Borrow Long, Dump Short: How Firms Game Negative Interest Rates?

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Abstract

We study the impact of negative interest rate policy (NIRP) on corporate capital structure using a Difference-in-Differences design on a panel of over 58,000 firms across 127 countries. NIRP leads to a pronounced reallocation from short- to long-term debt — consistent with locking in unusually low long-term rates — particularly among smaller, older, highly levered, and less liquid firms. Aggregate leverage remains stable initially but rises when NIRP persists beyond five years. A stylised refinancing-cost model shows that frequent rollover costs on short-term debt incentivise longer maturities under low-rate regimes. A calibrated DSGE model for the Euro Area replicates the maturity shift via a term-structure channel (long-rate compression) and a liquidity channel (reserve-carry taxes dampening leverage). Together, these frameworks rationalise the empirical results and reveal that NIRP's effect on leverage depends on refinancing frictions, balance-sheet constraints, and policy duration. Our results highlight that while NIRP can reshape debt maturity composition rapidly, its effect on corporate leverage is contingent on the temporal design of the policy.

JEL classification: E52; E58; G32; E44

Keywords: monetary policy; negative interest rate policy (NIRP); corporate financing; capital structure

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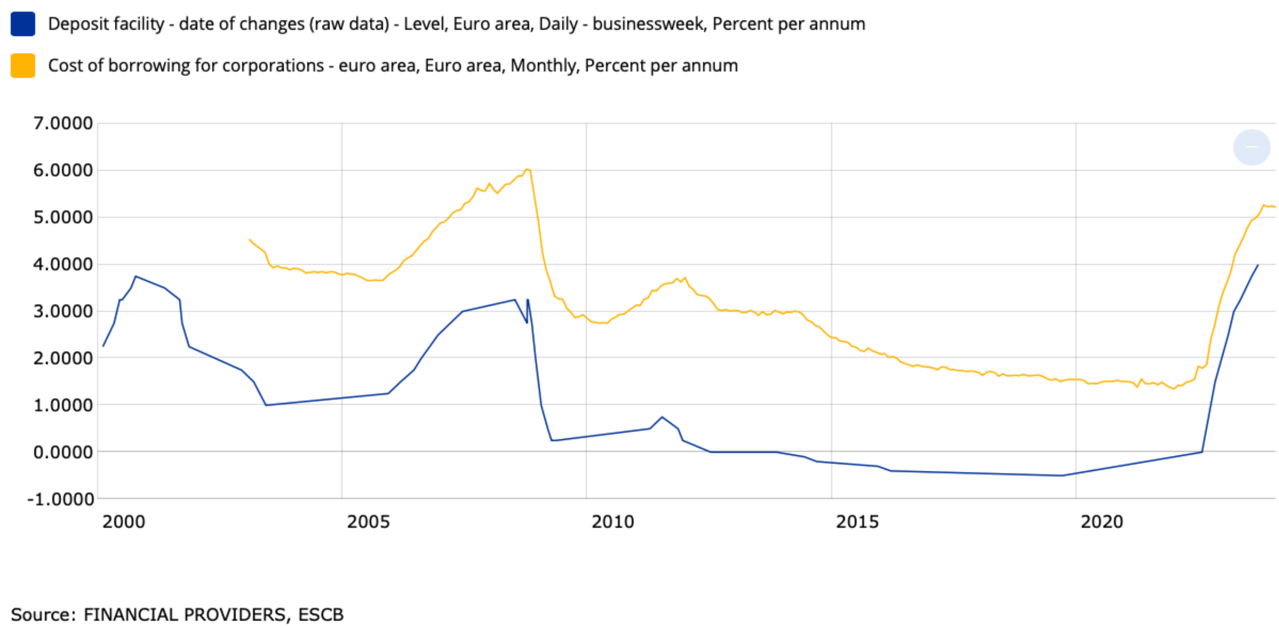
1 Introduction

Studies on corporate capital structure or financing decisions, *i.e.*, choosing between debt, equity or some hybrid form of securities, are not alien to the economics and finance literature, as the subject area dates back to the seminal work of Modigliani and Miller (1958). Surprisingly, specific studies on how changes in monetary policy stance affect corporate financing decisions are sparse. The importance of monetary policy in driving aggregate demand, especially in recessions, cannot be overemphasised. Interest rates tend to be lower in recessions and higher during expansions, reflecting the interrelationship between monetary policy stance and business cycles (Gertler and Gilchrist, 1994). Conventionally, in periods of recessions, one of the key transmission channels that central banks explore is the bank lending channel — where reductions in the policy rate tend to be reflected in lower bank rates — to spur aggregate demand through higher loan supply (Mishkin, 2016); although there is debate on the effectiveness of this conventional monetary policy tool on the supply of loans (Dwumfour et al., 2022; Fungáčová et al., 2014; Mishra and Montiel, 2013; Altunbaş et al., 2002; Kishan and Opiela, 2000). Though closely related, our study does not seek to add to this debate. Our focus is to add to the literature on the effectiveness of monetary policy from the demand side, *i.e.*, from the firms that demand the loans, which is the balance sheet channel (Bernanke and Gertler, 1995). However, in this paper, we focus on an unconventional monetary policy tool: negative interest rate policy (NIRP). This is important given that the adoption of this policy tool is relatively new and empirical studies on the implications of this policy remain scant (Bottero et al., 2022).

The last decade has witnessed several central banks in advanced countries, notably the European Central Bank (ECB), adopting unconventional monetary policy tools due to prolonged low economic activity in the Euro area. The ECB reduced its official policy rate (*i.e.*, deposit facility rate, DFR), to zero from 2012 through 2013 (see Figure 1). However, conventional monetary policy becomes ineffective when interest rates tend towards the zero-lower-bound (ZLB). Traditionally, central banks pay interest on deposits or reserves they hold for commercial banks. Nevertheless, when rates reached the ZLB, the ECB instead started to charge interest on these deposits as a measure to encourage commercial banks to increase credit supply as well as influence the interest rates in the country, which is the concept of negative interest rate policy.

The ECB added NIRP to the basket of its unconventional monetary policy tools with the core aim of achieving policy easing — *i.e.*, to stimulate economic activities in the Euro area following sustained periods of low aggregate demand and undesirable low inflation. This policy was implemented in 2014 when the ECB reduced the deposit facility rate below 0% to -0.1% (Figure 1). From Figure 1, we can see that prior to 2014, the deposit facility rate stayed at the ZLB until 2014, when the NIRP was implemented, then the rates fell below zero and remained so till 2022. During this period, the corporate loan rate followed a very similar pattern. This has direct cost implications for banks, especially those that hold excess reserves with their national central banks (NCBS).[1] Indeed, Claeys (2021) observes that these costs have been increasing, especially after the introduction of the pandemic emergency purchase program (PEPP) in 2020.

Figure 1: ECB deposit facility rate (%): level and cost of borrowing (%) for corporations



The implication and effectiveness of this policy are still unclear and at an infant stage of empirical enquiry (Bottero et al., 2022; Eggertsson et al., 2019). We identify two key scenarios on how the transmission of this new monetary policy tool can be effective. The first scenario is whether banks will pass on this policy through their lending or deposit rates (Brunnermeier and Koby, 2018). A pass-through to deposit rates would mean banks would have to charge negative interest rates on the retail deposits. This is more rigid, and banks are reluctant to use this channel (Heider et al., 2019) because of competition, and that depositors would prefer to hold cash, or for the fact that there may be some legal limitations for this action (Demiralp et al., 2021; Scheiber et al., 2016). Albertazzi et al. (2020) show that a few banks in some Euro area countries did actually implement negative interest rates on retail deposits, even though the majority of non-financial corporate retail deposits (about two-thirds) are still stuck at the ZLB, while negative rates on household deposits remained negligible. Indeed, some studies have found that the retail deposit channel could have a contractionary effect on loan supply (Eggertsson et al., 2019; Heider et al., 2019).

[1]Excess reserves are those funds above the minimum required reserves (MRR) held at the NCBs set by the ECB.

An alternative channel is through bank lending, with the hope that banks benefit from higher volumes of loans. This means that banks in the Euro area are likely to lend more at lower interest rates. As we observe clearly from Figure 1, the period of the 0% deposit facility rate saw corporate rates staying around 3% until it started on a downward trajectory when the negative interest rate was implemented. Bottero et al. (2022) and Demiralp et al. (2021) show that NIRP is expansionary in that, comparatively, banks in the Euro area give out more loans in periods of NIRP. As mentioned earlier, instead of focusing on the policy's effectiveness from the supply side — a perspective that has received some, albeit limited, attention in the literature — we aim to understand its impact from the demand side, which has been notably under-explored. Hence, this investigation addresses a pivotal policy question: What is the impact of negative interest rate policy on corporate financing decisions? This question underpins the motivation of our study, guiding us to adopt a second scenario focused on comprehending the effectiveness of NIRP through the lens of corporate demand for credit. Accordingly, we explore critical inquiries such as whether firms increase their leverage in a negative interest rate environment and, if so, the magnitude of this increase, alongside the nature of the debt (long-term *versus* short-term) that firms are inclined to augment.

While studies such as those by Bottero et al. (2022) and Demiralp et al. (2021) show the expansionary nature of NIRP from the supply side, specifically in terms of bank credit growth — the credit/bank lending channel — our analysis shifts the perspective to the balance sheet channel, which we see as more plausible. As indicated by Bernanke and Gertler (1995), the balance sheet channel relates to the impact of monetary policy on firms' balance sheets and income statements. The authors suggest that this channel is more plausible for monetary policy transmission, even though the bank lending channel has its own merits. By taking this approach, we are able to extract nuanced insights into the determinants of corporate capital structure decisions in the context of the NIRP. It is likely that there will be significant firm-specific heterogeneity in these decisions: for instance, it raises questions about whether, in negative interest rate environments, larger firms are more predisposed to increase their debt levels compared to smaller firms; whether more profitable firms are more inclined to leverage additional debt than their less profitable counterparts; and whether firms with substantial ex-ante liquid assets are more likely to take on further debt. These questions are of paramount importance, considering the nascent understanding of the NIRP's implications on corporate financing decisions, an area that remains relatively unexplored (Bottero et al., 2022).

Therefore, in summary, this paper makes three key contributions to the literature on unconventional monetary policy and corporate capital structure. First, we provide new empirical evidence on the causal effects of negative interest rate policy (NIRP) on corporate financing decisions, using a rich panel dataset of approximately 54,000 firms across 127 countries and over 400,000 firm-year observations within a Difference-in-Differences (DiD) framework. Despite nearly a decade since the ECB's adoption of NIRP, the firm-level implications of such policies remain underexplored. Our findings document a systematic reallocation from short-term to long-term debt among firms in NIRP jurisdictions, while overall leverage remains relatively stable in the short term. These results contribute to the broader literature on the effectiveness of monetary policy and advance the empirical understanding of capital structure dynamics under extreme policy regimes.

Second, we provide new theoretical insights by introducing a stylised model that explicitly characterises firm maturity choice under NIRP. In this framework, firms face heterogeneous refinancing costs associated with short- versus long-term debt, and the model demonstrates that lower rates combined with higher refinancing frequencies render short-term borrowing relatively more costly. This provides a micro-founded explanation for the observed maturity shifts and challenges the irrelevance of debt maturity mix postulated by the Modigliani-Miller theorem (Modigliani and Miller, 1958). Our empirical estimations also generate predictions about heterogeneity in firm responses, which we validate through sub-sample analysis across firm size, age, liquidity, and leverage.

Third, we complement our empirical and conceptual analyses with a calibrated dynamic stochastic general equilibrium (DSGE) model tailored to Euro area dynamics. The DSGE framework embeds liquidity shocks and policy rate dynamics and allows us to assess the general equilibrium impact of NIRP versus conventional monetary easing. We show that NIRP generates a sharper compression of real long-term yields, strengthening the incentive for firms to shift toward long-term debt. Moreover, the model captures the conditions under which overall leverage increases, particularly when the NIRP regime is persistent or gradual, consistent with the reserve-carry tax and capital gains effects.

Together, these contributions provide a comprehensive understanding of how NIRP transmits to firm balance sheets. By integrating rigorous empirical analysis with novel theoretical and structural modelling, we offer a unified framework that links micro-level firm behaviour to macro-financial conditions. These insights are critical for informing both monetary policy design and financial stability assessments in an era of prolonged low or negative interest rates.

2 Review of Related Literature

Our inquiry is motivated by three foundational theories in the capital structure literature. Dating back to 1958, *trade-off theory*, as posited by Modigliani and Miller (1958) and later refined by Modigliani and Miller (1963), suggests that firms are incentivised to increase debt to capitalise on the tax shield provided by interest deductions, while also mitigating free cash flow issues (Fama and French, 2002). Miller (1977) argues that the detriments of bankruptcy and agency costs, which could potentially negate this tax advantage, are, in fact, minimal. On the contrary, Myers (2001) underscores that firms, in identifying their optimal capital structure, strive for a balance between exploiting tax benefits and averting financial distress. Empirical support for firms augmenting their leverage is provided by Leland (1994), suggesting that more profitable entities are predisposed to higher debt levels. Hence, within our framework, we can test this theory to determine whether more profitable firms are likely to increase their leverage in a negative interest rate environment.

Subsequently, the *pecking order theory* (POT) (Myers and Majluf 1984; Myers 1984; Titman and Wessels 1988) delineates a financing hierarchy where firms prioritise internal funding over external debt and equity due to the higher costs associated with raising new securities. This theory implies that firms' capital structure choices are dictated not by a trade-off of debt's costs and benefits but by available net cash flows (Fama and French, 2002), leading to a predisposition for more profitable firms to eschew additional debt in favour of internal funds. Moreover, larger firms, having greater access to external funding, are posited to exhibit a higher propensity for debt uptake compared to smaller counterparts. We provide sub-sample analyses of the relationship between NIRP and capital structure based on the size of the firms.

The concept of *market-timing*[2] has also garnered renewed interest, particularly in the context of how firms adjust their capital structure in response to market conditions (Baker and Wurgler, 2002; Frank and Goyal, 2009). This includes *debt market-timing*, where firms are theorised to increase leverage during periods of low interest rates and *vice versa* (Graham and Harvey, 2001; Korajczyk and Levy, 2003; Bolton et al., 2013; Karpavičius and Yu, 2017). The advent of NIRPS presents an unprecedented context for evaluating these dynamics. We make preliminary hypotheses to suggest that there is a propensity for firms to increase leverage during negative interest rate periods, predicated on prolonged NIRP expectations in the Euro area as noted by Claeys (2021). This is in line with the view of Frank and Goyal (2009), who indicate that firms are likely to raise more debt if the market is unusually favourable, even if they have no need for the funds.

Literature exploring the interplay between interest rates, business cycles, and capital structure has bifurcated into two primary streams. One perspective considers capital structure's cyclical sensitivity, with some studies indicating pro-cyclical leverage adjustments (Gertler and Gilchrist, 1993; Baker and Wurgler, 2002; Frank and Goyal, 2004), while others suggest a counter-cyclical pattern (Korajczyk and Levy, 2003; Halling et al., 2016). For instance, Jermann and Quadrini (2006) show that the financial structure of firms tends to be volatile in response to business

[2]See, Taggart (1977),Marsh (1979) Marsh (1982) and Myers (1984) for initial discussions and introduction to market-timing theory.

cycles. Here, firms, especially those that have high debt exposure, tend to restructure their financial exposure during or after recessions. Specifically, firms reduce their capital structure in periods of recession and increase it during expansions. This is in line with earlier findings by Gertler and Gilchrist (1993), who show that firms, especially large firms, increase their debt following recessions while small firms do not change their capital structure. More recently, Gan et al. (2021) show that in favourable macroeconomic conditions, firms adjust their capital structure faster than when in poor macroeconomic conditions.

On the other hand, Halling et al. (2016) examined the relationship between firms' capital structure and the business cycle and found that, in contrast to literature, firms change their capital structure in a counter-cyclical manner: that is, firms have higher leverage during recessions than expansions. This seems to be inconsistent with the *trade-off* theory, which would suggest that in expansions when there is an expectation for low bankruptcy cost, higher taxable income to provide a shield and more free cash flow (Korajczyk and Levy, 2003), firms would increase their debt. The counter-cyclical nature of capital structure is also confirmed by Korajczyk and Levy (2003), but was mostly found for firms that are financially unconstrained, while constrained firms follow a pro-cyclical leverage. This means that firms that are not financially constrained tend to time their leverage issue to coincide with periods of good macroeconomic conditions, while constrained firms do not. The authors define financially constrained firms as those firms that do not have enough cash to take advantage of any investment opportunity or are constrained by extreme agency problems when they choose to go to the financial markets. However, they show that some firm-specific variables tend to predict the target leverage of firms consistent with some aspects of *trade-off* and *pecking order* theories. Specifically, their results show that higher operating income has a negative relationship with target leverage consistent with the *pecking order* theory.

The other perspective in the literature is where the relationship between interest rate or cost of debt and firms' capital structure is tested. Barry et al. (2008) using debt issued by U.S. corporations, examined how historical interest rates play a role in the relationship between current interest rates and corporate debt. They found that firms issue more debt when current interest rates are relatively lower than historical interest rates. However, in a later study, Karpavičius and Yu (2017) also tested whether U.S. industrial firms alter their capital structure decisions based on borrowing cost. The authors found that firms do not typically adjust their capital structure based on interest rates except in periods of expected recessions. They attribute this weak relationship to the high leverage adjustment costs.

This dichotomy in examining firms' capital structure decisions based on the interest rate or macroeconomic conditions highlights the complexity of financial decision-making in varying macroeconomic climates, underscored by the *trade-off*, *pecking order* and *debt market-timing* theories' predictions regarding firm behaviour under different conditions. For instance, concerning leverage financing and macroeconomic conditions, there is no consensus in the literature on the measure of a "good" or "bad" market condition. Frank and Goyal (2009), for example, use expected inflation and the term spread as proxies for debt market conditions and growth in profit after tax and GDP growth as "macroeconomic conditions". Korajczyk and Levy (2003) conversely use the growth rate of aggregate profits of non-financial firms, the two-year market return of stock traded on NYSE, AMEX, & NASDAQ, and the rate of the three-month commercial paper over the three-month Treasury bill, to capture macroeconomic conditions. Graham et al. (2015) studied the long history of capital structure of U.S. corporations and indicated four key macroeconomic themes that influence firms' capital structure. These are the changes in tax policy, uncertainty in the economic environment, development of the financial sector, managerial incentives and government borrowing. The authors found government debt to be a major determinant of firms' capital structure among other macroeconomic variables like inflation, GDP growth, and corporate bond yield spread.

These different macroeconomic measures and perspectives may not necessarily capture the monetary policy stance of central banks. Our study differs from the previous literature in that, by examining the effect of NIRP on capital structure, we are essentially able to capture the macroeconomic environment as well as interest rates. While we have some understanding of the relationship between conventional interest rate adjustments and capital structure, the specific impact of NIRP remains less understood, particularly in the context of potential operational differences from traditional rate cuts (Demiralp et al., 2021). This study endeavours to bridge this gap by employing a comprehensive cross-country dataset to elucidate the ramifications of NIRP on firms' capital structuring decisions, thereby contributing a novel perspective to the extant discourse on monetary policy's influence on corporate finance.

3 A Simple Stylised Model

3.1 Set up

We develop a simple, stylised model that explains firms' choice of debt composition in a negative interest rate environment. Our model explains that the choice of debt maturity is influenced by the frequency and refinancing cost. Hence, firms would choose long-term debt over short-term debt due to the high refinancing cost associated with short-term debt. We consider a firm that borrows two types of debt: short-term debt L_s and long-term debt L_ℓ. The total debt is given by:

$$D = L_s + L_\ell. \tag{1}$$

We express the short- and long-term debt as a ratio of total debt:

$$l_s = \frac{L_s}{D}, \quad l_\ell = \frac{L_\ell}{D} = 1 - l_s.$$

The interest rates on these two types of debt are defined as

$$r_s = r + \phi_s(-r), \quad r_\ell = r + \phi_l(-r), \tag{2}$$

where r is the central bank policy rate (with $r < 0$ in a negative interest rate environment), and $\phi_s(-r)$ and $\phi_l(-r)$ are risk premia of short - and long-term debt respectively that may depend on the magnitude of $-r$, where $\phi_l(-r) > \phi_s(-r)$.

Short-term debt is associated with higher refinancing or rollover risk (Friewald et al., 2022). When seeking to refinance, firms may face dramatically higher borrowing costs (Froot et al., 1993) or be forced into distressed asset sales (Brunnermeier and Yogo, 2009). As indicated by He and Xiong (2012), while ordinarily, debt with shorter debt maturity would lead to lower risk compared to longer-term debt, the intensity of rollover risk is higher for short-term debt.

To capture the refinancing or liquidity risks associated with both short-term and long-term debt, we assume that there is a quadratic[3] refinancing or debt adjustment distress cost for short- and long-term debt, respectively:

i) *Adjustment cost for short-term debt:*

$$\frac{1}{2}\, f_s\, \alpha(-r)\, L_s^2,$$

ii) *Adjustment cost for long-term debt:*

$$\frac{1}{2}\, f_\ell\, \beta(-r)\, L_\ell^2,$$

where $\alpha(-r) > 0$ and $\beta(-r) > 0$ are adjustment cost parameters for short- and long-term debt, respectively. These are increasing functions of $-r$ (i.e., the cost rises as the negative rate becomes deeper). Also f_s and f_ℓ are frequency factors (with $f_s > f_\ell$). Due to tax advantages, debt financing provides a tax shield; with a tax rate τ, the effective interest expense is multiplied by $(1 - \tau)$.

$$\tilde{C}(l_s) = (1-\tau)\Big[r_s\, l_s + r_\ell\,(1-l_s)\Big] + \frac{1}{2}\, f_s\, \alpha(-r)\, l_s^2 + \frac{1}{2}\, f_\ell\, \beta(-r)\,(1-l_s)^2. \tag{3}$$

[3]The quadratic cost function has been used in literature. see Görtz et al. (2023); Luo et al. (2023); Bolton et al. (2013).

A representative firm chooses l_s (and hence $l_\ell = 1 - l_s$) to minimize $\tilde{C}(l_s)$. We differentiate $\tilde{C}(l_s)$ with respect to l_s.

$$\frac{d\tilde{C}}{dl_s} = (1-\tau)\Big[r_s - r_\ell\Big] + f_s\,\alpha(-r)\,l_s - f_\ell\,\beta(-r)\,(1-l_s) = 0. \tag{4}$$

Given that $\phi_l(-r) > \phi_s(-r)$, the premium on long-term debt is traditionally higher than short-term debt, we have:[4]

$$r_s - r_\ell = \phi_s(-r) - \phi_l(-r) = -\big[\phi_l(-r) - \phi_s(-r)\big].$$

Therefore, Equation (4) becomes:

$$(1-\tau)\big[\phi_s(-r) - \phi_l(-r)\big] + f_s\,\alpha(-r)\,l_s - f_\ell\,\beta(-r)(1-l_s) = 0. \tag{5}$$

Rearrange the terms:

$$\Big[f_s\,\alpha(-r) + f_\ell\,\beta(-r)\Big]l_s = f_\ell\,\beta(-r) + (1-\tau)\big[\phi_l(-r) - \phi_s(-r)\big]. \tag{6}$$

Therefore, the optimal short-term debt share is:

$$l_s^* = \frac{f_\ell\,\beta(-r) + (1-\tau)\big[\phi_l(-r) - \phi_s(-r)\big]}{f_s\,\alpha(-r) + f_\ell\,\beta(-r)}. \tag{7}$$

The optimal long-term debt share is:

$$l_\ell^* = 1 - l_s^*. \tag{8}$$

3.2 Comparative statics

In our model, both short-term and long-term debt incur adjustment costs. However, because the frequency factor f_s for short-term debt is higher than f_ℓ for long-term debt, the effective (cumulative) cost of adjusting short-term debt is higher. In particular, Step 1: As the policy rate r becomes more negative (i.e., as $-r$ increases), both $\alpha(-r)$ and $\beta(-r)$ increase. Step 2: Due to the higher frequency f_s, the term $f_s\,\alpha(-r)$ in the denominator increases more sharply than $f_\ell\,\beta(-r)$. Step 3: Consequently, l_s^* declines (i.e. the firm reduces its short-term debt share), and $l_\ell^* = 1 - l_s^*$ increases.

Therefore, our model predicts that in a NIRP environment, the cumulative adjustment cost of short-term debt, amplified by its high adjustment frequency, may exceed that of long-term

[4] Recalling that $r_s = r + \phi_s(-r)$ and $r_\ell = r + \phi_l(-r)$.

debt. This drives firms to substitute short-term debt for long-term debt, even if long-term debt carries a higher per-adjustment cost. This result supports our hypothesis that firms shift their capital structure toward longer-term debt as refinancing risk intensifies in a negative interest rate environment.

4 Data

Following previous studies (Bekaert et al., 2013), we obtain data for close to 80,000 firms from the Bureau Van Dijk (BVD) OSIRIS database from the year 2001 to 2021. OSIRIS provides a comprehensive database covering most of the publicly listed and major non-listed companies, covering over 127 countries (Dai, 2012). This helps the study to provide a broader perspective of capital structure decisions of firms across the world. As indicated by Dai (2012), a major advantage of using OSIRIS is that it covers both developed and developing countries, including a large number of small firms. As we posit earlier, firms, particularly larger firms, that have access to the equity market would have a broader choice of capital structure than their counterparts. Hence, we are able to delineate the differences in the capital structure decisions of listed and unlisted firms as well as between small and large firms, among other firm-specific heterogeneity that may influence their capital structure decisions.

Initial data pre-processing involved, following the usual convention (for example, Adelino et al. 2023), excluding all financial firms (firms with two-digit Standard Industry Classification [SIC] codes from 60 to 69), utility firms (with primary SIC code 49) and public administration firms (90 and 99) and firms with no classification. Financial, utility, and public administration firms are usually regulated, and hence, their leverage choices ought to be quite different from other industrial firms. For this reason, and following the literature, we also remove these firms from our data. We omit firm-years with a negative book value of equity or missing data for any of our measures of capital structure. Again, following Husted et al. (2020) and Adelino et al. (2023), in order to minimise the potential impact of outliers, the data are winsorised at the 1^{st} and 99^{th} percentiles. We are left with around 58,000 firms across 127 countries after the data-cleaning process. We proceed to discuss the data used in the study.

Following previous literature (Husted et al. 2020), we choose three types of capital structure/leverage measurements using book value, namely, total debt ratio (TDR), which is the ratio of total debt to total assets, long-term debt ratio (LDR) which is the ratio of interest-bearing long-term debt to total assets and short-term debt ratio (SDR) which is the ratio of short-term debt to total assets. The use of these different measures allows us to capture the influence of NIRP on the debt maturity structure of firms.

We also employ various firm-specific variables following the literature. Firstly, asset structure

(AS) of firms — firms that have more tangible assets have higher liquidation value; hence, these firms are able to borrow against these assets — use the assets as collateral — at lower interest rates (Harris and Raviv, 1990; Titman and Wessels, 1988). Therefore, firms with higher collateralizable assets are more likely to take on more debt. Furthermore, firms with higher tangible assets are more likely to have stable returns and hence could take on more debts (Daskalakis et al., 2017). On the other hand, agency costs associated with the scrutiny of highly levered firms may encourage firms with less collateralisable assets to take on more debt. This is supported by earlier studies like that of Grossman and Hart (1982), who suggest that because of the increased probability of bankruptcy, managers are less likely to consume excessive perquisites because bondholders or lenders will closely monitor the activities of the firm (agency considerations). Due to this, firms with less collateralised assets would want managers to be closely monitored and hence will take on more debt for this scrutiny. On the other hand, given the assumption that debt maturity will be matched with asset life (Hall et al., 2004), firms with higher tangible assets would generally choose long-term debt at the expense of short-term debt, hence leading to a positive impact of asset structure on long-term debt but a negative impact on short-term debt. Hence, the literature on asset structure and firms' capital structure remains mixed. Asset structure is measured as the ratio of fixed assets to total assets.

Secondly, profitability (PROFIT) of firms — profitable firms can tap into their retained earning to finance their activities and hence are less likely to depend on debt, supporting the POT (Wu et al., 2022). Meanwhile, based on the TOT, more profitable firms can have a greater capacity to borrow and hence would take on more debt (Fan et al., 2012; Fama and French, 2002). Profitability is measured as the ratio of earnings before interest and tax to total assets.

Thirdly, we include a measure of firm size (SIZE) — compared to smaller firms, larger firms are more likely to have stable earnings and can take on more debt ratios (Titman and Wessels, 1988). Besides, smaller firms usually have less capacity to fully meet the credit requirements — particularly in relation to information asymmetry — of banks or finance companies; hence, they are less likely to have more debt ratios (Castanias, 1983). Firm size is measured as the natural logarithm of total assets.

Fourthly, firm liquidity (LIQ) — the ability of firms to meet short-term obligations, likely reduces the need for debt, especially short-term debt, as firms with ample cash can cover immediate needs without borrowing short-term debt, supporting the POT(De Jong et al., 2008). On the other hand, the TOT suggests that because bankruptcy costs are mostly associated with less liquid firms, these firms face more obstacles in obtaining debt compared with more liquid firms (Degryse et al., 2012); hence, liquidity may have a positive impact on the debt. Firm liquidity is measured as the ratio of cash to total assets.

Finally, firm age (AGE) — firms are generally assumed as a going concern. Hence, firms that have been in the market for long are likely to have built some reputation in the market over the years (Diamond, 1989). Therefore, compared to younger firms, older firms are likely to have higher debt ratios given that they are more likely to have access to debt at a potentially cheaper rate (Abor and Biekpe, 2009; Petersen and Rajan, 1994). Firm age is measured as the number of years since the firm was incorporated.

Independent variables: macroeconomic variables We also control for macroeconomic variables that are identified in literature to affect firm capital structure. Firstly, Gross Domestic Product (GDP) growth — we use GDP growth as a measure of aggregate demand in the economy. Higher growth would suggest higher demand for goods and services; hence, firms are more likely to increase their revenue and profits, leading to more retained earnings and, therefore, having less need for debt. On the other hand, the higher demand for goods and services could lead to the need for firms to take on more debt in order to expand to meet the growing demand. These views are supported by studies such as Frank and Goyal (2009).

Secondly, inflation (INF) — when firms expect inflation to increase, they are likely to increase their debt, given that debt will be relatively cheaper to pay when inflation goes up (Frank and Goyal, 2009). Following Graham et al. (2015), we use the percentage change in the consumer price index as a measure of expected inflation.

4.1 Descriptive statistics

Table 1 presents summary statistics for the key variables in the sample, covering 472,778 firm-year observations. On average, firms exhibit a total debt ratio (TDR) of 0.48, indicating that debt finances nearly half of their capital structure. Interestingly, the average short-term debt ratio (SDR) is considerably higher (0.30) than the long-term debt ratio (LDR) at 0.13, suggesting a general reliance on short-maturity debt instruments. The distribution of firm size (proxied by the natural logarithm of total assets) spans a wide range, with a median of 18.21, while firm age has a mean of 26 years, with some firms as old as 123 years. Profitability, measured as return on assets, is low on average (-0.02), and the liquidity ratio shows substantial heterogeneity across firms.

Table 2 disaggregates these statistics by treatment status. Firms in NIRP-exposed economies (treated group) exhibit markedly higher total debt ratios (mean = 0.58) compared to the control group (mean = 0.48), with the median also significantly higher at 0.59. This pattern is echoed in the LDR metric, where treated firms have a mean of 0.16 and a median of 0.14, compared to 0.12 and 0.06 in the control group, respectively. These patterns are consistent with a debt maturity extension among treated firms. Meanwhile, SDR remains largely comparable across the groups, albeit marginally higher in the treated group.

Table 1: Descriptive statistics

Variable	Obs.	Q1	Median	Mean	Q3	Max
TDR	472,778	0.31	0.49	0.48	0.66	0.96
SDR	472,778	0.15	0.27	0.30	0.43	0.84
LDR	472,778	0.01	0.07	0.13	0.20	0.65
AGE	472,778	10.00	19.00	26.02	33.00	123.00
PROFIT	472,778	-0.03	0.04	-0.02	0.09	0.35
LIQ	472,778	0.03	0.08	0.16	0.20	0.95
SIZE	472,778	16.64	18.21	18.12	19.85	24.07
AS	472,778	0.32	0.51	0.51	0.70	0.98
INF	472,778	1.53	2.37	3.14	3.77	15.84
GDP growth	472,778	1.84	3.09	3.53	5.95	11.39

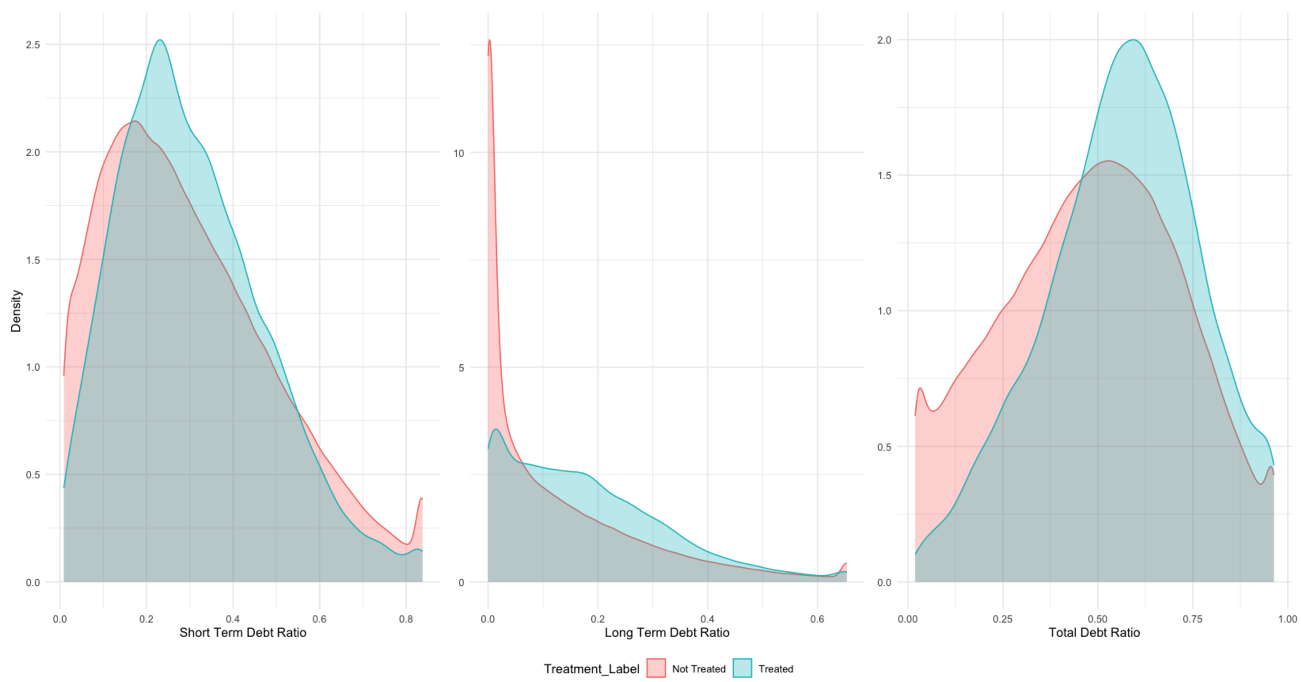
Notes: TDR: Total debt ratio; SDR: Short-term debt ratio; LDR: Long-term debt; AGE: Age of firms; PROFIT: return on assets; LIQ: ratio of liquid assets to total assets; SIZE: natural logarithm of total assets; AS: asset structure; INF: Inflation measured percentage change in consumer prices (%); GDP growth: Real GDP growth (%).

Table 2: Summary statistics of debt ratios by treatment group

Variable	Treatment	N	Q1	Median	Mean	Q3	Max
TDR	Control	458,268	0.31	0.49	0.48	0.66	0.96
TDR	Treated	14,510	0.43	0.57	0.56	0.71	0.96
SDR	Control	458,268	0.15	0.27	0.30	0.43	0.84
SDR	Treated	14,510	0.18	0.28	0.31	0.41	0.84
LDR	Control	458,268	0.01	0.07	0.13	0.20	0.65
LDR	Treated	14,510	0.06	0.15	0.18	0.27	0.65

These patterns are visually confirmed in the kernel density plots in Figure 2. The distribution of total debt ratios for treated firms (in blue) is noticeably right-shifted relative to non-treated firms (in red), consistent with the higher central tendency shown in the summary statistics. Similarly, the LDR distribution for treated firms is more right-skewed, reflecting greater long-term debt holdings. In contrast, the SDR distributions overlap substantially, reinforcing the interpretation that while short-term debt levels remain relatively stable, the shift in capital structure under NIRP is primarily driven by an increase in long-term debt. These visual patterns complement the tabulated statistics and provide additional descriptive support for the hypothesis that firms exposed to NIRP reallocate their debt composition in favour of long-term instruments, potentially to lock in persistently low rates. This motivates a deeper investigation using causal identification strategies.

Figure 2: Distribution of debt ratios



5 Empirical Methodology

5.1 Model specification

Following from the literature (Carbó-Valverde et al., 2021), we identify the causal effect of NIRP on the capital structure using the Difference-in-Differences (DiD) framework.

$$DR_{ict} = \theta_i + \eta_t + \lambda_{ht} + \beta(Treated_i \times POST_t) + \boldsymbol{\gamma}\boldsymbol{X}_{ict} + \varepsilon_{ict} \tag{9}$$

where i,c,t represents firm i in country c at time t. DR is the measure of the capital structure/financing decision of the firms proxied by the ratio of long-term debt to total assets (LDR), the ratio of short-term debt to total assets (SDR), and the ratio of total debt to total assets (TDR).

Treated is a dummy variable equal to 1 for firms in a country (for countries in the Euro area) that adopted an NIRP and 0 otherwise. POST is a dummy variable equal to 1 in the year (2014) of NIRP adoption and afterwards, and 0 otherwise. Essentially, the interaction of the two represents our difference-in-differences variable (DiD hereafter). The ECB has cut the Deposit Facility Rate(DFR) in June 2014 from 0 to -0.1%, from -0.1% to -0.2% in September 2014, from -0.2% to -0.3% in December 2015, from -0.3% to -0.4% in March 2016, and from -0.4% to -0.5% in September 2019 and remained so until it was changed to 0 in July 2022.[5]

β is the coefficient of interest, which is the average treatment effect, indicating the average difference in capital structure ($DEBT$) between the treated and control groups before and after the implementation of the negative interest rate policy. A positive and significant estimate of β would mean higher leverage by firms in countries with NIRP after the implementation of the NIRP, as long as capital structure decisions and other shocks evolve similarly for treated and control groups.

X_{ikt} is a vector of firm-specific and macroeconomic control variables identified in the literature to influence firms' capital structure. These include firm-specific controls: age, profitability, liquidity, size, asset structure and macroeconomic variables, which include financial development, inflation and real GDP growth. $\boldsymbol{\gamma}$ is a vector of parameters for the control variables; θ_i and η_t are the firm and year fixed effects, respectively; λ_{ht} is the industry (2-digit SIC)-year fixed effects to capture any shocks in the industry of the firms over time that may affect firms' financing decision; $\varepsilon_{i,k,t}$ is the idiosyncratic error term.

We estimate this model following the traditional Two-way fixed effect (TWFE). Given the 2×2-DiD framework with no heterogeneity in treatment effects across either time or units, the

[5] https://www.ecb.europa.eu/stats/policy_and_exchange_rates/key_ecb_interest_rates/html/index.en.html

standard within estimator produces consistent estimates (Dube et al., 2023; Roth et al., 2023).

6 Empirical Results

In this section, we discuss the results from our DID estimations. First, the results from the TWFE estimations are presented in Tables 3 to 5. Table 3 shows the results when *TDR* is used as the dependent variable. From the table, we see that the coefficient of *DiD* (*i.e.* $Treated_i \times POST_t$), though negative in the baseline model, was insignificant in the full model. On the other hand, from Table 4, when *SDR* is used as the dependent variable, the coefficient of *DiD* is negative and statistically significant at the 1% significance level. This shows that firms in a negative interest rate environment reduce their short-term debt. Thus, the implementation of the NIRP by the ECB resulted in a decrease in the short-term debt ratio. On average, this decrease was around 1.83%. Meanwhile, from Table 5, the *DiD* indicator has a statistically positive impact on the long-term debt ratio at 1% significance level. This shows that firms in the Euro area increased their long-term debt as a result of the implementation of the NIRP. The average increase was about 2.68%.

These results suggest that firms in the Euro area adopted a term maturity restructuring of their debt portfolio in order to benefit from the negative interest rate policy. This may go to support the theory of *debt market-timing* where firms adjust their capital structure in response to market conditions like the NIRP in order to take advantage of the lower interest rates (Bolton et al., 2013; Karpavičius and Yu, 2017). Moreover, as we have proven in our theoretical model, the decrease in the short-term debt in order to increase the long-term debt may be because the leverage adjustment cost for short-term debt may be higher compared to the higher risk premium on long-term debt. This supports the argument of Jungherr and Schott (2021), who find that long-term debt saves rollover costs.

While it is likely that short-term debt has lower initial issuance costs, such as legal and bank fees, because it's simpler to arrange, the need to refinance short-term debt frequently — potentially every year — can lead to higher total adjustment costs over time. Long-term debt, while having higher upfront costs, benefits from stability, with lower annual amortisation expenses for debt issuance costs. An unexpected detail is that in negative interest rate environments, firms might shift toward long-term debt to lock in low rates and avoid the risks of frequent refinancing, aligning with our hypothesis that firms reduce short-term debt and increase long-term debt, potentially due to the higher refinancing costs of short-term debt. This hypothesis aligns with the argument of Wu et al. (2022), who show that short-term borrowing makes firms vulnerable to credit denial, may force them to curtail operations or fire-sale assets, and increases the opportunity costs of management due to the need for more frequent debt issuance.

Table 3: NIRP and total debt (Full sample)

This table provides the estimates of the difference-in-difference estimates of the impact of NIRP on capital structure using total debt ratio (TDR) following Equation 9 with Two-way Fixed Effects (TWFE), where DiD is $Treated_i \times POST_t$.

Model:	(1)	(2)	(3)	(4)
DiD	-0.0093***	-0.0066*	-0.0020	-0.0005
	(0.0035)	(0.0035)	(0.0034)	(0.0034)
AGE			0.0022***	0.0015*
			(0.0008)	(0.0008)
PROFIT			-0.1352***	-0.1351***
			(0.0023)	(0.0023)
LIQ			-0.4180***	-0.4141***
			(0.0050)	(0.0050)
SIZE			−0.0001	0.0001
			(0.0008)	(0.0008)
AS			-0.1483***	-0.1502***
			(0.0048)	(0.0048)
INF			0.0023***	0.0018***
			(0.0002)	(0.0002)
GDP growth			0.0023***	0.0020***
			(0.0002)	(0.0002)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry × Year FE	No	Yes	No	Yes
Observations	472,778	472,778	472,778	472,778
No. of Firms	58,418	58,418	58,418	58,418
R^2	0.69	0.69	0.72	0.72

Note: Clustered (firm level) standard errors in parentheses.
****p<0.01, **p<0.05, *p<0.1*

Table 4: NIRP and short-term debt (Full sample)

This table provides the estimates of the difference-in-difference estimates of the impact of NIRP on capital structure using total debt ratio (TDR) following Equation 9 with Two-way Fixed Effects (TWFE), where DiD is $Treated_i \times POST_t$.

Model:	(1)	(2)	(3)	(4)
DiD	-0.0238***	-0.0215***	-0.0198***	-0.0186***
	(0.0025)	(0.0025)	(0.0023)	(0.0023)
AGE			0.0019***	0.0017***
			(0.0005)	(0.0006)
PROFIT			-0.0998***	-0.1010***
			(0.0018)	(0.0018)
LIQ			-0.4114***	-0.4100***
			(0.0042)	(0.0042)
SIZE			-0.0170***	-0.0165***
			(0.0006)	(0.0006)
AS			-0.3075***	-0.3066***
			(0.0041)	(0.0041)
INF			0.0024***	0.0022***
			(0.0001)	(0.0001)
GDP growth			0.0009***	0.0009***
			(0.0001)	(0.0001)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry × Year FE	No	Yes	No	Yes
Observations	472,778	472,778	472,778	472,778
No. of Firms	58,418	58,418	58,418	58,418
R^2	0.68	0.68	0.73	0.73

Note: Clustered (firm level) standard errors in parentheses.
****p<0.01, **p<0.05, *p<0.1*

Table 5: NIRP and long-term debt (Full Sample)

This table provides the estimates of the difference-in-difference estimates of the impact of NIRP on capital structure using total debt ratio (TDR) following Equation 9 with Two-way Fixed Effects (TWFE), where DiD is $Treated_i \times POST_t$.

Model:	(1)	(2)	(3)	(4)
DiD	0.0219***	0.0215***	0.0245***	0.0241***
	(0.0025)	(0.0026)	(0.0025)	(0.0025)
AGE			-0.0011**	-0.0013**
			(0.0005)	(0.0006)
PROFIT			-0.0328***	-0.0317***
			(0.0012)	(0.0012)
LIQ			0.0022	0.0044
			(0.0030)	(0.0030)
SIZE			0.0149***	0.0147***
			(0.0005)	(0.0005)
AS			0.1201***	0.1180***
			(0.0032)	(0.0032)
INF			−0.0001	-0.0002*
			(0.0001)	(0.0001)
GDP growth			0.0010***	0.0007***
			(0.0001)	(0.0001)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry × Year FE	No	Yes	No	Yes
Observations	472,778	472,778	472,778	472,778
No. of Firms	58,418	58,418	58,418	58,418
R^2	0.64	0.65	0.65	0.66

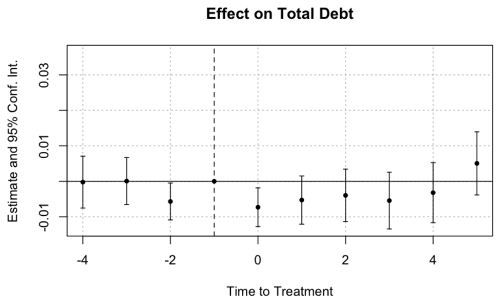
Note: Clustered (firm level) standard errors in parentheses.
****p<0.01, **p<0.05, *p<0.1*

Parallel Trends To ensure the validity of the parallel trends assumption in our Difference-in-Differences (DiD) framework, we examine the dynamics of the firm-level debt measures — short-term, long-term, and total debt ratios — comparing treated firms in the euro area with control firms outside the euro area. The identifying assumption is that, in the absence of the ECB's introduction of the negative interest rate policy (NIRP) in 2014, the debt trajectories of treated and control firms would have evolved similarly over time. Following from other studies (He and Wang, 2017), we formally evaluate this assumption using an event-study specification that includes multiple pre-treatment leads (four years prior to treatment), setting the year immediately before treatment ($t = -1$) as the reference period. Visual inspection of pre-treatment trends, as seen in Figure 3, reveals that the coefficients on pre-treatment leads are statistically indistinguishable from the base period (the year before the NIRP was implemented). This visual inspection suggests a plausible causal effect and parallel trends.

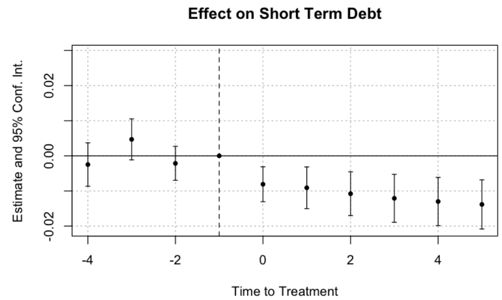
Beyond the event–study diagnostics, we strengthen the credibility of parallel trends using the panel-data matching framework of Imai et al. (2023), which we describe in our robustness analysis. For each treated firm–year, we construct a matched risk set of control firm–years drawn from the same calendar year that share an identical treatment history over a pre-specified lead and lag window. We then estimate average treatment effects via difference-in-differences within the matched sets. This design-based procedure clarifies the counterfactual construction, reduces model dependence relative to two-way fixed-effects regression, and provides transparent balance diagnostics. As we discuss further later on, applied to all three debt outcomes (*SDR, LDR, TDR*), the matched DiD estimates are consistent with our main findings.

Impact of control variables Here, we discuss the impact of the control variables on firms' capital structure. From the results, firm age generally has a positive impact on the total debt ratio of firms. On the other hand, while firm age has a positive impact on short-term debt in all estimations at the 1% significance level, firm age has a negative impact on long-term debt. These results suggest that, compared to younger firms, older firms seem to take on more short-term debt while reducing long-term debt. While current studies (Abor and Biekpe, 2009; Petersen and Rajan, 1994; Diamond, 1989) show that older firms are more likely to take on more debt due to their reputation, our findings show that this may be driven by short-term debt. This could be because, as firms get older, they often have more stable operations and need more short-term debt to manage daily expenses like payroll or inventory, which increases their total debt. Older firms may also have established relationships with banks, making it easier to get short-term loans for working capital. Mature firms typically do not need as much long-term debt because they are not expanding as much as younger firms. They might pay off long-term loans or avoid new ones to keep financial flexibility, focusing instead on short-term financing for operational needs.

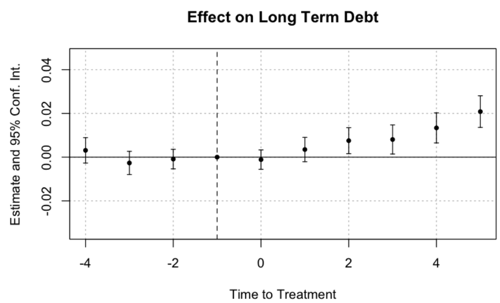
Also, we see that firm profitability has a negative impact on all the measures of debt at a



(a) Total Debt Ratio



(b) Short Term Debt



(c) Long Term Debt

Figure 3: Estimated Impact of NIRP For Years Before and After Treatment

1% significance level, supporting the *POT*. As mentioned earlier, profitable firms can have more retained earnings to fall on and hence may be less dependent on debts, especially short-term debts, compared to long-term debts.

Meanwhile, more liquid firms require less debt, with liquidity having the most pronounced negative impact on short-term debt. This is intuitive because the ability to meet short-term obligations likely reduces the need for debt, especially short-term debt, as firms with ample cash can cover immediate needs without borrowing short-term, also supporting the *POT* (Wu et al., 2022; De Jong et al., 2008). From the tables, we see that firm size has a positive impact on total debt and long-term debt but a negative impact on short-term debt. This supports studies like that of Hall et al. (2004), which find that firm size has a negative impact on short-term debt, while other studies, such as Degryse et al. (2012), find a positive impact on long-term debt. Larger firms can always leverage high-value assets to borrow more long-term debt because they are less likely to go bankrupt, suggesting their ability to pay off their debt (Ang et al., 1982; Warner, 1977).

In addition, the results show that firms with larger asset capacity are more inclined to take on more long-term debt compared to short-term debt. Therefore, asset structure has a negative impact on short-term and total-debt ratios, while having a positive impact on long-term debt.

This is in line with studies like (Hall et al., 2004; Myers, 1977), who note that tangible assets reduce short-term debt, as they are better suited for long-term financing, increasing long-term debt. This is because the proportion of tangible to intangible assets affects collateral availability; hence, firms with more tangible assets can secure more long-term debt. What we observe is that, on aggregate, the reduction in short-term debt is greater than the increase in long-term debt; hence, the total debt ratio falls.

At the macro level, we find that overall, inflation has a positive impact on short-term debt but a negative impact on long-term debt. Indeed, inflation impacts short-term and long-term debt differently due to how it affects borrowing costs, repayment dynamics, and firm behaviour. When inflation rises, firms may prefer short-term debt to maintain flexibility. Short-term debt lets firms refinance frequently, adjusting to new interest rates as inflation changes. This avoids locking into rates that might not keep up with inflation, which could increase real borrowing costs if rates lag. On the other hand, high inflation makes long-term debt less appealing because it locks firms into fixed nominal rates for years, like 5 or 10. If inflation outpaces these rates, the real value of debt payments falls, benefiting borrowers initially, but lenders, anticipating this, demand higher rates or shorter terms, raising the cost of long-term debt. Therefore, the decrease in long-term debt may result from lenders' preference for short-term debt or for firms seeking to keep up with changes in inflation. Additionally, GDP growth has a positive impact on all types of debt. This suggests that higher aggregate demand in the economy may require higher investments; hence, firms may borrow more to finance these investments to meet the growing demand.

6.1 Robustness: sub-sample analysis

In this subsection, we provide results for our sub-sample analysis. In this case, we provide analysis based on the firm size (Small *vs* Large), firm age (Young *vs* Old), firm leverage (High *vs* Low) and firm liquidity (High *vs* Low) defined relative to their respective median values[6]. These results are shown in the Online Appendix. The descriptive statistics of these sub-groups are provided in Tables C1 and C2. They generally show that large, older, and high-leverage treated firms have higher debt ratios than their counterparts. We proceed to discuss the results for the sub-samples.

[6]We also provide robustness results using the lower and upper terciles of *SIZE*, *AGE*, *TDR* and *LIQ* for firm size, firm age, firm leverage and firm liquidity respectively. The results also shown in the Online Appendix are consistent with our earlier findings.

6.1.1 The role of firm size

We define small firms as those with *SIZE* at or below the median and large firms as those above it (*See Tables D1 to D6 in the Online Appendix*). Regression results confirm our prior findings: firms in NIRP environments reduce short-term debt while increasing long-term debt. Both small and large firms exhibit this maturity restructuring, but small firms increase long-term debt proportionately more relative to their short-term debt reductions. This suggests that, under NIRP, small firms, which are comparatively constrained in obtaining debt in normal conditions, disproportionately benefit from the abundant debt supply and low rates, leading to a significant positive *DiD* effect on their total debt ratio (TDR). In contrast, large firms show no significant change in *TDR*, with an insignificant *DiD* effect, indicating stable overall leverage.

6.1.2 The role of firm age

The age of firms can influence their choice of debt composition. We, therefore, perform a sub-sample analysis comparing younger firms (at or below the median *AGE*) with older firms (above the median *AGE*). The results are presented in Tables D7 to D12 in the Online Appendix. Consistent with our initial results, firms reduce short-term debt but increase long-term debt in periods of negative interest rates. This, however, does not seem to have a significant impact on the overall debt ratio. Moreover, we see that older firms mostly undertake this debt maturity restructuring. Older firms will generally have the market experience and reputation, and hence would be able to take on more long-term debt.

6.1.3 The role of firm leverage

We also provide robustness by comparing low-levered (at or below median *TDR*) with high-levered firms (above median *TDR*), shown in Tables D13 to D18 in the Online Appendix. Again, we find that both high and low-leveraged firms reduce their short-term debt to increase their long-term debt. We do observe a marginal decrease in the total debt ratio.

6.1.4 The role of firm liquidity

We also provide robustness for low and high-liquid firms, where low-liquid firms are those at or below the median *LIQ*, and high-liquid firms are above the median. The results are shown in Tables D19 to D24 in the Online Appendix. Again, we find consistent results that firms reduce their short-term debt to increase their long-term debt in a negative interest rate environment, but with no significant impact on the overall debt ratio.

6.2 Robustness: using other heterogeneous DiD method

Roth et al. (2023) suggest further robustness to the TWFE in our 2×2-DiD framework when the data is an unbalanced panel, such as our study. The authors suggest considering any of the "heterogeneity-robust" estimators for the staggered treatment timings. Hence, we use the Callaway and Sant'Anna (2021) method as a robustness check. The results confirm our earlier findings that firms in negative interest rate environments reduce their short-term debt while increasing their long-term debt to take advantage of the low interest rates. We find that the decrease in short-term debt happens within a year after the implementation of the policy, while the increase in long-term debt happens 2 years after the implementation. Because of the significant decrease in short-term debt in the first year, with no significant impact on long-term debt, we only observe an increase in overall debt levels 5 years after the implementation of the policy. This shows that during the implementation of the NIRP, firms' overall capital structure does not change for the first few years. This may possibly be because the policy was quite unconventional; firms would take time to consider whether the policy would likely be in place over the medium term before deciding to change their capital structure.

Table 6: Difference-in-Differences (ATT) estimates of impact of NIRP on debt based on Callaway and Sant'Anna (2021)

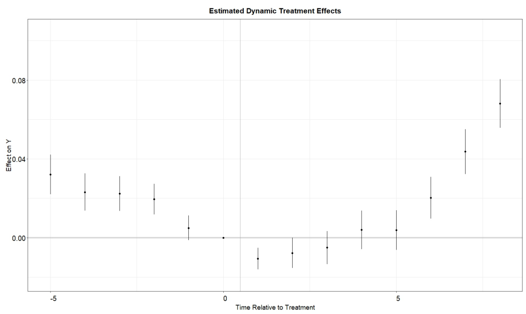
	TDR	SDR	LDR
DiD	0.015***	-0.014***	0.024***
	(0.004)	(0.003)	(0.003)

Note: Clustered (firm level) standard errors in parentheses.
****p<0.01*

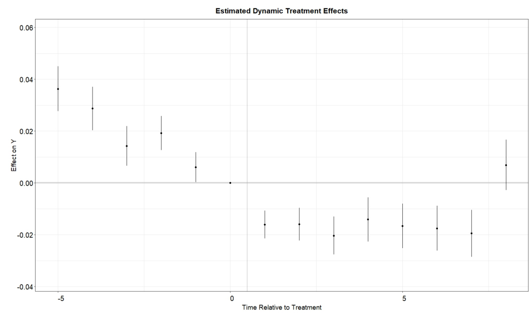
6.3 Robustness: using matching method

In order to provide further robustness, we use the panel data matching method of Imai et al. (2023),[7] which allows us to match each treated observation for a given unit in a particular period with untreated observations from other units in the same period that have a similar treatment and outcome histories. The matching process enhances the validity of the parallel trends assumption by mitigating key observable disparities between the treatment and control groups (Ben-Menachem and Morris, 2023). Thus, this method helps to improve the validity of causal inference through the reduction of model dependencies (Imai et al., 2023; Ho et al., 2007). From Table 7, we again find that while firms do not change their overall capital structure

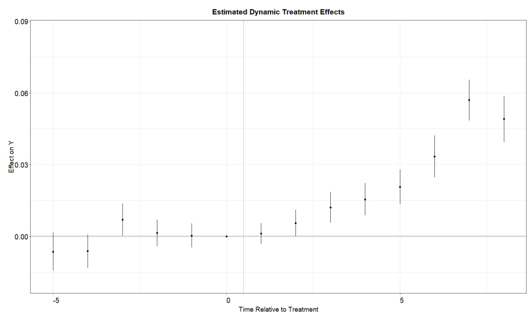
[7] See Imai et al. (2023) for more discussion on how traditional difference-in-differences methods are improved when matching is used.



(a) Total debt ratio



(b) Short term debt



(c) Long term debt

Figure 4: DiD plot of impact of NIRP on debt based on Callaway and Sant'Anna (2021)

following the implementation of the NIRP, firms reduce their short-term debt while increasing their long-term debt, consistent with our earlier findings.

Table 7: Difference-in-Differences (ATT) estimates of impact of NIRP on debt based on Imai et al. (2023).

	TDR	**SDR**	**LDR**
DiD	-0.006	-0.010^{***}	0.007^{**}
	(0.004)	(0.003)	(0.004)

Note: Standard errors in parentheses.
$^{***}p<0.01$, $^{***}p<0.05$

7 NIRP Transmission in a DSGE Framework

This section shows how a tractable DSGE model can rationalise the two reduced-form facts documented above: i) firms in negative-rate environments shift from short- to long-maturity debt on impact, and ii) overall leverage rises only when the regime is sufficiently persistent. We first summarise the transmission mechanism and then outline the model's key blocks. The full set of equilibrium conditions is collected in Appendix A, while calibration targets and parameter values are deferred to Appendix B.[8]

7.1 Conceptual framework

The policy rate paid on reserves, R_t^S, can be set below zero, whereas the deposit rate, R_t^D, is subject to a zero lower bound (ZLB). A binding reserve requirement then forces banks to hold reserves even when the carry is negative. Two channels follow: i) signalling channel: when the ZLB binds, $R_t^S < R_t^D$ signals lower expected future short rates once the floor ceases to bind and therefore compresses long yields today. ii) net-worth (balance-sheet) channel: The gap $R_t^D - R_t^S$ acts as a reserve-carry "tax", eroding financial intermediary equity and partially offsetting the stimulus from lower long rates.

A sufficient statistic for monetary transmission at the floor is the real long yield:

$$r_{L,t} = lnR_{L,t} - \mathbb{E}_t ln\Pi_{t+1}$$
$$R_{L,t} \equiv \frac{1 + \kappa Q_t^{Pvt}}{Q_{t-1}^{Pvt}}$$

where Q_t^{Pvt} is the price of a consol bond that pays a coupon depreciating at rate κ. With the short nominal rate pinned, movements in $r_{L,t}$ capture the stance of policy that is relevant for investment and, ultimately, for firms' financing choices. A compression in $r_{L,t}$ raises the relative price of long-term borrowing, thus firms immediately lock in longer maturities ("maturity rebalancing"). It also affects the firm's total leverage through the intermediary's net worth. When the reserve-carry tax is large and front-loaded, equity falls and leverage is slow to adjust; when the tax is staggered or tiered, equity rises and leverage follows sooner.

Finally, the aggregate effect of NIRP depends on the size of the central-bank balance sheet: the larger the stock of reserves, the larger the net-worth tax for a given negative spread and the weaker the stimulus.

7.2 Model structure

The economy is a standard New Keynesian model augmented with financial intermediaries and an occasionally binding ZLB on deposits. Only the features necessary for corporate finance exercise are kept in the main text; full derivations follow the Hashmi and Nsafoah (2024) and Sims and Wu (2021).

[8] The model builds on Hashmi and Nsafoah (2024) and Sims and Wu (2021), with parameter values updated to match Euro area data.

Households A representative household chooses consumption C_t, deposits D_t, and labor supply $L_{1,t}$ to maximise expected utility, subject to a standard habit formation and labour-disutility specification, and a nominal budget constraint [see Equations (001)–(006)] in full set of equilibrium conditions in Appendix A.

Labour market Wages are set according to a Calvo mechanism with rigidity parameter θ_w. In each period, a measure $1-\theta_w$ of labour unions, denoted $w_{2,t}(i)$, re-optimise their nominal wage, whereas the remaining fraction θ_w adjusts mechanically by indexing last period's wage to past inflation. A representative labour packer then aggregates these specialised labour inputs into an economy-wide labour bundle, delivering a common aggregate wage. The resulting wage Phillips curve — which links current wage inflation to expected future wage inflation and the marginal rate of substitution between consumption and leisure — is given by Equations (007)–(012) in full set of equilibrium conditions in Appendix A.

Non-financial firms The economy's production side comprises four blocks: a representative wholesale firm, a continuum of retail firms, a competitive final-good aggregator, and a representative capital-goods producer. Taken together, these blocks deliver the standard New-Keynesian supply side summarised by Equations (013)–(030) in the full set of equilibrium conditions in Appendix A. A key friction is that the wholesale firm must satisfy a *loan-in-advance* constraint, shown in equation (016), which forces a fixed fraction ψ of every investment outlay to be financed with newly issued long-maturity bonds. This restriction links bond prices and real investment activity, which is necessary for NIRP transmission.

Financial intermediaries Banks intermediate between households and asset markets by holding private and government consol bonds and reserves, and by financing these positions with deposits D_t. Their portfolio choice is restricted by a leverage (net-worth) constraint and by a reserve-requirement constraint, both detailed in Equations (031)–(039) in the full set of equilibrium conditions in Appendix A. Whenever the policy rate on reserves, R_t^S, falls below the deposit rate, R_t^D, the reserve requirement binds and the net-worth constraint becomes active.

Monetary authority The central bank sets the reserve rate R_t^S according to a forward-looking Taylor rule, given in (eqn. 044) in full set of equilibrium conditions in Appendix A, and manages the size of its balance sheet through autoregressive positions in private and government bonds (Equations. (047)–(048)in full set of equilibrium conditions in Appendix A). Depending on the level of R_t^S, the economy can be in one of three regimes, summarised in Table 8: a normal regime with $R_t^S > 1$; a zero-lower-bound (ZLB) regime with a zero reserve rate; and a ZLB regime with a negative reserve rate.

Fiscal authority The fiscal authority finances an exogenous stream of government spending with lump-sum taxes and monetary authority profits while maintaining the stock of nominal government debt at a fixed level, a budget constraint captured by Equations (049)–(051) in full set of equilibrium conditions in Appendix A.

Table 8: Three scenarios

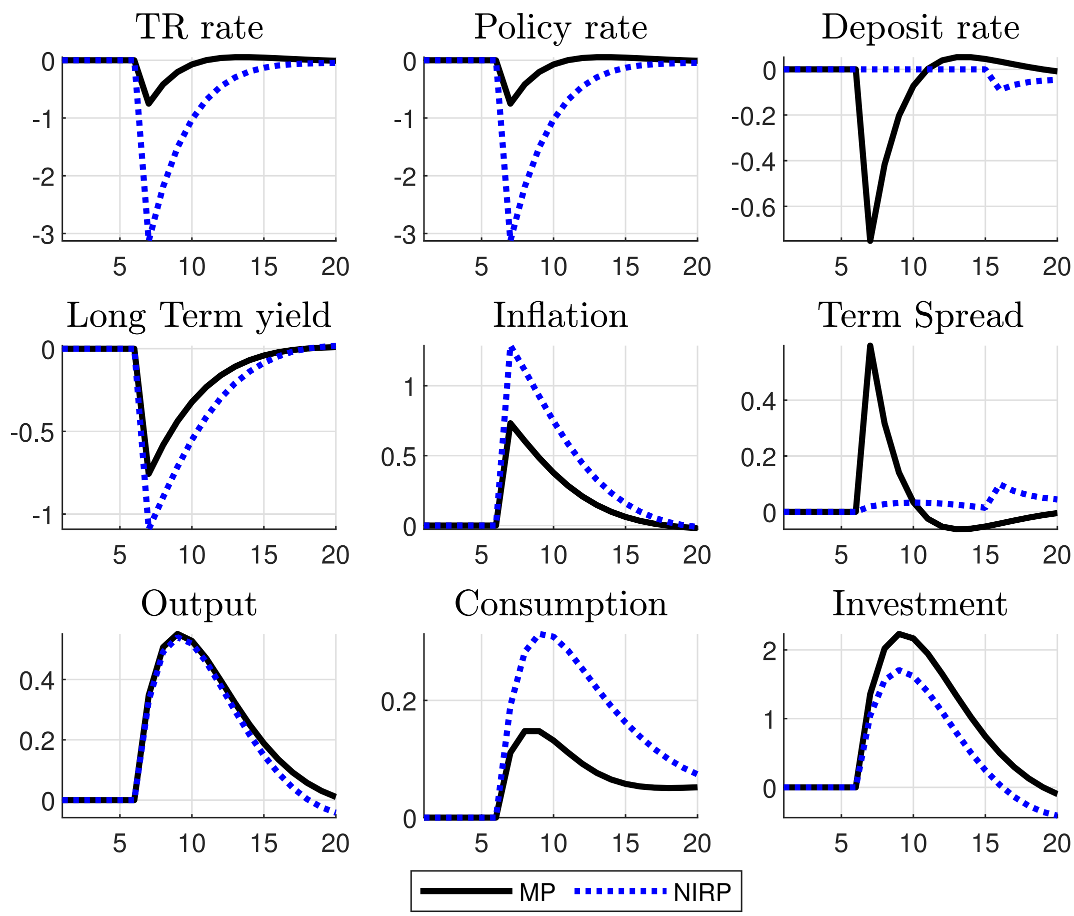
Scenario	Taylor-rule rate $\left(R_t^{Pol}\right)$	Rate on reserves $\left(R_t^S\right)$	Rate on deposits $\left(R_t^D = \max\left\{1, R_t^S\right\}\right)$
1	$R_t^{Pol} > 1$	$R_t^S = R_t^{Pol}$	$R_t^D = R_t^S$
2	$R_t^{Pol} \leq 1$	$R_t^S = \max\left\{1, R_t^{Pol}\right\}$ (which implies $R_t^S = 1$)	$R_t^D = 1$
3	$R_t^{Pol} \leq 1$	$R_t^S = \max\left\{\underline{R}, R_t^{Pol}\right\}$ (which implies $R_t^S \in [\underline{R}, 1]$)	$R_t^D = 1$

Calibration and solution Most parameters follow the baseline of Sims and Wu (2021); the two key changes are (i) a larger steady-state central bank balance sheet (21% of GDP in place of 6%) to match Eurosystem data for May 2014, and (ii) a higher government expenditure to GDP ratio (49.1%). The model is linearised around the non-stochastic steady state, and occasionally, binding constraints are handled with the OccBin algorithm of Guerrieri and Iacoviello (2015). Full parameter values appear in Tables B1 and B2 in the Appendix.

7.3 Model properties

In this subsection, our model serves as a tool to measure and compare the effects of conventional monetary policy and negative interest rate policy (NIRP). Both monetary policy shocks impact the overall economy through goods and asset market channels. Our approach focuses on their influence on the output of the economy. Our simulation includes both an initial liquidity shocks and subsequent monetary policy interventions, allowing us to assess the distinct impact of each monetary policy type on the macroeconomic dynamics. Specifically, i) we hit the economy with a -1% shock to its annualised policy rate (which results in about a 0.75 percentage point decline in the policy rate on impact, the difference being accounted for by the endogenous reaction of the policy rate to inflation and output growth). This is the conventional monetary-policy stimulus; ii) For NIRP, we hit the economy with a -3.5% shock to its annualised policy rate. All monetary-policy shocks hit the economy in period 7. We generate a binding zero lower bound (ZLB), applicable only to NIRP, in the economy with a sequence of liquidity shocks (shocks to θ_t) of 1.5 standard deviations for periods 1 to 6. We simulate the NIRP model twice: once with the liquidity shocks in periods 1 to 6 only and then with the liquidity shocks in periods 1 to 6 and the monetary-policy shock in period 7. We then plot the differences between the impulse response functions (IRFs) generated by the two simulations as NIRP responses in Figure 5.

Figure 5: Exogenous monetary policy shocks



An important goal of monetary policy is to affect real economic activity in the short run. We start with the conventional monetary policy (solid black lines) in Figure 5. The conventional cut (solid black) produces the familiar, hump-shaped increase in output: roughly 0.5% on impact, peaking after three quarters. Consumption follows with one-third the amplitude, while investment responds about four times as strongly. Inflation rises by about 0.6 percentage points on impact and remains above trend for almost three years.

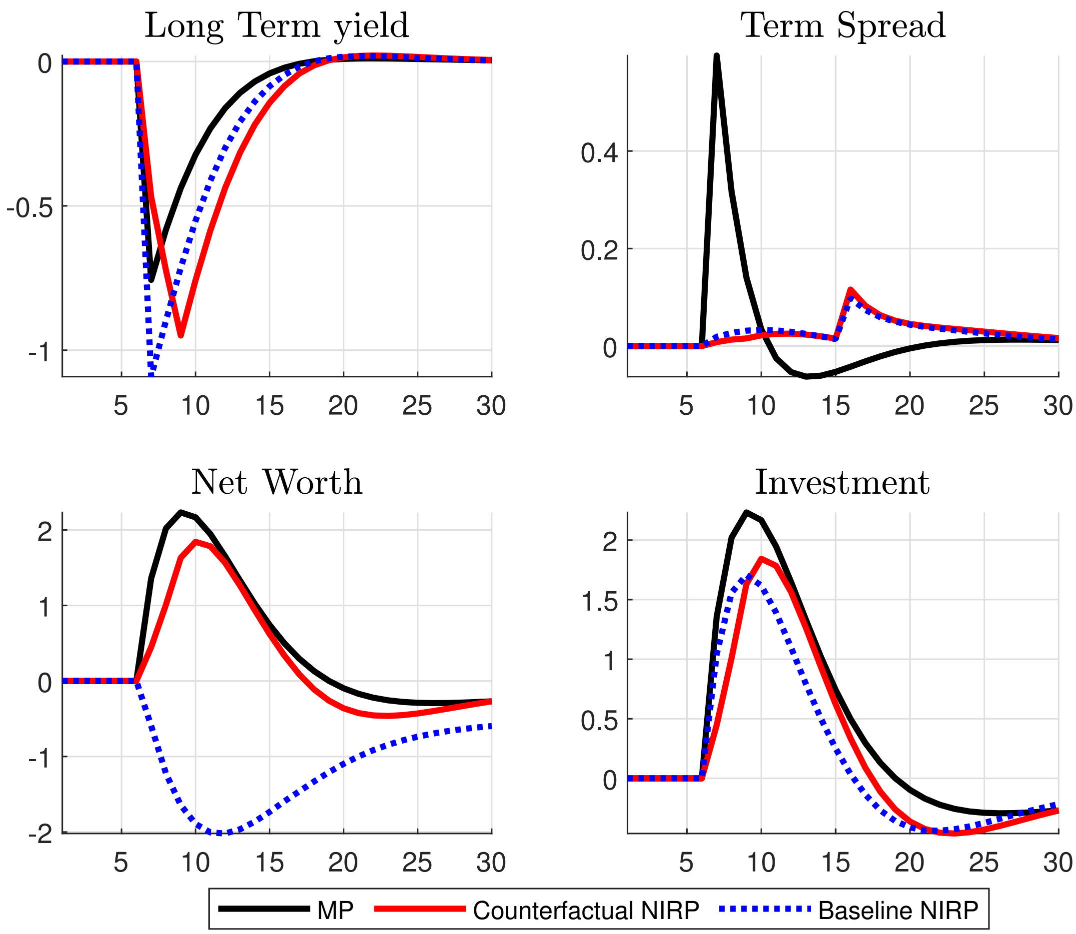
The effect of the NIRP shock (dashed blue lines) is carefully generated to produce a comparable increase of 0.5% of output. This implies that when the ZLB is binding, the policy rate has to decrease by -3.5% to generate a comparable effect on output. The -3.5% from our model is significantly different from estimates in Sims and Wu (2021) (who reports a -2.4% decrease in the policy rate). The larger NIRP cut is required because our calibration, anchored to Euro area data, assumes a central bank balance sheet equal to 21% of GDP, versus 6% in Sims and Wu (2021). A bigger balance sheet magnifies the reserve-carry "tax" and therefore attenuates the stimulus obtained for any given negative rate; the deeper cut simply equalises the impact on output. The response of all the other variables is qualitatively similar to the conventional monetary policy shock. Quantitatively, NIRP appears to be more inflationary, has a larger decline in real long-term yield, a bigger increase in consumption and a small increase in investment. Figure 5 also helps explain our main empirical finding that firms in NIRP environments restructure their debt maturity. These firms reduce their short-term debt to increase their long-term debt. Because the deposit rate is pinned at zero, the -3.5% policy rate cut compresses the real long yield far more than the conventional shock. Firms therefore face a steeper term structure flattening, which immediately makes long-term funding cheaper and induces the maturity rebalancing (short-term debt down, long-term debt up) that we document in the panel data.

To interpret our second empirical finding, that total corporate leverage eventually rises under NIRP, we compare the one shot NIRP (baseline NIRP as in Figure 5) with a staggered counterfactual that spreads the same cumulative -3.5% easing over three quarters (-0.2, -1, -1 percentage points) - Counterfactual NIRP. It can be observed from Figure 6 that both NIRP policies compress the real, so the maturity shift is similar in impact. However, the one-shot cut levies a large contemporaneous reserve-carry tax; net worth falls on impact and does not recover for several quarters. On the other hand, the staggered path imposes a much smaller per-period tax, so the capital gains from higher bond prices dominate early, leading to an increase in net worth within two quarters, spreads narrow, and leverage increases sooner.

The June 2014 ECB decision resembled the one-shot experiment: a single surprise move into negative territory with no tiering. Consistent with the model, we observe an immediate shift toward long-term debt but no increase in overall leverage through 2015. By contrast, once the Governing Council reiterated and gradually deepened NIRP and paired it with balance-sheet expansion, the data show leverage drifting up, mirroring the staggered path.

In short, the model delivers two clean predictions that line up with our micro evidence: i) maturity adjusts on any compression of the long yield, and ii) leverage adjusts only when the negative-rate regime is persistent, gradual, or cushioned, i.e., when net-worth effects turn positive.

Figure 6: Exogenous monetary policy shocks



8 Conclusion and Policy Implications

This study examines the impact of the negative interest rate policy (NIRP) introduced by the ECB in 2014 on firms' financing structures. We hypothesise that firms operating in an NIRP environment would restructure their debt maturity by shifting from short-term to long-term debt in order to lock in lower interest rates over a longer horizon. To test this, we employ a DiD framework where Eurozone countries under ECB policy serve as the treatment group and firms in non-NIRP countries as controls.

We use multiple estimation strategies, including the traditional two-way fixed effects estimator suitable for our 2×2 DiD setting, as well as the heterogeneous treatment effect methods of Callaway and Sant'Anna (2021) and the matching-based approach of Imai et al. (2023), which strengthens the plausibility of the parallel trends assumption. Across these approaches, we consistently find evidence that firms reduce their short-term debt while increasing their long-term debt in response to NIRP. Subsample analysis shows that this effect is most pronounced among smaller, older, more leveraged, and less liquid firms. However, the shift in debt maturity does not always translate into an immediate increase in total firm leverage. We find that leverage increases only when the policy is sustained over a longer period.

To interpret these empirical findings, we develop two complementary models. First, a stylised partial equilibrium model in which the frequency of refinancing imposes an implicit cost on short-term debt. In a persistently low-rate environment such as NIRP, this cost becomes non-trivial, incentivising firms to lock in longer-term borrowing. This firm-level behavioural channel provides a clear microeconomic rationale for maturity restructuring, even without changes in the yield curve.

Second, we build a medium-scale DSGE model calibrated to Eurozone data to study the general equilibrium effects of NIRP on macroeconomic aggregates and firm financing. The model shows that NIRP leads to a sharper compression of real long-term yields relative to conventional monetary policy, due to the binding zero lower bound on deposit rates. This steepening of the term structure makes long-term borrowing substantially cheaper, thereby inducing the same maturity rebalancing observed in the data. Moreover, the DSGE model highlights that corporate leverage increases only when NIRP is gradual or persistent—mimicking the ECB's post-2015 forward guidance and tiered implementation. In contrast, a one-shot NIRP shock may depress firm net worth due to reserve-carry taxes, delaying any rise in leverage.

The stylised and DSGE models, therefore, offer distinct but reinforcing insights. The former emphasises firm-level refinancing frictions, while the latter underscores the macro-financial transmission of NIRP through long-term yields. Together, they provide a robust explanation for our empirical findings.

From a policy perspective, our results suggest that negative interest rate policies are more likely to influence corporate leverage and maturity choices if they are implemented persistently and with clear forward guidance. While maturity restructuring may occur immediately due to relative pricing effects, a sustained policy environment is needed to stimulate aggregate corporate borrowing. Finally, future research should explore firm-level data on refinancing costs and debt contract structures to directly test the refinancing channel we identify in the stylised model.

Appendix

A Non-linear equilibrium conditions

Following Hashmi and Nsafoah (2024), we list our 51 non-linear equilibrium equations. We have divided these equations into 6 blocks: (A) Household; (B) Labour market; (C) Non-financial firms; (D) Financial intermediaries; (E) Monetary authority; and (F) Fiscal authority.

A.1 Household

$$\mathrm{MU}_{C,t} \equiv Z_t[C_t - hC_{t-1}]^{-\sigma} - \beta h \mathbb{E}_t Z_{t+1}[C_{t+1} - hC_t]^{-\sigma} \qquad \text{(eqn. 001)}$$

$$\ln Z_t = \rho_Z \ln Z_{t-1} + s_Z \varepsilon_{Z,t} \qquad \text{(eqn. 002)}$$

$$\Lambda_{t,t+1} \equiv \frac{\beta \mathbb{E}_t \mathrm{MU}_{C,t+1}}{\mathrm{MU}_{C,t}} \qquad \text{(eqn. 003)}$$

$$\omega Z_t L_{1,t}^{\varphi} = \mathrm{MU}_{C,t} w_{1,t} \qquad \text{(eqn. 004)}$$

$$\mathbb{E}_t \Lambda_{t,t+1} \pi_{t+1}^{-1} R_t^D = 1 \qquad \text{(eqn. 005)}$$

$$Y_t = C_t + I_t + G_t \qquad \text{(eqn. 006)}$$

A.2 Labour market

A.2.1 Labour unions

$$w_{2,t}^{*} = \frac{\epsilon_w}{\epsilon_w - 1} \frac{f_{1,t}}{f_{2,t}} \qquad \text{(eqn. 007)}$$

$$f_{1,t} = w_{1,t} w_{2,t}^{\epsilon_w} L_{2,t} + \theta_w \pi_t^{-\epsilon_w \gamma_w} \mathbb{E}_t \Lambda_{t,t+1} f_{1,t+1} \pi_{t+1}^{\epsilon_w} \qquad \text{(eqn. 008)}$$

$$f_{2,t} = w_{2,t}^{\epsilon_w} L_{2,t} + \theta_w \pi_t^{(1-\epsilon_w)\gamma_w} \mathbb{E}_t \Lambda_{t,t+1} f_{2,t+1} \pi_{t+1}^{\epsilon_w - 1} \qquad \text{(eqn. 009)}$$

A.2.2 Labor packer

$$L_{1,t} = L_{2,t} \upsilon_t^w \qquad \text{(eqn. 010)}$$

$$\upsilon_t^w = (1-\theta_w) \left(\frac{w_{2,t}^{*}}{w_{2,t}} \right)^{-\epsilon_w} + \theta_w \left(\frac{\pi_t}{\pi_{t-1}^{\gamma_w}} \right)^{\epsilon_w} \left(\frac{w_{2,t}}{w_{2,t-1}} \right)^{\epsilon_w} \upsilon_{t-1}^w \qquad \text{(eqn. 011)}$$

$$w_{2,t}^{1-\epsilon_w} = \left(\frac{\pi_{t-1}^{\gamma_w}}{\pi_t} \right)^{1-\epsilon_w} \theta_w w_{2,t-1}^{1-\epsilon_w} + (1-\theta_w) \left(w_{2,t}^{*} \right)^{1-\epsilon_w} \qquad \text{(eqn. 012)}$$

A.3 Non-financial firms

A.3.1 Wholesale

$$Y_{2,t} = A_t(u_t K_t)^{\alpha} L_{2,t}^{1-\alpha} \quad \text{(eqn. 013)}$$

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \quad \text{(eqn. 014)}$$

$$K_{t+1} = \hat{I}_t + (1 - \delta(u_t))K_t, \quad \text{(eqn. 015)}$$

where $\delta(u_t) = \delta_0 + \delta_1 (u_t - 1) + \frac{\delta_2}{2} (u_t - 1)^2$

$$\psi p_{K,t} \hat{I}_t = Q_t^{Pvt}(b_t^{Pvt} - \kappa b_{t-1}^{Pvt} \pi_t^{-1}) \quad \text{(eqn. 016)}$$

$$b_t^{Pvt} = b_t^{Pvt}(fi) + b_t^{Pvt}(ma) \quad \text{(eqn. 017)}$$

$$w_{2,t} = (1-\alpha) p_{2,t} A_t (u_t K_t)^{\alpha} L_{2,t}^{-\alpha} \quad \text{(eqn. 018)}$$

$$p_{K,t} M_{1,t} \delta'(u_t) = \alpha p_{2,t} A_t (u_t K_t)^{\alpha-1} L_{2,t}^{1-\alpha}, \quad \text{(eqn. 019)}$$

where $\frac{\partial \delta(u_t)}{\partial u_t} \equiv \delta'(u_t) = \delta_1 + \delta_2 (u_t - 1)$

$$p_{K,t} M_{1,t} = \mathbb{E}_t \Lambda_{t,t+1} \left[\alpha p_{2,t+1} A_{t+1} K_{t+1}^{\alpha-1} u_{t+1}^{\alpha} L_{2,t+1}^{1-\alpha} + (1 - \delta(u_{t+1})) p_{K,t+1} M_{1,t+1} \right] \quad \text{(eqn. 020)}$$

$$Q_t^{Pvt} M_{2,t} = \mathbb{E}_t \Lambda_{t,t+1} \pi_{t+1}^{-1} \left[1 + \kappa Q_{t+1}^{Pvt} M_{2,t+1} \right] \quad \text{(eqn. 021)}$$

$$\frac{M_{1,t} - 1}{M_{2,t} - 1} = \psi \quad \text{(eqn. 022)}$$

A.3.2 Retail

$$p_t^* = \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}} \quad \text{(eqn. 023)}$$

$$x_{1,t} = p_{2,t} p_t^{\epsilon_p} Y_t + \theta_p \pi_t^{-\gamma_p \epsilon_p} \mathbb{E}_t \Lambda_{t,t+1} x_{1,t+1} \pi_{t+1}^{\epsilon_p} \quad \text{(eqn. 024)}$$

$$x_{2,t} = p_t^{\epsilon_p} Y_t + \theta_p \pi_t^{\gamma_p(1-\epsilon_p)} \mathbb{E}_t \Lambda_{t,t+1} x_{2,t+1} \pi_{t+1}^{\epsilon_p - 1} \quad \text{(eqn. 025)}$$

A.3.3 Final-good producer

$$Y_{2,t} = Y_t \upsilon_t^p, \quad \text{(eqn. 026)}$$

where $\upsilon_t^p \equiv \int_0^1 \left(\frac{p_t(f)}{p_t} \right)^{-\epsilon_p} df$

$$\upsilon_t^p = \left(\frac{p_{t-1}}{p_t} \frac{\pi_{t-1}^{\gamma_p}}{\pi_t} \right)^{-\epsilon_p} \theta_p \upsilon_{t-1}^p + (1 - \theta_p) \left(\frac{p_t^*}{p_t} \right)^{-\epsilon_p} \quad \text{(eqn. 027)}$$

$$p_t^{1-\epsilon_p} = \left(\frac{\pi_{t-1}^{\gamma_p}}{\pi_t}\right)^{1-\epsilon_p} \theta_p p_{t-1}^{1-\epsilon_p} + (1-\theta_p)(p_t^*)^{1-\epsilon_p} \qquad \text{(eqn. 028)}$$

A.3.4 Capital-good producer

$$\hat{I}_t = \left[1 - \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \qquad \text{(eqn. 029)}$$

$$p_{K,t}\frac{\partial \hat{I}_t}{\partial I_t} + \mathbb{E}_t \Lambda_{t,t+1} p_{K,t+1} \frac{\partial \hat{I}_{t+1}}{\partial I_t} = p_t \qquad \text{(eqn. 030)}$$

A.4 Financial intermediaries

$$Q_t^{Pvt} b_t^{Pvt}(fi) + Q_t^{Gov} b_t^{Gov}(fi) + s_t = d_t + n_t \qquad \text{(eqn. 031)}$$

$$n_t = \vartheta \pi_t^{-1}\left[\left(R_t^{Pvt} - R_{t-1}^D\right) Q_{t-1}^{Pvt} b_{t-1}^{Pvt}(fi) + \left(R_t^{Gov} - R_{t-1}^D\right) Q_{t-1}^{Gov} b_{t-1}^{Gov}(fi) + \left(R_{t-1}^s - R_{t-1}^D\right) s_{t-1} + R_{t-1}^D n_{t-1}\right] + \chi$$

(eqn. 032)

$$\phi_t n_t = Q_t^{Pvt} b_t^{Pvt}(fi) + \Delta Q_t^{Gov} b_t^{Gov}(fi) \qquad \text{(eqn. 033)}$$

$$\mathbb{E}_t \Omega_{t+1} \Lambda_{t,t+1}\left(R_{t+1}^{Pvt} - R_t^D\right)\pi_{t+1}^{-1} = \frac{\lambda_{1,t}}{1+\lambda_{1,t}}\theta_t \qquad \text{(eqn. 034)}$$

$$\mathbb{E}_t \Omega_{t+1} \Lambda_{t,t+1}\left(R_{t+1}^{Gov} - R_t^D\right)\pi_{t+1}^{-1} = \frac{\lambda_{1,t}}{1+\lambda_{1,t}}\Delta\theta_t \qquad \text{(eqn. 025)}$$

$$\mathbb{E}_t \Omega_{t+1} \Lambda_{t,t+1}\left(R_{t+1}^{s} - R_t^D\right)\pi_{t+1}^{-1} = -\frac{\lambda_{2,t}}{1+\lambda_{1,t}} \qquad \text{(eqn. 036)}$$

$$\Omega_t \equiv 1 - \vartheta + \vartheta\theta_t\phi_t \qquad \text{(eqn 037)}$$

$$\theta_t\phi_t = (1+\lambda_{1,t})\,\mathbb{E}_t \Lambda_{t,t+1}\Omega_{t+1} R_t^D \pi_{t+1}^{-1} - \frac{\lambda_{2,t} s_t}{n_t} \qquad \text{(eqn. 038)}$$

$$\ln\theta_t = (1-\rho_\theta)\ln\theta + \rho_\theta \ln\theta_{t-1} + s_\theta \varepsilon_{\theta,t} \qquad \text{(eqn. 039)}$$

$$R_t^{Gov} = \frac{1+\kappa Q_t^{Gov}}{Q_{t-1}^{Gov}} \qquad \text{(eqn. 040)}$$

$$R_t^{Pvt} = \frac{1+\kappa Q_t^{Pvt}}{Q_{t-1}^{Pvt}} \qquad \text{(eqn. 041)}$$

A.5 Monetary authority

$$Q_t^{Pvt} b_t^{Pvt}(ma) + Q_t^{Gov} b_t^{Gov}(ma) = s_t \qquad \text{(eqn. 042)}$$

$$DIV_{ma,t}^{\text{real}} \equiv \frac{DIV_{ma,t}}{P_t} = \pi_t^{-1}\left[R_t^{Pvt} Q_{t-1}^{Pvt} b_{t-1}^{Pvt}(ma) + R_t^{Gov} Q_{t-1}^{Gov} b_{t-1}^{Gov}(ma) - R_{t-1}^S s_{t-1}\right] \qquad \text{(eqn. 043)}$$

$$\begin{aligned}\ln R_t^{Pol} &= (1-\rho_r)\ln\left(R^{Pol}\right)^{SS} + \rho_r \ln R_{t-1}^{Pol} \\ &+ (1-\rho_r)\left[\phi_\pi\left(\ln\pi_t - \ln\pi_C^{SS}\right) + \phi_y\left(\ln Y_t - \ln Y_{t-1}\right)\right] + s_r\varepsilon_{r,t}\end{aligned} \quad \text{(eqn. 044)}$$

$$R_t^S = R_t^{Pol} \quad \text{(eqn. 045, Scenario 1)}$$

$$R_t^S = \max\left\{1, R_t^{Pol}\right\} \quad \text{(eqn. 045, Scenario 2)}$$

$$R_t^S = \max\left\{\underline{R}, R_t^{Pol}\right\} \quad \text{(eqn. 045, Scenario 3)}$$

$$R_t^D = \max\left\{1, R_t^S\right\} \quad \text{(eqn. 046)}$$

$$b_t^{Pvt}(ma) = (1-\rho_1)\left(b^{Pvt}(ma)\right)^{SS} + \rho_1 b_{t-1}^{Pvt}(ma) + s_1\varepsilon_{1,t} \quad \text{(eqn. 047)}$$

$$b_t^{Gov}(ma) = (1-\rho_2)\left(b^{Gov}(ma)\right)^{SS} + \rho_2 b_{t-1}^{Gov}(ma) + s_2\varepsilon_{2,t} \quad \text{(eqn. 048)}$$

A.6 Fiscal authority

$$G_t + b^{Gov}\pi_t^{-1} = T_t + DIV_{ma,t}^{\text{real}} + Q_t^{Gov} b^{Gov}\left(1-\kappa\pi_t^{-1}\right) \quad \text{(049)}$$

$$\ln G_t = (1-\rho_G)\ln G^{SS} + \rho_G \ln G_{t-1} + s_G\varepsilon_{G,t} \quad \text{(eqn. 050)}$$

$$b^{Gov} = b_t^{Gov}(fi) + b_t^{Gov}(ma), \quad \text{(eqn. 051)}$$

where $b_t^{Gov}(fi) = \int b_t^{Gov}(j)\,dj$

B Calibration and Computation of Solution

The parameters, along with their corresponding values or targets for the model, are detailed in Tables B1 and B2. Table B1 outlines 14 parameters related to shock dispersion and persistence, while the other 31 parameters are enumerated in Table B2.

Table B1: Standard deviation and persistence of shocks

Parameter	Symbol	Value
SD of shock to MA's pvt. bond holdings	s_1	0.01
SD of shock to MA's govt. bond holdings	s_2	0.01
SD of shock to technology	s_A	0.0065
SD of shock to government expenditure	s_G	0.01
SD of shock to Taylor-rule policy rate	s_R	0.0025
SD of preference shock	s_Z	0.01
SD of liquidity shock	s_θ	0.04
Degree of persistence in the MA's purchase of pvt. bonds	ρ_1	0.8
Degree of persistence in the MA's purchase of govt. bonds	ρ_2	0.8
Degree of persistence of technology shock	ρ_A	0.95
Degree of persistence of government expenditure shock	ρ_G	0.95
Degree of persistence of the Taylor-rule rate	ρ_R	0.8
Degree of persistence of preference shock	ρ_Z	0.8
Degree of persistence of a liquidity shock	ρ_θ	0.98

Table B2: Calibrated parameters or targets

Parameter	Symbol	Value/Target
SS government expenditure	$\bar{G}$	0.491
Target: Govt. expenditure to GDP ratio		
Neutral policy rate	R^{Pol}	1.005
SS real govt. bond holdings of MA	$b^{Gov}(ma)$	0.21
Target: Bond value to GDP ratio		
SS real pvt. bond holdings of MA	$b^{Pvt}(ma)$	0
Target: Bond value to GDP ratio		
Fixed real govt. debt	$\bar{b}^{Gov}$	0.868
Target: Govt. debt to GDP ratio		
Habit parameter	h	0.7
Govt. bond recovery	Δ	1/3
Target: Excess return, govt. vs pvt. bonds		
Share of capital in output	α	0.33
Discount factor	β	1/1.005
Backward price indexation parameter	γ_p	0
Backward wage indexation parameter	γ_w	0
Quarterly depreciation of capital in the steady state	δ_0	0.025
Coefficient of linear term in depreciation function	δ_1	1
Target: u^{SS}		
Coefficient of squared term in depreciation function	δ_2	0.01
Elasticity of substitution between any two retail goods	ϵ_p	11
Elasticity of substitution between any two labor types	ϵ_w	11
Fraction of pvt. bonds in total bonds held by FI's	θ	0.0075
Target: Pvt. bond excess return		
Degree of price rigidity	θ_p	0.75
Degree of wage rigidity	θ_w	0.75
Fraction of FI's that survive each period	ϑ	0.95
Depreciation rate of coupon payment on bonds	κ	40
Target: Bond duration (in quarters)		
Adjustment cost of investment parameter	κ_I	2
Inverse of the intertemporal elasticity of substitution	σ	1.38
Parameter on output growth in the Taylor rule	ϕ_y	0.25
Parameter on inflation gap in the Taylor rule	ϕ_π	1.25
Inverse Frisch elasticity	φ	1
Minimum share of borrowing to finance investment	ψ	0.7582
Lumpsum transfer from household to entering FI's	χ	4
Target: Leverage ratio		
Weight on disutility of work	ω	1
Target: L_1^{SS}		

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