aspect is the length of the event window. This choice involves a trade-off between minimizing the risk of confounding effects and the possibility of not fully capturing the impact of the intervention. When documenting the efficacy of the QE operations undertaken by the Fed in response to the Great Recession, Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) use 1-day and 2-day event windows, respectively. In what follows, the impact of the two QE shocks will be estimated using 1-day changes in interest rates. Unlike in 2008-2009, financial markets were not entirely surprised by the adoption of these unconventional monetary policy measures. As a result, most investors likely adjusted their portfolio composition - and, consequently, generated the price and yield fluctuations I aim to quantify - within the trading day of each QE announcement[4].

[4]It is reasonable to believe, however, that market participants did not fully anticipate the timing of the announcements. This assumption is crucial for the high-frequency analysis to effectively identify the effects of QE.

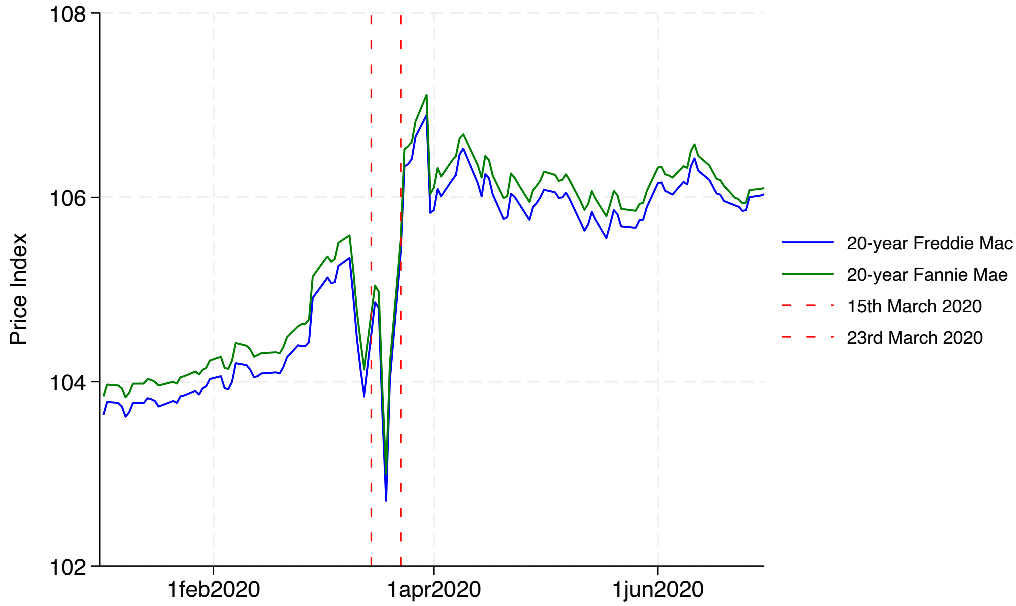
As an initial description, Figure 1 plots the daily movements in U.S. Treasury yields and agency MBS prices during the first two quarters of 2020. On the two announcement days, the 10-year and 30-year U.S. government securities experienced significant yield declines, while the return on the 1-year bond saw only minimal movements. Even more notably, the market price of 20-year mortgage-backed securities guaranteed by Freddie Mac and Fannie Mae spiked on both dates.

Figure 1: Fluctuations in Yield/Price and QE Announcements

(a) U.S. Treasuries Yield



(b) Agency MBS Price



Notes: The two subfigures display, respectively, the market yield on 1-year, 10-year, and 30-year U.S. Treasury, and the Bloomberg U.S. MBS Index for 20-year securities guaranteed by Freddie Mac and Fannie Mae. Each series is plotted at a daily frequency from January through June 2020. The vertical dashed lines indicate the two LSAPs announcements made by the Fed on March 15 and March 23.

In addition to computing changes in the selected interest rates over the event windows, I test whether fluctuations on these dates statistically differ from those on other trading days. For each series, 1-day changes are regressed on a time dummy indicating the occurrence of a QE announcement, and the statistical significance of this regressor is assessed. Table 1 reports the results. The market returns on the 10-year and 20-year Treasuries declined by approximately 20 basis points following each QE announcement, whereas MBS prices increased by more than 1 percent on each event date. These effects are highly significant: when estimating the specification using daily observations from 2018 to 2021, the null hypothesis of no impact is rejected at all significance levels. Remarkably, the same conclusions hold when restricting the sample period to 2020 alone. On the announcement dates, the yield/price of the four long-term securities experienced significant fluctuations, even when compared to the already volatile pandemic period.

Table 1: The Effects of QE Announcements

Announcement Date	1-Day Change				
	Treasury Yield			MBS Price Index	
	1-year	10-year	30-year	20-year Freddie Mac	20-year Fannie Mae
15th March 2020	-0.09	-0.20	-0.22	1.02	0.91
23rd March 2020	0.02	-0.16	-0.22	1.40	1.36
Total	-0.07	-0.36***	-0.44***	2.42***	2.27***
	(0.387)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: The table shows the changes in U.S. Treasury yields and the agency MBS price index on the two QE announcement days. The last row presents the cumulative effect across the two event dates for each variable. As outlined in the main text, statistical significance is determined by regressing 1-day changes on a time dummy for QE dates. The figures in parentheses in last row indicate the p-values for testing the significance of the QE shocks combined. Asterisks denote statistical significance at the ***1 percent, **5 percent, and *10 percent level.

Table 1 also shows that the sizable movements observed for the long-term financial assets do not extend to the 1-year U.S. Treasury. The yield on this short-term security recorded only small and statistically insignificant changes on the two event dates. This result supports the notion that central banks implement LSAPs to lower long-term interest rates, ultimately aiming to stimulate private spending and investment. Such distinct effects for short-term and long-term securities provide some reassurance that the results in Table 1 are not driven by confounding forces. If the observed yield and price fluctuations were attributable to other aggregate shocks or policy interventions occurring simultaneously with the QE announcements, then the 1-year Treasury would have been affected to a comparable degree.

As a robustness check, Table 6 in the Appendix replicates the analysis enlarging the event window to two and three trading days. The resulting yield effects for U.S. Treasuries are no longer statistically different from zero and become substantially more erratic. Similar observations hold for agency MBS prices when using 3-day changes. Thus, with few exceptions[5], expanding the event window does not yield more consistent estimates and, on the contrary, leads to the inclusion of external disturbances.

Given these results, one might ask how the effectiveness of QE during the pandemic compares to its initial implementation during the Great Recession.

Krishnamurthy and Vissing-Jorgensen (2011) documented the impact of five LSAPs announcements made by the Fed between November 2008 and March 2009 on the yields of U.S. Treasuries and agency securities. Table 2 reports the high-frequency estimates from this paper for 1-year, 10-year, and 30-year U.S. government bonds around the five QE dates. For complete comparability with the previous results, I supplement these measures with price changes for 20-year MBS guaranteed by Freddie Mac and Fannie Mae, calculated using the same methodology described above[6].

[5]The specification based on 2-day changes detects a statistically significant price effect for Freddie Mac and Fannie Mae MBS. However, these movements are larger than in the baseline setting only for the March 23 announcement.

[6]Krishnamurthy and Vissing-Jorgensen (2011) calculated average yield movements for agency MBS with 30-year and 15-year maturities. To avoid any definitional discrepancies that could lead to differences in estimates, I do not reference these figures but, instead, directly compute changes for the selected variables.

Table 2: QE during the Great Recession

Announcement Date	2-Day Change				
	Treasury Yield			MBS Price Index	
	1-year	10-year	30-year	20-year Freddie Mac	20-year Fannie Mae
25th November 2008	-0.02	-0.36	-0.24	1.43	1.48
1st December 2008	-0.13	-0.25	-0.27	0.31	0.21
16th December 2008	-0.05	-0.33	-0.32	0.50	0.39
28th January 2009	0.04	0.28	0.31	-0.62	-0.58
18th March 2009	-0.09	-0.41	-0.21	0.70	0.66
Total	-0.25**	-1.07**	-0.73*	2.32	2.16
	(0.045)	(0.046)	(0.096)	(0.145)	(0.155)

Notes: The table replicates the high-frequency analysis focusing on the Fed's QE interventions in 2008-2009. In particular, it presents the yield and price fluctuations of the same securities around the five QE dates identified in Krishnamurthy and Vissing-Jorgensen (2011). The figures for U.S. Treasuries are taken directly from that paper, while the price movements of agency MBS are based on my own calculations. Note that, unlike Table 1, the effects of QE are computed using 2-day changes. This choice is consistent with Krishnamurthy and Vissing-Jorgensen (2011). Due to the larger event window, p-values for statistical significance are now based on an F-test of the sum of the estimated coefficients for the QE dummy and its first lag. Asterisks denote statistical significance at the ***1 percent, **5 percent, and *10 percent level.

When comparing the effects of QE announcements during the two economic downturns, similar qualitative considerations emerge. These measures resulted in sizable yield declines for long-term U.S. Treasuries: each QE shock caused an average yield drop of 30 basis points during the Great Recession, compared to a 20 basis point decrease in pandemic times. In both downturns, by contrast, LSAPs led to much less pronounced movements for the 1-year Treasury. As for agency-guaranteed MBS, both Table 1 and Table 2 show price jumps corresponding to the Fed's announcements. Interestingly, the magnitude of the price changes induced by the interventions between 2008 and 2009 is significantly smaller than the effects observed in 2020. Since the collapse of the mortgage-backed securities market was at the core of the Financial Crisis, it is not surprising that any stimulus provided by the central bank would have had a somewhat weaker impact.

Thus, despite the absence of a surprise effect and the very different nature of the economic contraction, this analysis demonstrates that announcements of asset purchases have continued to be effective in lowering interest rates at the long end of the maturity curve.

3 The Portfolio Rebalancing Effect

Section 2 established that the Fed's announcements of LSAPs in the early months of the pandemic effectively lowered market interest rates on long-term U.S. government and agency securities. Through these first-round effects, QE promotes economic recovery by easing borrowing conditions for firms that draw on capital markets to finance their activities. Although these forces support the flow of credit to larger firms, they do not reach small businesses that depend heavily on credit relationships with banks.

On top of these effects, QE may have additional implications by indirectly influencing banks' behavior. Faced with lower returns on securities targeted by the central bank's purchases, financial institutions may adjust their asset portfolios in search of more profitable investment opportunities. In doing so, they may, among other options, increase the supply of credit to the private sector. These second-round effects, operating through the banking system, would help sustain the availability of credit, particularly for smaller enterprises. This mechanism, which I will refer to as the portfolio rebalancing effect, will be examined empirically in this section.

To investigate a potential adjustment in banks' portfolio composition in the months following the Fed's intervention, I turn to the Federal Financial Institutions Examination Council (FFIEC) filings. These mandatory regulatory reports are submitted quarterly by all federally insured commercial banks, and provide detailed data on banks' financial position and profitability. In particular, the following analysis will be based on the Consolidated Reports of Condition and Income, sometimes referred to as Call Reports. An accurate description of this source of information can be found in Section A.1 of the Appendix.

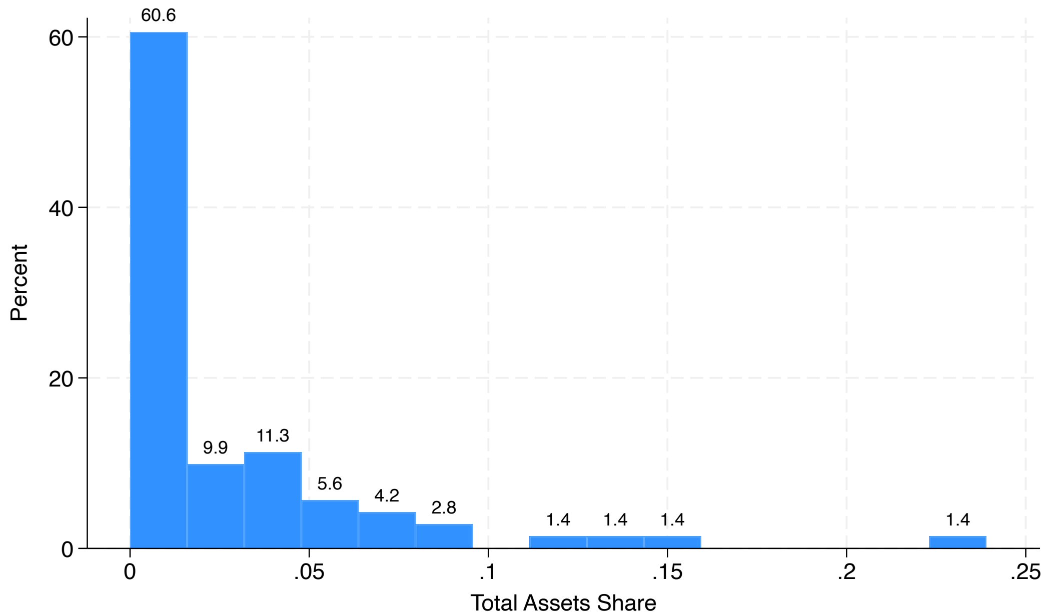
To detect any rebalancing toward loan creation, it is essential to account for the confounding forces related to the pandemic: the Fed's announcements of LSAPs were made during a period of severe economic disruptions, with several factors potentially influencing banks' investment decisions. With this aim, the analysis that follows will be based on differential trends in credit supply: by comparing the evolution of lending activities among banks affected to varying degrees by the FOMC statements, the causal effect of QE on loan creation is identified.

The first step is to describe the heterogeneity in financial institutions' exposure to the assets targeted by the central bank at baseline. Figure 2 plots the distributions of the share of total assets consisting of U.S. Treasury securities, agency-sponsored MBS, and their combined total - referred to as "QE securities" - at the beginning of 2020. In what follows, the sample of U.S. banks is restricted to include only institutions with holdings in either type of financial asset[7]. Section A.1 of the Appendix presents a set of summary statistics for the resulting sample.

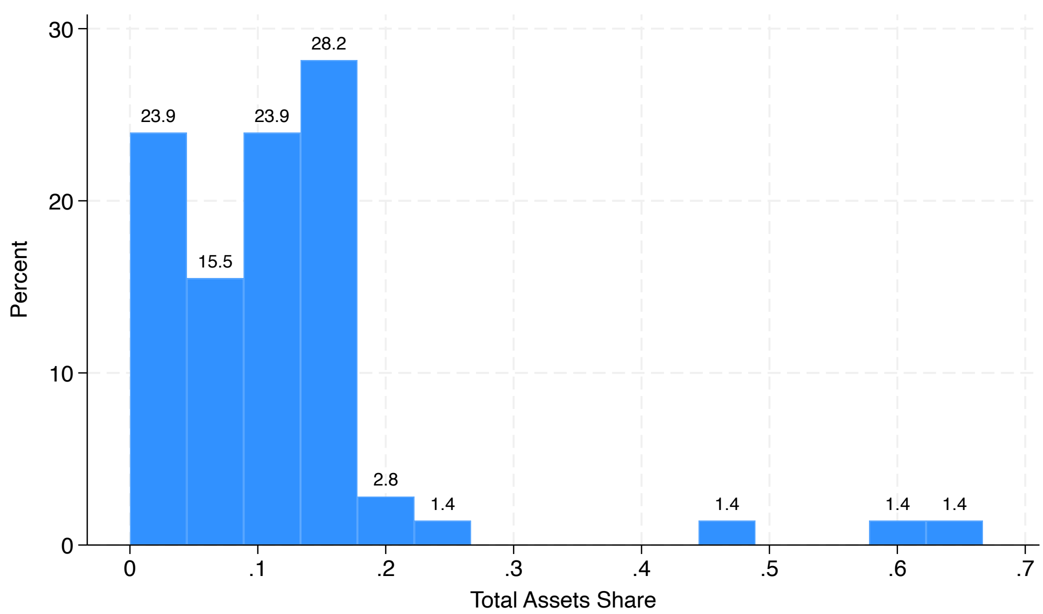
[7]Although this leads to a significant reduction in the number of available observations, it is necessary to focus on the financial intermediaries most directly exposed to the yield effects of QE. Despite this loss of statistical power, the remaining banks are the largest in the country, so any portfolio rebalancing motive revealed is likely to have tangible consequences at the aggregate level.

Figure 2: Heterogeneity in Banks' Portfolio Composition in 2020q1

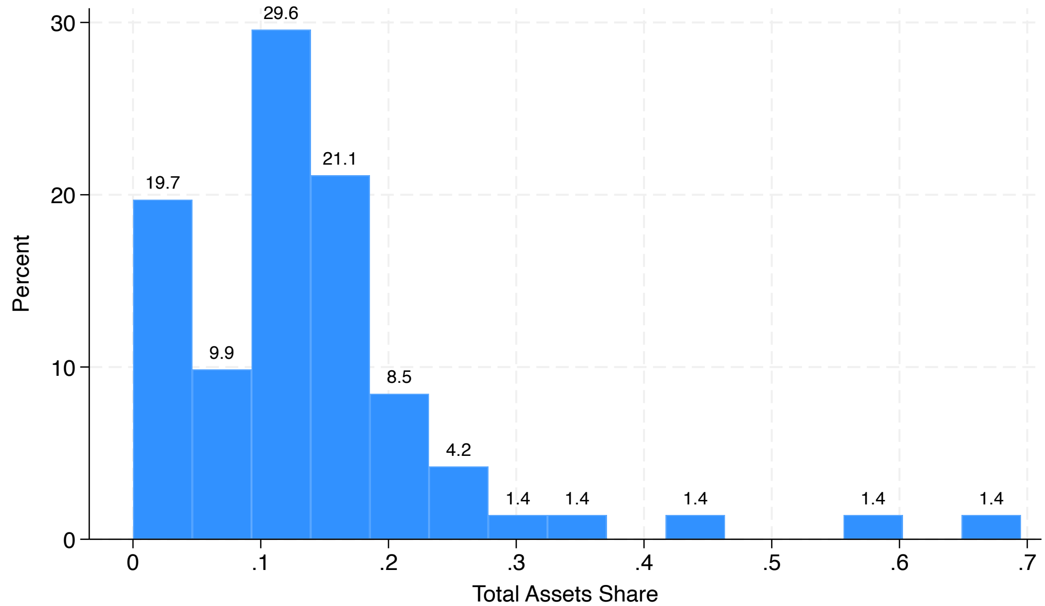
(a) U.S. Treasuries



(b) Agency MBS



(c) QE Securities (U.S. Treasuries + Agency MBS)



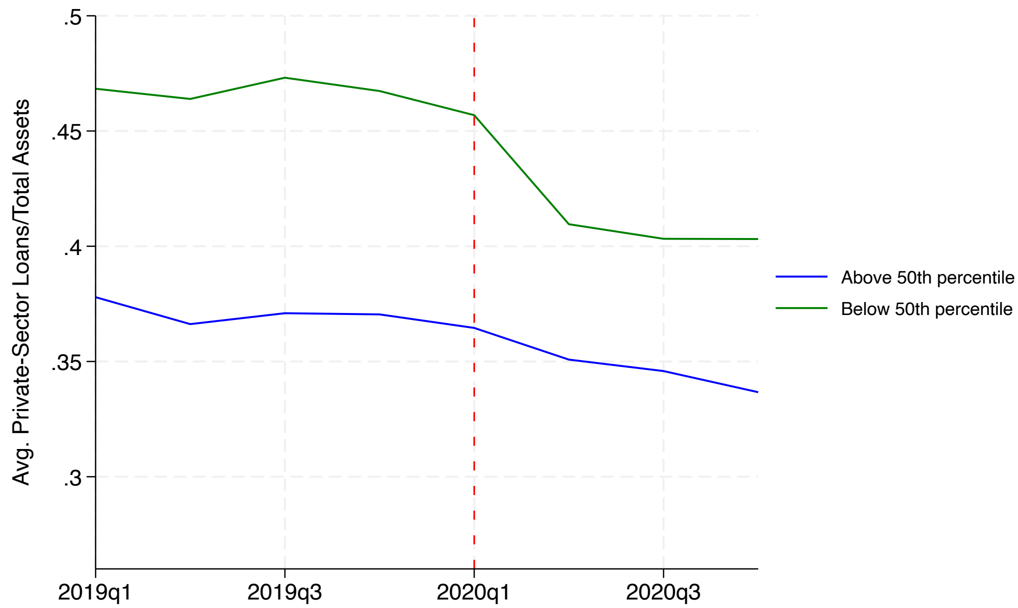
Notes: The three bar charts describe the asset share distributions of U.S. Treasuries, agency MBS, and QE securities for the restricted sample of banks in the first quarter of 2020. The labels correspond to the height of each bar, representing the relative conditional frequency of a given interval of asset exposure. Summary statistics for the three variables are reported in Table 5 of the Appendix.

The figures show that asset portfolios contain a significant portion of these securities, with an average asset share of 14.4 percent invested in QE securities. Additionally, considerable cross-sectional variation in the holdings of these assets is revealed. These results are promising regarding the quantitative relevance of the QE-induced yield declines, and the possibility of exploiting their heterogeneity for identification.

As preliminary descriptive evidence, Figure 3 illustrates loan creation trends for banks more and less exposed to QE. Holding the portfolio composition as of the first quarter of 2020, the sample is divided based on the distribution of asset shares invested in QE securities. Then, the time series of the average ratio of private-sector loans to total assets is plotted for different groups of financial institutions.

Figure 3: Loan Creation by QE Exposure

(a) Top 50% vs Bottom 50%



(b) Top 25% vs Bottom 25%

Notes: The two subfigures display the average asset shares of private-sector loans for U.S. banks, grouped based on their holdings of QE securities relative to total assets in the first quarter of 2020. In particular, the top panel compares financial institutions with above-median and below-median baseline exposure, while the bottom panel considers banks in the top and bottom 25 percent.

In all four subsamples, credit supply underwent a decline, relative to total assets, with the onset of the pandemic: the high uncertainty during the first months after the Covid-19 outbreak, along with consumer loan demand factors driven by the lockdown restrictions, likely contributed to this pattern. This shows why a naive comparison of average loan creation before and after the Fed's intervention would be inadequate for determining the impact of QE on lending, thus underlining the need to analyze differential trends. Remarkably, the two subfigures reveal a clear divergence between more and less exposed financial institutions, which coincides with the QE announcements of March 2020. Although declining, lending by banks with higher baseline holdings of QE securities experienced a less drastic halt in relative terms. This divide is more pronounced in the bottom panel, where I compare institutions in the top 25% of the exposure distribution with those in the bottom 25%. These findings are consistent with a portfolio rebalancing motive toward private-sector loans, driven by the decline in the yield of the financial assets targeted by the Fed. In Section A.3 of the Appendix, the same exercise is repeated, splitting the sample separately by exposure to U.S. Treasuries and agency MBS, with the same considerations still applying.

Moving beyond this initial description, I employ a dose-response difference-in-differences design, based on the QE exposure heterogeneity portrayed in Figure 2, to estimate the impact of the LSAPs announcements on banks' credit supply. In this context, treatment intensity will be defined as the portfolio share consisting of QE securities at baseline[8]. In particular, I consider the regression model:

$$LoanShare_{it} = \alpha PostQE_t + \delta Exposure_i + \beta PostQE_t \times Exposure_i + X_{it}'\theta + \varepsilon_{it} \quad (1)$$

where $PostQE_t$ is a time dummy differentiating pre- and post-QE periods, $Exposure_i$ denotes holdings of QE securities relative to total assets at baseline, and X_{it} is a set of controls to address potential endogeneity concerns. In particular, X_{it} includes: the return on assets and the net interest margin to account for differences in banks' profitability; the equity-to-assets ratio and interbank borrowing-to-assets ratio are included to control for the funding dimension of financial intermediation; the reserves-to-assets ratio to ensure that any estimated portfolio rebalancing is not simply a mechanical effect of the Fed's asset purchases. The outcome variable $LoanShare_{it}$ is banks' portfolio share consisting of private-sector loans. The main coefficient of interest is β, which captures how movements in credit supply in the months following the Fed's intervention were related to the exposure to QE shocks in early 2020.

As explained by De Chaisemartin and D'Haultfoeuille (2018), three conditions must be

[8]This corresponds to extending the analysis in Figure 3 to include a continuum of exposure levels, as opposed to a binary classification.

met for this approach to identify the causal effect of QE on lending activities. First, in the absence of the policy intervention, banks with higher or lower QE exposure in the first quarter of 2020 would have exhibited similar trends in loan creation. This condition relies on the existence of parallel trends in outcomes prior to the onset of the pandemic. Although characteristics correlated to QE securities holdings could produce differential lending patterns[9], Figure 3 shows that, even without restrictions, subsamples with different exposure exhibit very similar pre-trends. Second, the treatment effect must be homogeneous. This requirement imposes a linear relationship between baseline holdings of QE securities and changes in credit supply following the QE announcements. Figure 7 in Section A.4 of the Appendix plots these two variables in a binned scatterplot and finds an approximately linear positive association between them. Third, identification requires the absence of anticipation effects: U.S. banks must not have altered their behavior in expectation of the QE announcements in March 2020. The unpredictability of the outbreak of Covid-19 and the promptness of the Fed's intervention give credit to this hypothesis.

In estimating the regression model, two alternative treatment definitions will be considered: in addition to the QE exposure measure previously discussed, I will focus on a more narrowly defined treatment variable, which includes only long-term QE securities. In particular, leveraging information on the maturity structure of asset holdings, this alternative treatment definition will cover QE securities with a remaining maturity of at least 5 years. Given the findings in Section 2, this distinction may be relevant for a yield-induced portfolio rebalancing, as the estimated effects of QE are especially pronounced for long-term financial assets.

Table 3 reports the estimates of (1) for the two treatment definitions, with and without controls, over the sample period 2019-2020. In light of the analysis by Bertrand et al. (2004) on the consequences of error serial correlation in difference-in-differences models, I use two-

[9]To tackle these confounding forces, the regression specification includes the controls X_{it}.

way clustered standard errors at the bank and quarter levels[10].

Table 3: The Portfolio Rebalancing Effect

	$LoanShare_{it}$			
	(1)	(2)	(3)	(4)
$PostQE_t$	-0.0691**	-0.0448*	-0.0752***	-0.0634***
	(0.035)	(0.026)	(0.029)	(0.024)
$Exposure_i$	-0.655***	-0.651***		
	(0.081)	(0.075)		
$Exposure_i * PostQE_t$	0.174	0.0611		
	(0.141)	(0.096)		
$LT\_Exposure_i$			-0.681***	-0.707***
			(0.174)	(0.169)
$LT\_Exposure_i * PostQE_t$			0.593**	0.516**
			(0.262)	(0.217)
$EquityRatio_{it}$		-1.272*		-1.256
		(0.693)		(1.070)
ROA_{it}		-0.795***		-0.782***
		(0.240)		(0.236)
$ReserveRatio_{it}$		-0.794***		-0.785***
		(0.102)		(0.111)
$IB\_BorrowingRatio_{it}$		-5.303**		-5.317*
		(2.614)		(2.754)
NIM_{it}		3.159		3.188
		(3.521)		(3.229)
Constant	0.513***	1.271***	0.516***	1.269***
	(0.021)	(0.146)	(0.032)	(0.131)
N	569	569	569	569
R^2	0.0830	0.398	0.0872	0.402

Notes: The table reports point estimates and standard errors for the difference-in-differences regression model (1), estimated using quarterly data for U.S. banks from 2019 to 2020. In columns (1) and (2), treatment is defined as exposure to the entirety of QE securities, while in columns (3) and (4), it includes only their long-term component. The specifications in (2) and (4) incorporate the control set X_{it}. To handle error serial correlation, standard errors in parentheses are clustered at the bank and quarter levels. Asterisks denote statistical significance at the ***1 percent, **5 percent, and *10 percent level.

[10]For a comprehensive review of alternative solutions for serially correlated errors in panel data, see Petersen (2009).

For both exposure variables, the estimated coefficient for $PostQE_t$ is negative and statistically significant. In line with the descriptive evidence of Figure 3, private-sector loans relative to total assets declined with the onset of the pandemic across the entire distribution of intermediaries.

Remarkably, the interaction term exerts a positive impact on lending activities: in the months following the two QE announcements, banks with higher baseline exposure to QE securities increased their credit supply relative to less exposed intermediaries. This portfolio rebalancing effect is not statistically significant when the treatment definition includes all QE securities, but it becomes considerably stronger and significant when focusing on their long-term share. In light of the findings from the high-frequency analysis above, this pattern is entirely consistent with a yield-induced portfolio rebalancing toward loan creation. If banks adjusted their portfolio composition in response to the yield effects of LSAPs announcements, then this reallocation motive would be stronger for long-term QE securities, as their return experienced substantially more significant declines. Although the inclusion of controls reduces the estimated coefficient for this portfolio rebalancing, its sign remains positive and, under the narrower treatment definition, statistically significant at a 5 percent level. As a more concrete interpretation of the results in column (4) of Table 3, a one standard deviation increase in baseline exposure to long-term QE securities led to an additional 3.2% of total assets being invested in private-sector loans after the Fed's intervention.

A further step in the analysis is to investigate which private-sector agents benefited the most from this relative increase in lending. To this end, leveraging Call Reports data on the composition of banks' credit, (1) is re-estimated separately for real estate, commercial, and consumer loans under the long-term treatment definition. Table 4 presents the results. This decomposition shows that the portfolio rebalancing motive was almost exclusively driven by an expansion in loan creation toward businesses. This result emphasizes the relevance of the portfolio rebalancing transmission mechanism and highlights the effectiveness of QE in sustaining credit flow during the pandemic. Faced with a sudden drop in revenues due to virus containment measures, U.S. firms relied on lending from financial institutions to address sunk costs and meet their liquidity needs.

Table 4: Decomposing the Portfolio Rebalancing Effect

	$RealEstate$ $LoanShare_{it}$	$Commercial$ $LoanShare_{it}$	$Consumer$ $LoanShare_{it}$
$LT\_Exposure_i * PostQE_t$	0.0626	0.519***	-0.0748
	(0.168)	(0.132)	(0.124)

Notes: The table re-estimates the difference-in-differences model (1) separately for real estate, commercial, and consumer loans. The specification uses the narrower treatment definition and includes the full set of controls X_{it}. For the sake of conciseness, I report only estimated coefficients and standard errors for the interaction term, which reflects the portfolio rebalancing effect. Asterisks denote statistical significance at the ***1 percent, **5 percent, and *10 percent level.

4 A Model of Portfolio Rebalancing

Having documented the portfolio rebalancing effects of QE, this section presents a theoretical framework that rationalizes the empirical findings above. The following analysis will outline a model in which a mass of banks with heterogeneous risk preferences intermediates funds between a representative household and a final good producer. A QE shock, in the form of a reduction in the return on safe assets, will motivate a reallocation toward credit supply. As will be discussed, this simple model produces patterns of portfolio rebalancing similar to those observed in the data.

4.1 The Financial Intermediation Sector

In defining the banking system of the economy, I borrow some simplifying assumptions from the theoretical framework in Coimbra and Rey (2024). Despite these similarities, the model will have distinctive features, notably the form of heterogeneity, with relevant implications for analyzing QE interventions.

Intermediaries live for two periods. They collect funds through equity and household deposits, directing them to the productive sector in the form of loans. Due to productivity shocks at the aggregate level, financial institutions earn a stochastic return R^K_{t+1} on lending activities, which will be determined in equilibrium. In addition to the supply of credit, banks' resources can also be allocated to a safe asset, that guarantees a deterministic rate of return R^S. The optimal portfolio allocation between the two assets will be determined by banks' heterogeneous attitudes toward risk, as explained in detail in the next subsection.

Thus, the balance sheet of intermediary i at time t is given by:

Assets	Liabilities
k_{it}	ω_{it}
s_{it}	d_{it}

where k_{it} denotes private-sector loans, s_{it} safe asset holdings, ω_{it} indicates intermediary i's equity endowment, and d_{it} are households' deposits.

By choosing portfolio composition and deposit supply, intermediaries maximize their expected second-period net cash-flow, defined as:

$$\pi_{i,t+1} \equiv R^K_{t+1} k_{it} + R^S s_{it} - R^D_t d_{it}$$

To examine a QE-induced portfolio rebalancing within this framework, the interest rate declines observed in the high-frequency analysis above will be modeled as a reduction in R^S. In other words, the risk-free asset represents U.S. Treasuries and agency MBS, the securities targeted by the Fed. This modeling choice implies that QE operations involve the purchase of safe assets. In reality, central banks may use LSAPs to remove toxic assets from the financial system, as was the case with mortgage-backed securities during the Great

Recession. Nonetheless, since this analysis focuses on the Fed's interventions in 2020, it is reasonable to assume that the targeted securities were considered safer than private-sector loans.

A further consideration is that, as clearly illustrated by intermediary i's balance sheet, the model abstracts from central bank reserves. Although some authors have focused on the accumulation of reserves due to the asset purchases to evaluate the impact of QE on bank credit, this paper investigates different forces. As explained in Section 1, the portfolio rebalancing channel is a second-round mechanism that operates through the market impact of QE - specifically, via reductions in targeted interest rates. Any potential effect on loan creation stemming from the increase in reserve holdings associated with the asset purchases is thus outside the scope of my investigation. It should be noted once again that any mechanism based on the acquisition of additional reserves applies only to the subset of banks that are direct counterparts in the Fed's transactions. In contrast, the portfolio rebalancing effect may influence the entire cross-section of intermediaries.

4.2 The Bank's Portfolio Problem

When forming asset portfolios, banks maximize heterogeneous mean-variance preferences: each intermediary trades off expected returns for portfolio variance, depending on its risk aversion[11]. The time-invariant, intermediary-specific parameters ϕ^i determine the balance in this trade off, and their distribution will characterize the model's equilibrium.

[11]This idea originates from Markowitz (1952). Although there exist several ways to induce a return-risk trade-off in banks' portfolio formation, this modeling approach captures these forces in a direct and simple manner.

Intermediary i solves the problem problem:

$$\begin{aligned}
\max_{w_{it}^K, w_{it}^S} \quad & E_t(R_{i,t+1}^A) - \frac{\phi^i}{2} Var(R_{i,t+1}^A) \\
\text{s.t.} \quad & R_{i,t+1}^A = w_{it}^K R_{t+1}^K + w_{it}^S R^S \\
& w_{it}^K + w_{it}^S = 1
\end{aligned} \tag{2}$$

where w_{it}^K and w_{it}^S are portfolio weights for private-sector loans and the safe asset, respectively. Accordingly, the objective function increases with the mean return on assets $E_t(R_{i,t+1}^A)$ and decreases with its variance $Var(R_{i,t+1}^A)$. These two quantities can be written as:

$$E_t(R_{i,t+1}^A) = w_{it}^K E_t(R_{t+1}^K) + w_{it}^S R^S, \quad Var(R_{i,t+1}^A) = (w_{it}^K)^2 Var(R_{t+1}^K)$$

Using these expressions and the balance sheet constraint $w_{it}^S = 1 - w_{it}^K$ in the objective function, a simple first-order condition defines the optimal portfolio weight for lending activities:

$$w_{it}^K = \frac{E_t(R_{t+1}^K) - R^S}{\phi^i Var(R_{t+1}^K)} \tag{3}$$

As expected, the optimal w_{it}^K increases with the expected return on private-sector loans, declines with its variability, and decreases with the degree of risk aversion.

The numerator defines the risk premium from supplying credit vis-à-vis investing in the safe asset. Banks will optimally allocate a positive share of their portfolios to loans as long as this premium remains strictly positive. To prevent an equilibrium in which no flow of capital for final good production leads to zero output, I will focus on the case where $E_t(R_{t+1}^K) > R^S$. Notably, this relationship is consistent with the application in this paper: before the Fed's QE announcements in March 2020, the average return on commercial and industrial loans was approximately 5%, compared to 2.09% for 20-year U.S. Treasuries and 2.68% for agency MBS.

Introducing this form of heterogeneity within the financial intermediation sector marks a significant departure from the framework by Coimbra and Rey (2024). In their model, banks are subject to a Value-at-Risk constraint, which limits heterogeneously the probability of a negative return on equity. As shown by the authors, this modeling choice divides financial institutions into those participating in the market for the risky asset - their model's counterpart to private-sector loans - and those allocating their entire resources to the safe asset. This equilibrium outcome would not be consistent with the empirical analysis in this paper, where all banks in the sample hold both loans and QE securities. Moving to heterogeneous risk preferences solves the issue: the optimal portfolio weight for lending (3) implies that, under a positive risk premium, all intermediaries invest in both credit supply and the safe asset.

The portfolio problem defines the optimal composition of banks' asset portfolio, but it does not determine the optimal balance sheet size. As will be discussed in detail below, the equilibrium distribution of intermediaries will be divided between those who would find it optimal to raise an infinite amount of deposits, and those who would choose a null deposit supply. This type of divergent behavior, which is common in models with a banking sector[12], is clearly incompatible with market clearing for deposits. To address this problem, I introduce an exogenous limit to deposit creation in the form of a simple debt-to-equity ratio constraint: each intermediary is restricted from collecting deposits exceeding a fraction λ of its equity endowment. This constraint lends itself to a regulatory requirement interpretation, as it indirectly enforces a form of capital adequacy. Although this modeling choice limits the model's ability to describe movements in funding structure and balance sheet size, it still allows to examine changes in the composition of a bank's total assets[13].

[12]This can be seen, for example, in Gertler and Karadi (2011). In their model, the authors address this issue with a moral hazard friction that enables bankers to appropriate a fraction of the funds lent by households.

[13]This is precisely what the portfolio rebalancing effect entails: an adjustment in the holdings of QE securities and private-sector loans as shares of an asset portfolio.

Given this outline, the complete maximization problem for intermediary i, that takes the deposit rate and the distribution of returns on capital lending as given, is given by:

$$\begin{aligned} V_{it} = \max_{k_{it}, s_{it}, d_{it}} \quad & E_t(R^K_{t+1} k_{it} + R^S s_{it} - R^D_t d_{it}) \\ \text{s.t.} \quad & k_{it} + s_{it} = \omega_{it} + d_{it} \\ & w^K_{it} = \frac{E_t(R^K_{t+1}) - R^S}{\phi^i Var(R^K_{t+1})} \\ & d_{it} \leq \lambda \omega_{it} \end{aligned} \tag{4}$$

4.3 Final Good Production

Finally, a representative firm produces the final good, which is set as the numeraire, by combining financial capital K_t and labor L_t. The former is borrowed from the banking system at the rate R^K_t, while the latter input is supplied by households. The final good production technology exhibits constant returns to scale and is given by:

$$Y_t = A_t K^{\alpha}_{t-1} L^{1-\alpha}_t$$

where A_t denotes total factor productivity at time t.

The economy is subject to aggregate uncertainty in the form of TFP shocks. In particular, total factor productivity evolves according to the AR(1) process:

$$A_t = \rho A_{t-1} + \epsilon_t, \quad \epsilon_t \overset{iid}{\sim} N(0, \sigma^2)$$

where ρ represents the persistence of the TFP process, and ϵ_t is a zero-mean i.i.d. normal productivity shock.

Assuming a fixed labor supply, which is normalized to 1 for simplicity (i.e., $L_t = 1$), profit maximization by the representative firm requires that the equilibrium rental rate of capital equals its ex-post marginal product:

$$R_t^K = \alpha A_t K_{t-1}^{\alpha-1}$$

4.4 Equilibrium

Taking as given the law of motion of productivity and the deposit rate, the solution to the intermediaries' maximization problem and the rental rate of capital that emerges from final good production are two key elements for determining the equilibrium of the economy. As a starting point, the following proposition formalizes the earlier discussion on the interaction between a bank's risk aversion and its optimal deposit supply.

At the equilibrium, there exists a threshold ϕ^* that divides the distribution of intermediaries, $g(\phi^i)$, between banks for which the debt-to-equity ratio constraint holds with equality and those that do not raise any deposits. That is, $d_{it}^N = 0$ for $\phi^N \in [\phi^*, \overline{\phi}]$, and $d_{it}^L = \lambda\omega_{it}$ for $\phi^L \in [\underline{\phi}, \phi^*]$.

By continuity of $g(\phi^i)$, the bank characterized by the marginal coefficient ϕ^* - which, from now on, will be referred to as "the marginal intermediary" - must be indifferent between leveraging up to the constraint and not raising deposits at all. Let V^L denote the value of a bank for which the debt-to-equity ratio constraint holds with equality, and V^N denote the value of a non-levered intermediary:

$$V^L = E_t(R_{t+1}^K)k_{it}^L + R^S s_{it}^L - R_t^D d_{it}^L$$

$$V^N = E_t(R_{t+1}^K)k_{it}^N + R^S s_{it}^N = (E_t(R_{t+1}^K) - R^S)k_{it}^N + \omega_{it}$$

where the last equality in the second equation follows from the balance sheet identity, $s_{it}^N = \omega_{it} - k_{it}^N$.

Therefore, for the marginal intermediary ϕ^*,

$$E_t(R_{t+1}^K)k_{it}^L + R^S s_{it}^L - R_t^D d_{it}^L = (E_t(R_{t+1}^K) - R^S)k_{it}^N + \omega_{it}$$

From the portfolio problem, safe asset holdings for levered intermediaries are given by:

$$s_{it}^L = \frac{(\omega_{it} + d_{it}^L)(\phi^L Var(R_{t+1}^K) - E_t(R_{t+1}^K) + R^S)}{\phi^L Var(R_{t+1}^K)}$$

Substituting the expression for s_{it}^L into the previous equation,

$$E_t(R_{t+1}^K)k_{it}^L + \frac{(\omega_{it} + d_{it}^L)(\phi^L Var(R_{t+1}^K) - E_t(R_{t+1}^K) + R^S)}{\phi^L Var(R_{t+1}^K)} - R_t^D d_{it}^L = (E_t(R_{t+1}^K) - R^S)k_{it}^N + \omega_{it} \tag{5}$$

The equilibrium supply of credit by levered and non-levered banks can be determined by combining the bank's portfolio problem with the previous proposition. For $\phi^L \in [\underline{\phi}, \phi^*]$, the asset share allocated to private-sector loans equals:

$$w_{it}^{K,L} = \frac{k_{it}^L}{d_{it}^L + \omega_{it}} = \frac{k_{it}^L}{(1+\lambda)\omega_{it}}$$

where the second equality comes from the binding debt-to-equity ratio constraint, $d_{it}^L = \lambda \omega_{it}$. Accordingly, these intermediaries channel resources toward the final production sector in the amount given by:

$$k_{it}^L = \frac{\omega_{it}(1+\lambda)(\alpha\rho A_t K_t^{\alpha-1} - R^S)}{\phi^L \sigma^2 (\alpha K_t^{\alpha-1})^2} \quad \text{for} \quad \phi^L \in [\underline{\phi}, \phi^*]$$

Similarly, considering non-levered banks, the equilibrium loan portfolio share equals:

$$w_{it}^{K,N} = \frac{k_{it}^L}{\omega_{it}}$$

And, thus,

$$k_{it}^N = \frac{\omega_{it}(\alpha\rho A_t K_t^{\alpha-1} - R^S)}{\phi^N \sigma^2 (\alpha K_t^{\alpha-1})^2} \quad \text{for} \quad \phi^N \in [\phi^*, \overline{\phi}]$$

With the expressions for k_{it}^L and k_{it}^N, equation ((5)) implicitly defines the threshold ϕ^* as a function of the aggregate financial capital stock K_t, the deposit rate R_t^D, and the TFP process $f(A_t)$.

The market clearing condition for private-sector loans completes the characterization of the model in partial equilibrium. The aggregate capital stock must equal the combined supply of funds by levered and non-levered intermediaries:

$$K_t = \int_{\underline{\phi}}^{\overline{\phi}} k_{it}\, dG(\phi^i) = \int_{\underline{\phi}}^{\phi^*} k_{it}^L\, dG(\phi^i) + \int_{\phi^*}^{\overline{\phi}} k_{it}^N\, dG(\phi^i) \tag{6}$$

As equation (6) expresses aggregate capital as a function of the marginal risk aversion ϕ^*, the deposit rate R_t^D, and the law of motion of total factor productivity $f(A_t)$, combining it with (5) allows to fully describe the equilibrium of the economy, when taking the deposit rate and technology as given.

4.5 Quantitative Easing in the Model

To operationalize this framework for studying the portfolio rebalancing effect[14], the model's parameters need to be calibrated. In addition to the objects commonly found in the literature, such as the law of motion for TFP and the capital share of output, calibrating the distribution of the risk aversion coefficients ϕ^i requires particular attention.

This is done by matching pre-pandemic heterogeneity in banks' asset composition. In particular, the expression for the optimal portfolio weight for lending in (3) is inverted and,

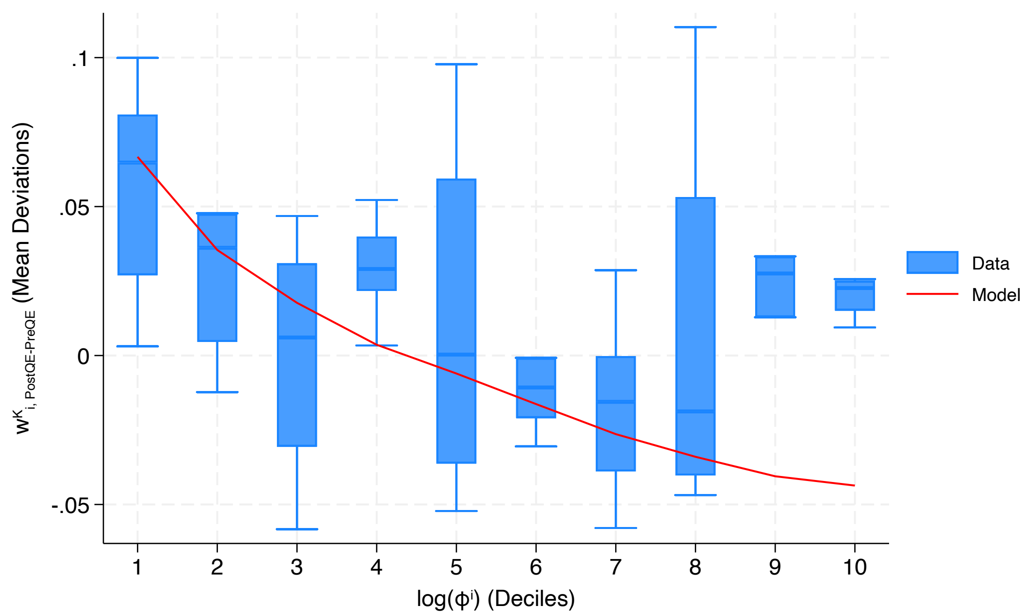
[14]Since the equilibrium in the financial intermediation sector consists of a series of static maximization problems, I will not investigate dynamics, but rather examine the cross-section of banks before and after a QE intervention.

for each intermediary in the sample, ϕ^i is set to be consistent with its average ratio of private-sector loans to total asset in 2019. This procedure involves estimating the expected value and variance of the yield from lending investments. The ex-post return on credit is defined as loan interest receipts over total outstanding loans, taking into account the share of the latter that results in charge-offs. Differently from the setting of the model, this exercise delivers bank-specific expected return and variance of credit supply, allowing for a more precise calibration of $g(\phi^i)$ that controls for differences in loan risk and profitability not captured in the framework. Figure 8 in Appendix A.5 plots the resulting estimated distribution. To verify the success of this calibration, I analyze the relationship between banks' asset shares consisting of private-sector loans and the estimated risk aversion coefficients. Figure 9 presents the results, showing that baseline credit supply relative to total assets decreases with ϕ^i in both simulation and data.

As discussed in Section 4.1, QE policy is described in the model economy as a decrease in the return on the safe asset. Doing so requires considering two alternative calibrations for the risk-free return, $\bar{R}^S$ and $\underline{R}^S$, the first for before and the second for after a QE shock. To investigate the effects of the Fed's LSAPs in 2020, these two parameters are chosen to match the average yield on long-term QE securities in the pre- and post-treatment subsamples. In line with the evidence presented in Table 1, I thus calibrate the two to 1.5% and 1.1%, respectively, mirroring 30-year Treasury yields.

To investigate the resulting portfolio rebalances, I compute, for each intermediary, the change in its portfolio share allocated to private sector loans between the pre- and post-treatment subsamples in the data, and after the safe asset return reduction in the model. However, a direct comparison between the simulated theoretical framework and the observed empirical patterns based on this measure would be misleading. As shown in Figure 3, the Covid-19 pandemic resulted in a contraction in loan creation across the entire cross-section of banks. This phenomenon is attributable to a set of forces - such as reductions in consumers' demand for some sectors due to containment measures, or cuts in firms' investment expenses as a result of the increased uncertainty - not directly linked to the Fed's QE interventions and not contemplated in the model. Following the shift from $\bar{R}^S$ to $\underline{R}^S$, all financial institutions in the modeled economy, irrespective of their attitudes toward risk, will, instead, find it optimal to relocate their portfolio composition towards credit supply. Thus, to account for this discrepancy, the adjustments in asset shares are demeaned in both the theoretical and empirical settings, de facto controlling for the "fixed effects" of the pandemic period. Figure 4 presents the results of this analysis, grouping banks in deciles according to their degree of risk aversion.

Figure 4: Portfolio Rebalancing and Banks' Risk Aversion



Notes: The red line in the figure represents the changes in banks' portfolio share allocated to private-sector loans generated by a QE shock that parallels the difference between the average pre- and post-pandemic yields on long-term U.S. Treasuries. Similarly, the blue boxplots indicate the observed portfolio rebalances following the yield effects of the two QE announcements analyzed in Table 1. In both the model and the data, these portfolio adjustments are related to each intermediary's risk aversion coefficient ϕ^i on a log scale.

A comparison of the continuous red line with the blue box plots shows that the model is fairly effective in matching the observed portfolio rebalances. In both environments, intermediaries at the left-hand side of the spectrum increased loan extension to the private sector, relative to the average change in portfolio shares, and moving up in the risk aversion distribution results in an almost linear reduction in the magnitude of the adjustment.

5 Conclusion

In this paper, I have demonstrated the relevance of the portfolio rebalancing effect in the transmission of Quantitative Easing, with a particular focus on its implementation during the Covid-19 recession. Although several existing papers have documented the effectiveness of LSAPs, the operation of this particular mechanism, in the period under study, has significant implications from multiple angles.

First, most of the knowledge produced by economic research on the functioning of QE is based on evidence from the Great Recession. Undoubtedly, we witnessed an unprecedented deployment of this unconventional monetary policy measure between 2008 and 2009. However, the unique nature of that contractionary period could raise concerns about the external validity of its investigation. As the financial system was at the heart of the Great Recession, and given the interactions between LSAPs and the banking sector, forces intrinsic to the financial crisis likely influenced the transmission channels of QE. For this reason, the Covid-19 recession presents an opportunity to test the mechanisms proposed by the existing literature and validate their implications.

Second, in this context, the portfolio rebalancing effect was likely important for sustaining the flow of credit to small and medium enterprises, which could not directly benefit from the decline in market interest rates generated by QE announcements. Crucially, these businesses were the ones disproportionately affected by the pandemic. As they tend to engage in more labor-intensive activities, which were particularly impacted by the virus and its containment measures, and are unable to rely on large capital reserves, liquidity constraints were severely tightened for these firms.

Finally, from the central bank's perspective, the portfolio rebalancing effect significantly amplifies the credit stimulus generated by a given amount of asset purchases. By operating through the market impact of QE - specifically, via reductions in targeted interest rates - this second-round mechanism can potentially involve all financial institutions holding QE securities. In contrast, any rebalancing stemming from the additional reserves acquired through LSAPs applies only to the subset of banks that are direct counterparts in the central bank's transactions. Given the dramatic expansion of the Fed's balance sheet following interventions during the recent recessions, understanding how to leverage this amplification effect is crucial for the long-term sustainability of Quantitative Easing.

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A Appendix

A.1 Data

In Section 2, I used daily time series of the yield or price of a set of financial assets to document the market effects of QE announcements. In particular, I examined the market yield on U.S. Treasuries at 1-year, 10-year, and 30-year constant maturity, and the Bloomberg U.S. mortgage-backed securities Index for 20-year securities guaranteed by Freddie Mac and Fannie Mae.

A detailed description of the latter variables can be found at https://assets.bbhub.io/professional/sites/27/US-MBS-Index.pdf. The core construction procedure can be summarized as follows: *"The U.S. MBS Index is formed by grouping the universe of individual TBA-deliverable MBS pools into pool cohorts and then applying the index inclusion rules at the cohort level. Each cohort is a representation of its mapped individual pools and contributes their total amount outstanding to the U.S. MBS Index."*

Information at a daily frequency on the yield of U.S. government bonds is publicly available and was retrieved from the FRED website. The agency MBS price indices, on the other hand, were downloaded from FactSet, a proprietary data source.

In Section 3, I used quarterly data on the balance sheet of U.S. financial institutions to provide evidence for the portfolio rebalancing effect. As briefly mentioned in the main text, I leveraged information from the Consolidated Reports of Condition and Income filed at the Federal Financial Institutions Examination Council (FFIEC). A set of mandatory forms are filed by every national bank, state member bank, and insured non-member bank within the last day of each calendar quarter, and the accuracy of the reported information is overseen by the Federal Deposit Insurance Corporation (FDIC). Within the schedules forming the call report, I analyzed forms RC, RC-B, and RC-C to gather data on banks' balance sheets, securities holdings, and lending activities, respectively. The Consolidated

Reports of Condition and Income of all U.S. financial intermediaries are publicly accessible, with available information starting from 2001.

Given the choice of restricting the analysis to financial institutions with some holdings of either U.S. Treasury securities or agency-guaranteed MBS, Table 5 reports sample averages for a set of balance sheet variables recorded in the call reports of the first quarter of 2020.

Table 5: Banks' Descriptive Statistics

	Statistics at Baseline (2020q1)			
	Mean	Std. Deviation	Median	Observations
Total Assets (mln dollars)	209770	475462	48562	71
Private Sector Loans/Assets	0.406	0.262	0.445	71
U.S. Treasuries/Assets	0.025	0.042	0.005	71
Agency MBS/Assets	0.119	0.115	0.119	71
QE Securities/Assets	0.144	0.120	0.131	71
Long-Term QE Securities/Assets	0.054	0.062	0.033	69
Real Estate Loans Share	0.352	0.286	0.380	67
Commercial Loans Share	0.448	0.310	0.348	67
Consumer Loans Share	0.198	0.253	0.126	67
Equity/Assets	0.129	0.124	0.106	71
Return on Assets	0.002	0.006	0.001	71
Reserves/Assets	0.081	0.070	0.062	71
Interbank Borrowing/Assets	0.006	0.021	0.000	71
Net Interest Margin	0.008	0.008	0.007	71

A.2 Event Time Window for High-Frequency Analysis

Table 6 presents the yield and price changes for the securities of interest over two and three trading days around the two QE announcements of March 2020. In particular, following the analysis in the main text, I compute the effects on the yield of 1-year, 10-year, and 30-year U.S. Treasuries, and the price impact for the 20-year Freddie Mac and Fannie Mae MBS.

Table 6: Multi-day Windows Around QE Announcements

(a) 2-Day Changes

Announcement Date	2-Day Change				
	Treasury Yield			MBS Price Index	
	1-year	10-year	30-year	20-year Freddie Mac	20-year Fannie Mae
15th March 2020	-0.08	0.08	0.07	0.96	0.84
23rd March 2020	0.10	-0.08	-0.16	2.32	2.33
Total	0.02 (0.783)	0.00 (0.993)	-0.09 (0.586)	3.28*** (0.000)	3.17*** (0.000)

(b) 3-Day Changes

Announcement Date	3-Day Change				
	Treasury Yield			MBS Price Index	
	1-year	10-year	30-year	20-year Freddie Mac	20-year Fannie Mae
15th March 2020	-0.17	0.24	0.21	-0.21	-0.25
23rd March 2020	0.04	-0.04	-0.10	2.35	2.36
Total	-0.13 (0.196)	0.20 (0.246)	0.11 (0.514)	2.14* (0.055)	2.11* (0.059)

As discussed above, the extension of the time window results in more unstable estimates for all the securities considered, except for possibly the price movement for agency MBS when using 2-day changes. When examining 2-day changes (respectively, 3-day changes), to quantify the relevance of the fluctuations induced by the QE shocks, 1-day changes in the yield/price of each financial asset are regressed on the QE announcement dummy and its first (respectively, first two) lags. I then assess significance through an F-test evaluating whether the sum of the estimated coefficients for the QE dummies is statistically different from zero. Differently from what documented for the specification using 1-day movements, apart from the case previously analyzed, the resulting effects of the two QE shocks are now statistically insignificant for all the variables in the table.

A.3 Loan Creation Trends by Asset Exposure

Figures 5 and 6 describe the evolution of the average share of private-sector loans with respect to total assets for subsamples defined over banks' exposure to U.S. Treasuries and agency MBS, respectively. In particular, in each of the two exhibits, I compare the two halves of the exposure distribution in the top panel, and the top 25% to the bottom 25% in the lower panel.

Figure 5: Loan Creation by U.S. Treasuries Exposure

(a) Top 50% vs Bottom 50%

(b) Top 25% vs Bottom 25%

Figure 6: Loan Creation by Agency MBS Exposure

(a) Top 50% vs Bottom 50%

(b) Top 25% vs Bottom 25%

The divergence in lending trends between the exposure groups is again in clear correspondence with the QE intervention, and it appears more pronounced when considering agency-sponsored MBS holdings. In any case, the plots fully confirm the analysis extensively discussed in the main text, also when dividing banks separately according to the two asset categories.

A.4 Homogeneous Treatment Effects

Figure 7: QE Exposure and Loan Creation Trends

A.5 Calibration

Figure 8: Pre-Pandemic Calibration of ϕ^i

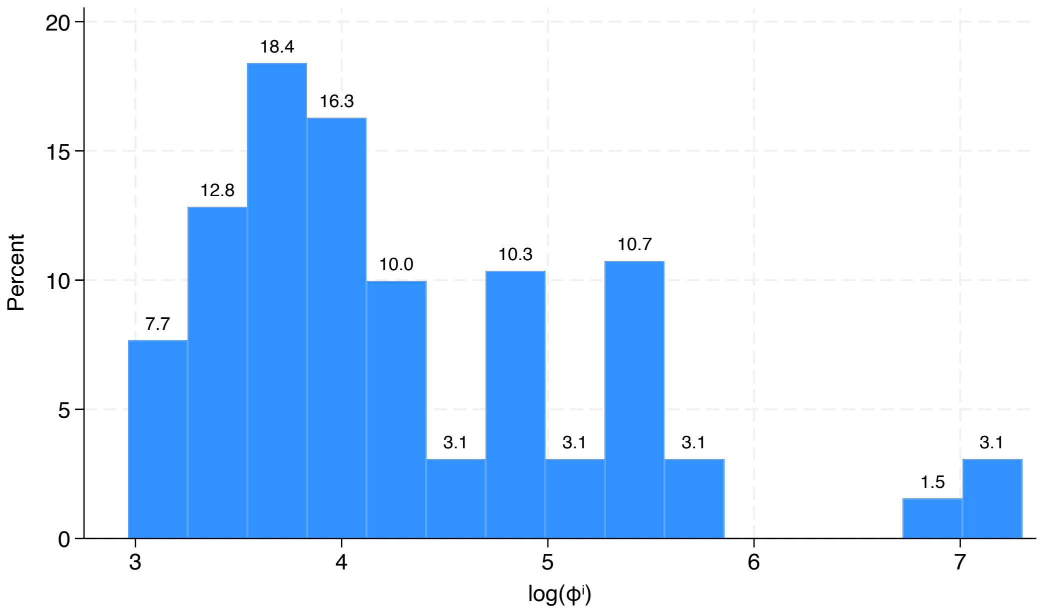
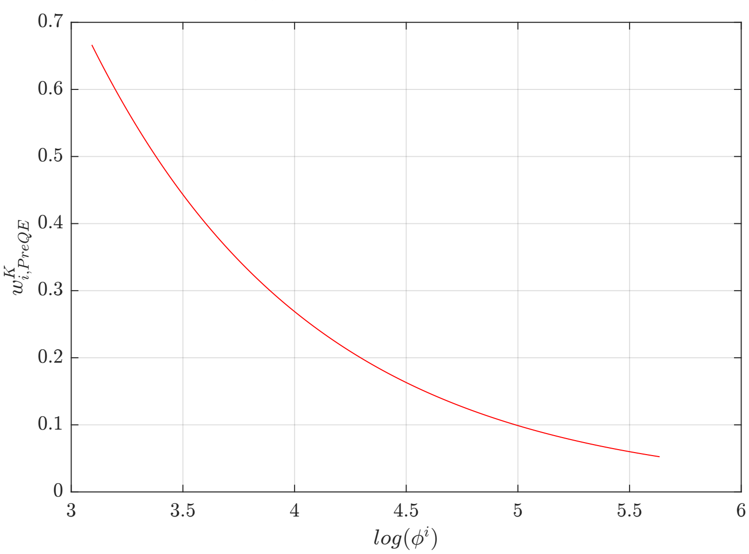


Figure 9: Loan Asset Share Distribution at Baseline

(a) Calibrated Model



(b) Data