Monopsony, Income Risk and R^* Multiplicity[†]

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Abstract: The equilibrium real interest rate, R^*, is a key determinant of monetary policy, but what is the role of policy in determining this crucial rate and what is the cause of fluctuations in it? While traditionally R^* is viewed as independent of policy, we develop a model in which labor market monopsony and income risk give rise to multiple equilibria for R^*, and to a role for policy in determining it. In our framework, firms' debt issuance affects their labor-market power, creating a link between firms' supply of assets and the labor income risk that households face. This interaction creates a non-monotonic curve for household asset demand, leading to multiple R^*-equilibria. We show that one equilibrium always features a high interest rate and low income risk, while another features a low interest rate, high debt, and high income risk. We show that policy crucially affects R^*: central bank asset purchase programs can select the low-interest rate equilibrium and reduce R^*, while government debt issuance can raise R^* and select the high-interest rate equilibrium. Near the low-interest rate equilibrium, a rise in firms' debt supply leads to a fall in the equilibrium R^*, while the converse occurs near the high-interest rate equilibrium. We find empirical support for this prediction: changes in the asset supply give rise to different responses of interest rates before and after the Global Financial Crisis.

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"Even if asset purchases have clearly quantifiable benefits, they also come with side effects. These may be difficult to assess, as they can materialise with considerable delay." (Schnabel, 2024)

1. Introduction

The equilibrium real interest rate is generally considered a key reference point for monetary policy. The concept was formalized by Wicksell (1898; 1907) as the real interest rate that equates saving and investment and clears the goods market with output at its potential level. We will refer to this rate as R^*. It is a key driver of the low-frequency movements in the shorter-run equilibrium rate, r^*, that is also shifted by transitory shocks (Woodford, 2011). In New Keynesian models, such as Clarida et al. (1999), the stance of monetary policy depends on the gap between the real rate and its equilibrium value. In such workhorse models, there is a unique R^* and monetary policy plays no role in its determination. Classical dichotomy holds and the equilibrium real rate is determined exclusively by real factors, such as productivity, as well as other factors driving demand and supply in the market for savings such aging populations and changes in risk-taking behavior.

Because the gap between the real rate and its equilibrium value determines the stance of monetary policy, central banks must respond to movements in R^*. A major concern among Federal Reserve policymakers in revising the monetary policy strategy was to deal with the decline in R^* that increased the "likelihood that a central bank's policy rate will reach its effective lower bound (ELB) in future economic downturns" and "make it more difficult during downturns for monetary policy to support spending and employment, and keep inflation from falling too low" (Clarida, 2019, 2022).

In this paper, we revisit the drivers of R^* and challenge the view that there is a unique R^*, and that policy plays no role in its determination. While there is a well-documented gradual decline in the equilibrium real rate, our focus is on the much more steep decline that took place around and after the Global Financial Crisis (GFC)—such a decline is difficult to explain relying on the slow-moving low frequency real factors. Instead, our main contribution is to develop a model that admits multiple equilibrium real interest rates. In the model, the total level of private debt determines which equilibrium we are in. As a result, it is possible that policy actions that affect the net demand or supply of private assets, such as recent quantitative easing policies or possibly fiscal policies, can select which equilibrium real interest rate holds. This gives a potential role for balance sheet policies in determining the level of R^*—and thus, ultimately, the interest rate stance of monetary policy.

To start, we present a number of motivating empirical facts that help discipline and frame our theoretical framework. We first document that popular estimates of R^* declined smoothly around a trend until the onset of the Great Financial Crises (GFC), after which estimates of R^* fell rapidly. The overall decline from 2009-2011 was around 2pp. Crucially, although most estimates have showcased renewed volatility since then, the overall level of R^* is estimated to have remained low.

We then proceed to present five empirical regularities that motivate our theoretical analysis using micro-lelve data on firms and households. The first two relate to firms: We document that (i)firm

corporations increased their leverage and around the same time as (ii) their labor market monopsony power is estimated to have increased (Chan et al. (2024)). The next two, in contrast, relate to workers and households: We show that (iii) wages became more volatile for workers, and (iv) household saving increased markedly before gradually settling back at a level about 2pp higher than before the GFC. Finally, we attempt to link the two sets of facts by exploiting firm-level data. We document that, since the late nineties, (v) firms with higher leverage have paid systematically lower wages across most sectors in the economy.

To explain this combination of evidence, we study a workhorse macroeconomic framework with two types of households workers and entrepreneurs. Workers supply labor to firms, while entrepreneurs own firms and receive their profits but do not work. Workers are heterogeneous and supply differentiated labor to firms. They also experience stochastic shocks to their labor supply, creating variations in their income. Two central frictions interact in the model. First, incomplete financial markets prevent workers from fully insuring themselves against idiosyncratic income risk. Second, firms hold monopsony power vis-a-vis workers. However, this monopsony power does not apply to all worker types in the economy-tying labor market power to fluctuations in workersâ labor income. Consistent with our empirical evidence, we assume that a firm's monopsony power increases with its financial leverage, such that debt issuance can amplify workers' income fluctuations. In particular, a higher leverage through debt issuance allows firms to markdown wages more, which, in turn, creates a more risky environment for workers who must increase their saving to self-insure. The only source of uncertainty in the model is a sunspot shock that coordinates expectations.

Two key sets of results arise from our framework. First, we rationalize the observed decline and increased fluctuations in R^* as arising from shifts across multiple equilibria in the model economy. Second, we highlight an important role for policy in determining R^*, since asset purchase programs by monetary authorities can select a low-interest-rate equilibrium, while the issuance of government debt raises interest rates by supplying assets to households without inducing adverse income fluctuations.

Multiple equilibria for the interest rate arise in the model. Both multiple steady-state equilibria and–within a dynamic economy–multiple equilibria in each period are possible for a given state of the economy. Hence, non-fundamental (sunspot) shocks can determine which equilibrium the economy operates in. In one equilibrium, the interest rate is high, and household saving and corporate debt issuance are low. In another, the interest rate is low, and both household saving and firms' debt issuance are high. The model can thus account for the sharp decline in R^* observed at the time of the GFC as being driven by a pessimistic and persistent realization of a sunspot shock.

In the model, the possibility of multiple equilibria arises due to two crucial forces. The first is incomplete financial markets, as binding borrowing constraints prevent low-income households from smoothing consumption. The second is a linkage between firms' debt issuance and their monopsony power in the labor market, which in turn magnifies household income fluctuations.

Through the lens of the model, we can interpret recent decades as a period of tightening borrowing constraints (due to the GFC and associated financial regulation), combined with increased monopsony

power in labor markets—factors that opened the door to multiple equilibria and the associated sharper fluctuations in the equilibrim real rate, R^*.

Policy plays a key role in determining the equilibrium interest rate in our framework. First, we find that purchases by monetary authorities of assets issued by firms can lead to a substantial decline in R^*. The key mechanism is that these programs subsidize corporate debt issuance. When corporate debt issuance is positively linked to sharper fluctuations in household income, such programs increase household demand for saving, eliminate equilibria with high interest rates, and result in an equilibrium featuring high debt and low interest rates. Thus, an unintended consequence of an unconventional monetary policy meant to stabilize the economy in the presence of a lower bound on nominal interest rates can paradoxically be a reduction in R^*.

Second, we can rationalize the recent rise in R^* observed in recent years as driven by the increase in government debt associated with pandemic-related stimulus policies. Issuance of government debt increases the supply of public assets, allowing households to save without relying on firm-issued assets. This higher asset supply generates two positive effects on the interest rate. The first is improved consumption smoothing across time and states of the world, as resources are transferred from high-consumption to low-consumption households. The second (and more novel) effect is a reduction in the amount of debt issued by firms for a given level of household saving. When a linkage between corporate leverage, labor market monopsony power, and household income fluctuations is present, this lower demand for firm-issued assets reduces the adverse implications of household saving and puts upward pressure on interest rates.

Our paper is related to several strands of research. First, our paper is most related to two new papers which also examine R^* multiplicity and the possibility that policy can drive natural rates of interest. Beaudry et al. (2024) focus on determinants of asset demand and focus on the role of a growing desire to accumulate assets for retirement by households controlling for age and income. Their model, like ours, admits multiple steady-state R^* though they do not discuss dynamic equilibria. Campos et al. (2024) who show that the stock of public debt affects the natural interest rate in a HANK model. This introduces a novel monetary-fiscal interaction and highlights, as in our paper, the difficulty of monetary policy responding to the natural rates of interest where it itself is potentially policy-driven.

Second, our paper takes inspiration from the growing literature on monopsony power in labor markets. Although the idea goes back at least as far as Robinson (1933), recent interest in the topic is due to Manning (2003). In recent years there is increasing evidence that employers have wage-setting power at least over some sets of workers (Naidu and Dube (2024) provide a discussion of recent work). The source of monopsony power is typically thought to relate to (i) workers valuing a non-wage dimension of a particular employer-job match, (ii) search frictions which make it costly (potentially in terms of time and money) to leave an employer for another role, and (iii) employer concentration within a particular area or industry for which there are particular skills. Langella and Manning (2021) builds a model that nests (i) and (ii), while Schubert et al. (2024) focus on (iii). It is

likely that all can play a role and interact. Though we do not build an explicit model of monopsony power, our reduced form specification linking firm monopsony power with the amount of debt issued by the firm seems most related to a concentration channel.[1]

2. Motivating Evidence

In this section, we first discuss the recent behaviour of R^* showing that after many decades of gradual decline, likely driven by well-documented factors such as demographic trends and slowing productivity growth, around and after the Global Financial Crisis R^* fell sharply before gradually increasing albeit in a volatile way. We then present five empirical regularities that motivate our theoretical analysis. The first two relate to firms: (i) corporations increased their leverage and, around the same time, (ii) their labor market monopsony power increased. The next two relate to workers/households: (iii) wages became more volatile for workers, and household saving increased markedly before gradually settling back at a level about 2 p.p. higher than before the financial crisis. Finally, we attempt to link the two sets of facts by showing that, since the late 1990s, (v) firms with higher leverage pay lower wages. This latter regularity motivates our key novel modeling choice—higher leverage through debt issuance allows firms to markdown wages more and this creates a more risky environment for workers who must increase their saving to self-insure.

2.1 The Evolution of R^*: Smooth or Jumpy?

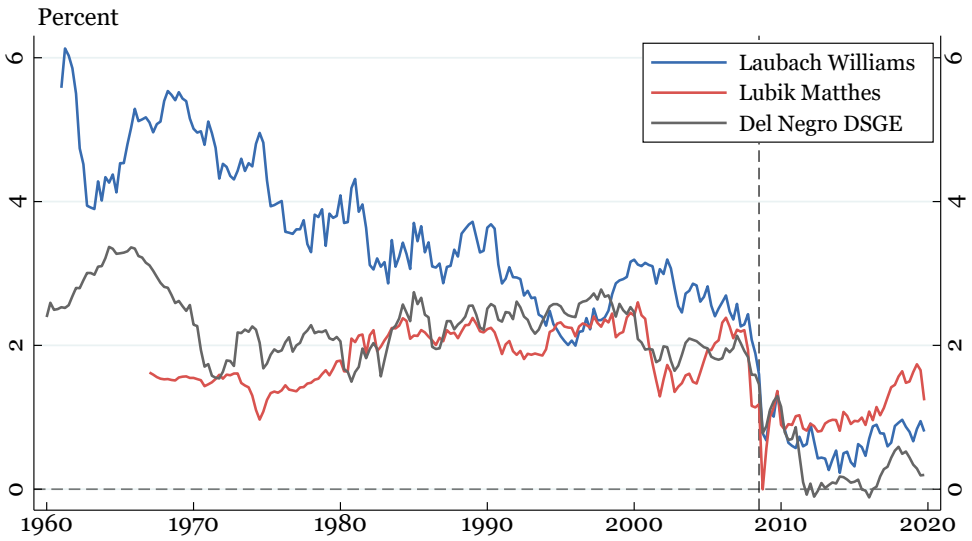
Since R^* is unobservable, a large literature has sought to estimate it using various methods, ranging from statistical filtering models to estimated DSGE models. These different approaches produce estimates of R^* with varying degrees of smoothness. To try to see the underlying movements in R^*, we look at a variety of estimated measures. These include:

- Laubach and Williams (2003): Laubach and Williams use a state-space model that links observed real interest rates with economic activity measures, such as real GDP and inflation, to extract the underlying trend in the unobservable natural rate. The methodology specifies a simple theoretical relationship and then employs a filter to dynamically estimate R^* from the data. The measure availability stretches back to January 1961. LW hereafter.

- Lubik and Matthes (2015): Lubik and Matthes employ a time-varying parameter VAR (TVP-VAR) approach to estimate the natural rate of interest. They estimate a simple TVP-VAR with three variables—the growth rate of real GDP, the PCE inflation rate, and the real interest rate (as used by Laubach and Williams)—over the period 1961 through the second quarter of

[1] Empirically, Yeh et al. (2022) show that not only is the U.S. manufacturing labor market monopsonistic, but that monopsony power has increased sharply in the last 20 years. Together with Manningâs broader theoretical perspective provide compelling support for the idea that the post-crisis period has been characterized by a structural increase in monopsony power, we link this development to important significant implications for wage inequality and labor income risk. Our novel empirical analysis suggests that financial structure plays a significant role in wage determination.

Figure 1 R^* Over Time



Note. This figure plots estimated level of R^* from Laubach and Williams (2003), Lubik and Matthes (2015), Del Negro et al. (2017), as well as a measure of R^* derived from term structure models, i.e. a 10-year real forward rate. Sample period: 1960q1 to 2019q4.

2015. Their method defines the natural rate as the conditional five-year forecast of the observed real rate, computed at each data point from 1967 onward. Because the TVP-VAR's coefficients follow random walks, the forecasts do not revert to the sample mean, effectively capturing both long-term secular trends and business-cycle dynamics,. LM hereafter.

- Del Negro et al. (2017): Del Negro et al.'s measure is derived from a medium-scale DSGE model with nominal and financial frictions, estimated using yield data along with a broad set of macroeconomic variables. The model equilibrium conditions generates a complete historical trajectory of the natural rate of interest.

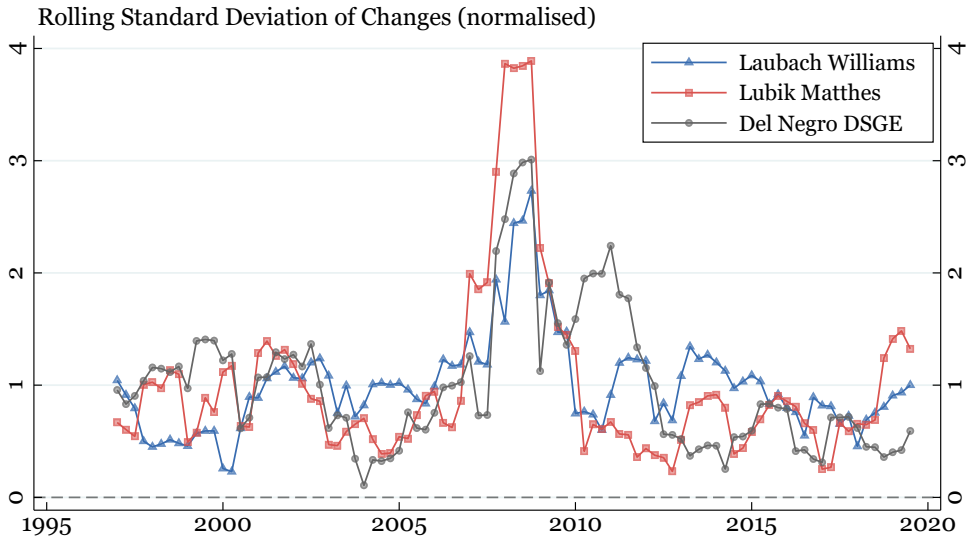
Our measures have estimates from starting as far back as 1960 Q1, with the last sample starting in 1967. Our sample runs to 2019 Q4. [2]

Figure 1 plots the estimated R^* for each of our measures. Two main facts stand out. First, different approaches estimate different precise levels at each point in time. Some of the measures, notably LW and the real yield, display a clear low-frequency downward trend until the financial crisis while such a trend is less apparent in the LM and DN-DSGE measures. Second, despite these differences, all estimates drop quickly and repeatedly over the period 2008 to 2012/2013 [MM: CHECK]. It is this sudden volatility following the GFC that is at odds with the usual low-frequency explanations for movements in R^* that we specifically aim to explain.

Another way to see this sudden change in behaviour is to look at what is typical movements in

[2]Including the 10-year forward real rate would yield similar results; however, we opt to exclude it because liquidity effects might distort its behavior.

Figure 2 Volatility of R^* Over Time



Note. This figure plots the forward 8-quarters rolling standard deviation of quarter-on-quarter changes in the R^* measures of Laubach and Williams (2003), Lubik and Matthes (2015), Del Negro et al. (2017). Sample period: 1960q1 to 2019q4.

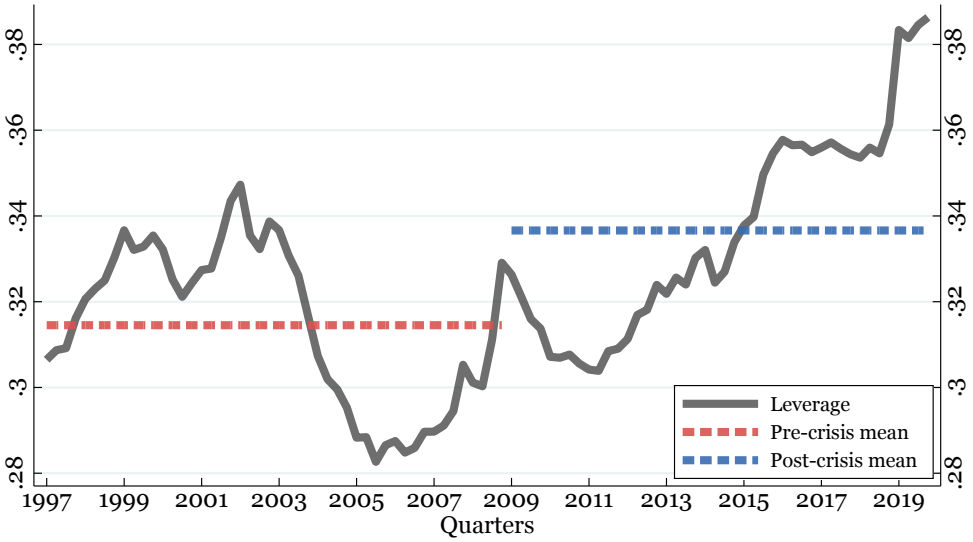
each measure. Figure 2 illustrates the rolling 8-quarters forward rolling window standard deviation of quarter-on-quarter changes in each of the R^* measures. To allow for potential fixed effects in the volatility of the different measures, each standard deviation is normalised by the average of each measure across the sample.. This figure shows that post-GFC estimates exhibit heightened volatility of quarter-to-quarter changes relative to prior to 2008. The estimates from structural or econometric models are twice or even three times as volatile in the period from 2007 to 2009. This shift highlights that the previously assumed smooth, gradual movement of R^* is not necessarily a given and it suggests that multiplicity in its estimation deserves closer attention.

2.2 Motivating Facts from Firm and Household Behavior

While the above evidence raises the possibility of multiplicity of R^* equilibria, it does not guide us as to the mechanism that might give rise to such an outcome. In this section, we bring together four data facts that directly motivate the modeling choices that we make—two relate to firms and two to households. In the next section, we show that there is evidence linking these household and firm facts which guides our key model assumption.

Fact 1: Increasing indebtedness of corporations. Since just before the GFC, with only temporary interruption amidst the height of financial disruptions, corporate leverage measured by the average ratio of total debt to total assets has increased. Specifically, we use the firm-level data from Compustat Fundamental Quarterly (WRDS) which covers publicly listed firms in the United States from 1997q1 to 2019q4. We follow standard practice as in Ottonello and Winberry (2020) to clean

Figure 3 The Evolution of Leverage



Note. This figure plots the evolution of leverage. Sample period 1997q1 to 2019q4.

the data.[3] Total assets are measured with variable `atq`, total debt is `dlcq+dlttq` and then leverage is defined the ratio of total debt to total assets. We then calculate the cross-sectional average of leverage, weighted by total assets.

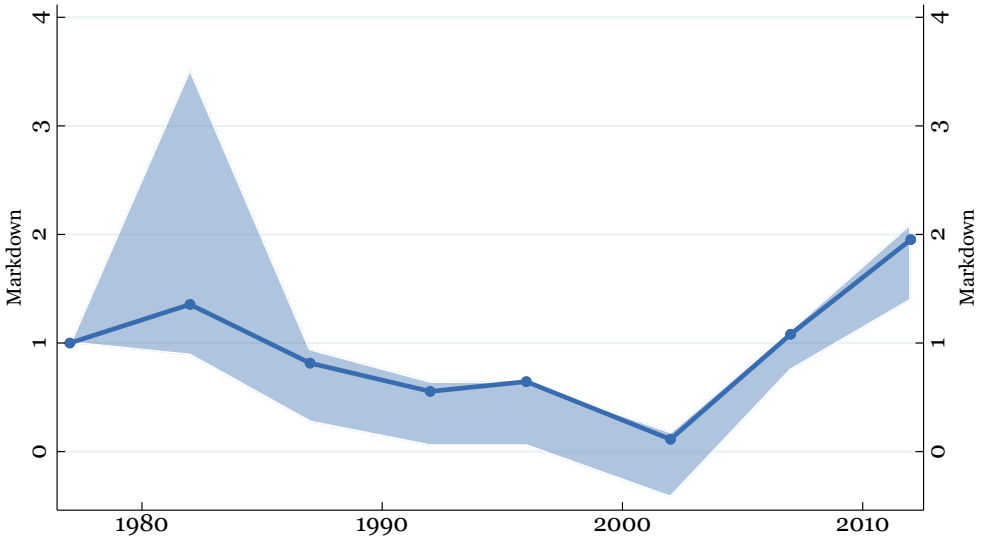
Figure 3 shows this evolution over time between 1997 and 2019. Leverage was relatively stable before the global financial crisis (arguable the low-frequency trend was a slight decline to 2007). However, in the last decade, it increased from about 0.3 to almost 0.4.

Fact 2: Monopsony power of firms has increased. Langella and Manning (2021) underscore that monopsony power is widespread in modern economies, and not merely a feature of niche or rural labor markets. They argue that monopsony arises naturally from job search frictions, labor mobility constraints, and firm-specific wage-setting power-even in otherwise competitive industries. Crucially, they highlight that monopsony power has intensified after the Global Financial Crisis, as labor market concentration increased, workers faced fewer outside options, and non-compete agreements and other restrictive employment practices proliferated. They also points to the declining elasticity of labor supply to individual firms, meaning that workers are becoming less responsive to wage changes, further strengthening firms' ability to set wages below competitive levels.

Yeh et al. (2022) present empirical estimates of the growing wage-setting power of firms. They construct wage markdowns using administrative data for U.S. manufacturers via the Census and Annual Surveys of Manufactures from the U.S. Census Bureau. These data allow them to estimate

[3]These are fully discussed in Appendix A, but include dropping duplicates, removing non-US and also financial firms (SIC code $\in$ [6000, 6799]) and dropping observations with negative assets. To mitigate the influence of extreme observations, we exclude the top and bottom 0.5% of observations for these variables.

Figure 4 Wage Markdown from Yeh, Macaluso and Hershbein (2022)



Note. Figure from Yeh, Macaluso and Hershbein (2022) showing the estimated wage markdown across US firms. The shaded area represents bootstrapped standard errors.

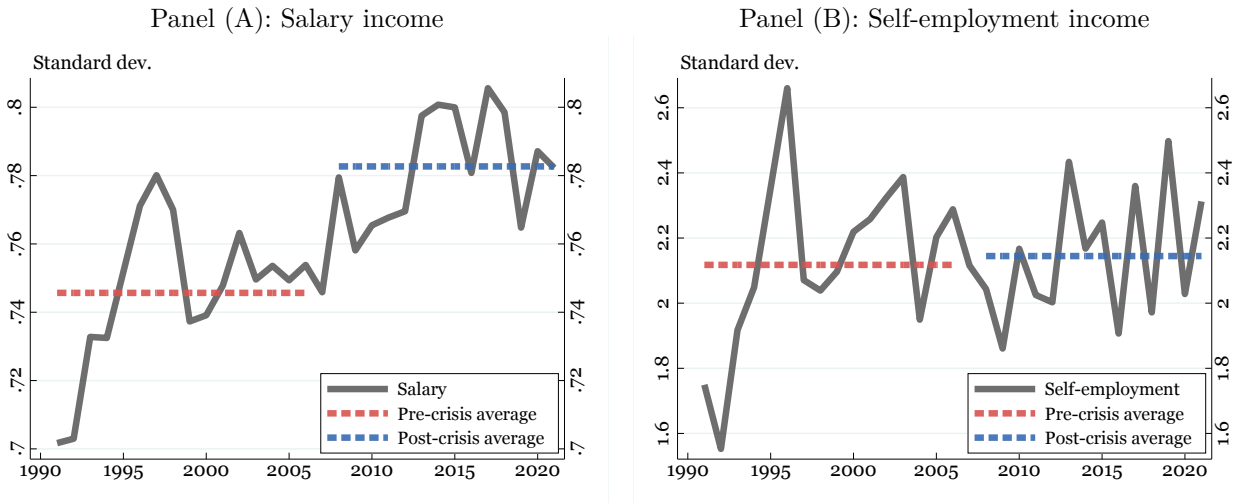
plant-level markdowns which is then aggregated and normalized such that the initial value in 1977 is 1. Their evidence runs from 1977 to 2012 and we replicate their aggregate findings in Figure 4. This figure shows that wage markdowns—an indicator of firms monopsony power—have been increasing sharply in the U.S. since just before the GFC.

Khan and Metaxoglou (2021) use the same procedure to estimate the aggregate U.S. wage markdown but applied to KLEMS data which allows them to estimate the markdown from 1987 to 2018. Like Yeh et al. (2022), they find that the markdown increased recently and was especially elevated between 2006 and 2015. Their higher frequency estimates also allow them to show aht the markdown is strongly procyclical.

Fact 3: Income risk. We document that wage dispersion in the U.S. increased by 5% after 2008. Using income microdata from the CPS (1990-2021), we analyze income risk and find that, as shown in Figure 5, the income risk of employed workers rose significantly around and after the crisis, whereas the risk for self-employed workers-who are not subject to monopsony power-remained stable. The time series also exhibits a spike in the mid-1990s, which is common to both worker types. Our findings align with prior research documenting a rise in earnings inequality around the GFC. For instance, Abowd et al. (2018) show that post-2008 earnings inequality increased, particularly among workers at the lower end of the earnings distribution.

Personal Savings Rate. A natural response to greater income risk is to increase saving. Of course, around the financial crisis there are many possible drivers of saving behaviour. But Figure 6 plots the aggregate US Personal saving rate, expressed as a % of disposable income, from the U.S.

Figure 5 Evolution of Income Risk



Note. Evolution of income risk for employed workers (panel A) and self-employed (panel B) workers. Source: CPS 1990-2021.

Bureau of Economic Analysis. This figure shows that savings started to increase strongly during 2008 and continued to rise until 2012. Even from 2013 until the Covid pandemic, personal savings remained above the average rate in the run up to the GFC.

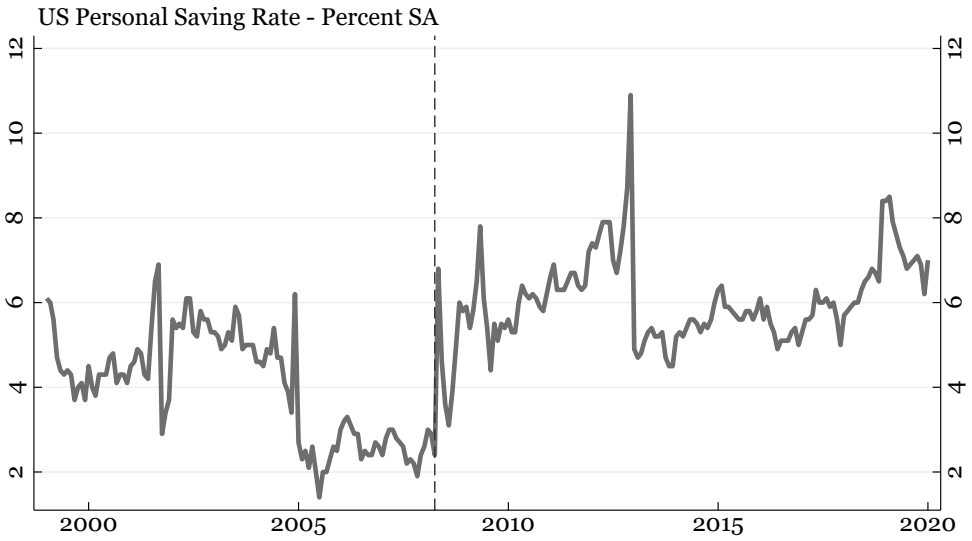
2.3 The Relation Between Debt and Wages

The empirical evidence just presented shows that firms' ability to suppress wages has grown alongside broader trends of rising corporate leverage, growing income risk for employees and higher personal savings. The parallels between rising monopsony power and corporate leverage raise essential questions about whether financial pressures, such as the need to service higher levels of debt, have reinforced firms' incentives to suppress wages. This connection may be particularly relevant for understanding post-2008 labor market dynamics.

To establish whether there is a relationship wages and firm leverage, we again use the firm-level data from Compustat data described above. We proxy for salary costs per worker (wages) using Selling, General, and Administrative Expenses' divided by the number of employees. Using this proxy increases the number of observations that we can use as the Salary variable (code `XLR`) is available only at a yearly frequency and for a limited subset of firms (about 3,000 out of 15,000 firms with `XSGA` data). We show in the appendix (Figures B6 and B7) that `XSGA` and `XLR` are closely related, and that our main results hold when using `XLR` for the smaller subset (see Tables D1 and D2 in the appendix). Additional key variables are those used already including the book value of total assets (proxying for firm size), total debt (sum of short-term and long-term debt), and leverage (total debt-to-assets ratio). As before, Appendix A provides further details on data construction.

Given these data, we would ideally compare identical firms - similar in size and industry - differing

Figure 6 Personal Saving Rate



Note. US Personal saving rate, % of disposable income. U.S. Bureau of Economic Analysis, Personal Saving Rate [PSAVERT], retrieved from FRED, Federal Reserve Bank of St. Louis.

only in their debt levels. However, in practice, this is challenging since larger firms are typically more productive, pay higher wages, and also tend to carry more debt. A naïve regression of wages on debt could therefore confound the impact of debt with productivity effects.

To address this, we estimate the following regression model:

$$Wages_{it} = \alpha_{sct,t} + \beta Assets_{it} + \gamma \left(Assets_{it} \times Leverage_{it}\right) + \Gamma Z_{it} + u_{it} \tag{1}$$

where $Wages_{it}$ is the log of salary costs per worker for firm i in quarter t, $\alpha_{sct,t}$ represents sector-time fixed effects (based on the first two digits of the SIC classification), $Assets_{it}$ is the log of total assets (proxying for firm size), $Leverage_{i,t}$ is the log of leverage, and $Z_{i,t}$ is a vector of firm-level controls, including the log number of employees.

The key coefficient is on the interaction between Assets and Leverage (γ) which captures the relationship between debt and wages while controlling for firm size. By incorporating fixed effects over the sector, our model exploits variation within the sector, helping to mitigate biases from both observed and unobserved factors that might otherwise drive the observed correlation between debt and wages. Incorporating firm fixed effects further controls for time-invariant characteristics of the firm, observed and unobserved.

Table I presents our estimation results. Our analysis reveals a strong positive relationship between wages and firm size, but crucially, firms with higher leverage (meaning higher levels of debt), pay lower wages, even after controlling for firm size. Column (1) confirms that larger firms tend to pay higher wages, while column (2) demonstrates that, conditional on firm size, higher leverage is

Table I Wages and Leverage

	(1)	(2)	(3)	(4)
Assets	0.49***	0.47***	0.36***	0.36***
	(0.02)	(0.02)	(0.01)	(0.01)
Assets × Leverage		-0.03***		-0.01***
		(0.00)		(0.00)
Sector × Time FE	yes	yes	yes	yes
Firm FE	no	no	yes	yes
Observations	285,075	285,075	284,606	284,606
R-squared	0.64	0.65	0.93	0.93

Note. Robust standard errors (clustered two-way, at the year and firm level) are reported in parentheses, with (0.00) indicating a value lower than 0.005. *** p<0.01, ** p<0.05, * p<0.1. Coefficients corresponding to the constant, fixed effects, and controls (log number of employees and log leverage) are not reported.

associated with lower wages. This negative relationship persists even after including fixed effects of the firm in columns (3) and (4).

These results suggest that financial structure plays a significant role in wage determination. In particular, they highlight the potential role of financial constraints or risk considerations in wage setting. In the next section, we will propose a novel theory that embeds a link between firm debt levels and monopsony power in labor markets. This model provides a unified explanation for the comovement between corporate leverage, monopsony power in labor markets, income risk facing workers and their need to increase savings. It yields a multiplicity of R^* equilibria and admits a potential role for stabilization policies in selecting the equilibrium.

3. The Model

We study a closed economy with two types of households: workers and entrepreneurs. Workers supply labor to firms; entrepreneurs own firms and receive their profits, but do not work. Workers are heterogeneous and supply labor of different types to firms. They also experience fluctuations in the type of labor they supply. Two key frictions interact. First, incomplete financial markets prevent workers from fully insuring themselves against idiosyncratic income risk. Second, firms hold *monopsony power* vis-à-vis workers. However, this monopsony power does not apply to all worker types—tying labor market power to fluctuations in workers' labor income—and it increases with firms' financial leverage, so debt issuance can amplify workers' income fluctuations. The only source of uncertainty in the model is a sunspot shock that coordinates expectations. We next describe the problem of workers and entrepreneurs, then characterize the equilibrium of the economy.

3.1 Workers

A continuum of worker-households populates the economy. Households come in two types, high (H) or low (L), each of constant unit mass, and they switch deterministically between types every period. These fluctuations across types may give rise to a motive for borrowing or lending, as in Townsend (1980). Each household, in turn, comprises a continuum of measure one of members, providing a differentiated labor input (task) to firms. All members pool their labor income within the household. The preferences of a household of type $j \in \{H, L\}$ are described by

$$\mathcal{U}_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_{j,t}) - \int_0^1 \frac{L_{j,t}(i)^{1+\varphi}}{1+\varphi} di \right], \tag{2}$$

where $\mathbb{E}_t[\cdot]$ is the mathematical expectation operator conditional on information available at time t, $\beta \in (0,1)$ is the household's subjective discount factor, $\varphi > 0$ is the inverse Frisch elasticity of labor supply, $C_{j,t}$ represents household consumption at time t, and $L_{j,t}(i)$ the amount of hours supplied by the member of household j that provides the differentiated labor input $i \in [0,1]$.

Households can save in risk-free bonds $B_{j,t+1}$, which pay the gross interest rate R_{t+1}. Each member receives the wage $W_{j,t}(i)$ per unit of differentiated labor input i supplied. The per-period budget constraint for a worker-household of type j is

$$C_{j,t} + B_{j,t+1} = R_t B_{j,t} + \int_0^1 W_{j,t}(i) L_{j,t}(i) di - T_{j,t}, \tag{3}$$

where $T_{j,t}$ are lump-sum taxes. Finally, households are subject to the borrowing constraint

$$B_{j,t+1} \geq 0. \tag{4}$$

Worker-household j's problem is to maximize utility (2) subject to (3) and (4).

The optimal consumption-saving decision obeys

$$1 - \mu_{j,t} = \beta R_{t+1} \mathbb{E}_t \frac{C_{j,t}}{C_{j,t+1}}, \tag{5}$$

where $\mu_{j,t}$ is the (normalized) Lagrange multiplier on the borrowing constraint. The optimal labor supply for each task i must respect

$$W_{j,t}(i) = L_{j,t}(i)^{\varphi} C_{j,t}. \tag{6}$$

The budget constraint and the borrowing constraint, with the associated non-negativity constraint on the Lagrange multiplier ($\mu_{j,t} \geq 0$), complete the set of first-order conditions for worker-households.

3.2 Entrepreneurs

A representative entrepreneur (or firm) produces output Y_t of a homogeneous good using a technology that combines labor from households of both types, H and L

$$Y_t = L_{H,t}^{\alpha} L_{L,t}^{1-\alpha}, \tag{7}$$

where $\alpha \in (0,1)$ represents the elasticity of total output with respect to labor input from households of type H. For each household type j, total labor input $L_{j,t}$ aggregates individual labor across all tasks according to

$$\log L_{j,t} = \int_0^1 \log L_{j,t}(i)\, di.$$

Firms can fund their time-t operations by issuing one-period debt, D_{t+1}, which pays a gross interest rate R_{t+1} at maturity.

The representative firm operates competitively in the goods market but exerts market power in labor markets. Crucially, the extent of this labor market power is endogenous and depends on the firm's issuance of debt. Specifically, the firm acts as a monopsonist in a fraction χ of the tasks performed by type-L workers. This fraction increases with the firm's debt issuance each period, according to

$$\chi = \chi(D_{t+1}), \tag{8}$$

with $\chi(0) = 0$, $\chi'(0) = 0$, and $\chi'(D) > 0 \ \forall D > 0$. The positive relationship between labor market power and firm leverage aligns with the empirical evidence discussed in Section 2.3. Conceptually, greater debt issuance can increase monopsony power because firms can allocate some borrowed resources toward lobbying efforts aimed at shaping labor regulations in their favor.[4]

Bond issuance entails a cost to the firm, over and above interest payments on debt. This issuance cost is given by $\psi\left(D_{t+1}, \overline{Y}_t\right)$, where $\overline{Y}_t$ denotes aggregate output, which the individual firm takes as given. The function $\psi(\cdot,\cdot)$ is convex in its first argument (debt issuance), capturing, in reduced form, the financial frictions faced by firms, whose severity increases non-linearly with the level of debt issued.[5]

Entrepreneurs are risk-neutral and discount the future at rate $\widetilde{\beta} \in (0,1)$. In each period, profits are given by

$$\mathcal{P}_t = Y_t - \int_0^1 W_{H,t}(i) L_{H,t}(i), di - \int_0^1 W_{L,t}(i) L_{L,t}(i), di + D_{t+1} - R_t D_t - \psi\left(D_{t+1}, \overline{Y}_t\right), \tag{9}$$

representing revenues net of total wages paid across all tasks, adjusted for resources raised through borrowing, and net of debt issuance costs. The entrepreneur's problem is to maximize the present discounted value of per-period profits (9), subject to the technological constraint (7) and the labor

[4] Chan et al. (2024) discuss an alternative mechanism involving adjustment costs, through which larger firms achieve greater wage markdowns.

[5] We detail the specific functional form of ψ in Section 4.3.

supply constraint (6), for all tasks where the firm exercises monopsony power-specifically, that is, the tasks of type L with $i \in [0, \chi]$. Additionally, entrepreneurs internalize how their debt issuance choice influences the fraction of tasks over which they hold monopsonistic power, as described by (8).

The entrepreneur's optimal demand for each differentiated labor input (task) is the solution to a static problem. Labor demand for tasks supplied by type H is

$$W_{H,t}(i) = \alpha \frac{Y_t}{L_{H,t}(i)}. \tag{10}$$

Similarly, labor demand for tasks supplied by type L in competitive conditions (indexed by c) is

$$W^c_{L,t}(i) = (1-\alpha)\frac{Y_t}{L^c_{L,t}(i)}, \tag{11}$$

for $i \in (\chi, 1]$. Finally, the optimal labor input for tasks supplied by type L in monopsonistic conditions (indexed by m) satisfies

$$(1+\varphi)W^m_{L,t}(i) = (1-\alpha)\frac{Y_t}{L^m_{L,t}(i)}, \tag{12}$$

for $i \in [0, \chi]$.

In equilibrium, the firm employs identical labor amounts and wages are equal across all tasks within type H, reflecting their symmetric role in both the production function and household preferences

$$W_{H,t}(i) = W_{H,t} \qquad \text{and} \qquad L_{H,t}(i) = L_{H,t}$$

$\forall i \in [0, 1]$. Similarly, within type L, equilibrium wages and employment levels are identical. For the monopsonistic sets of tasks we have

$$W^m_{L,t}(i) = W^m_{L,t} \qquad \text{and} \qquad L^m_{L,t}(i) = L^m_{L,t}$$

$\forall i \in [0, \chi]$, while for the competitive set of task we have

$$W^c_{L,t}(i) = W^c_{L,t} \qquad \text{and} \qquad L^c_{L,t}(i) = L^c_{L,t}$$

$\forall i \in (\chi, 1]$, where m and c denote the monopsonistic and competitive market, respectively.

The value function of the firm, incorporating these static results, can thus be expressed as

$$
\begin{aligned}
V(R_t D_t) = \max_{D_{t+1}} \quad & (L_{H,t})^{\alpha} (L^m_{L,t})^{(1-\alpha)\chi(D_{t+1})} (L^c_{L,t})^{(1-\alpha)[1-\chi(D_{t+1})]} \\
& - W_{H,t} L_{H,t} - \chi(D_{t+1}) W^m_{L,t} L^m_{L,t} - [1-\chi(D_{t+1})] W^c_{L,t} L^c_{L,t} \\
& + D_{t+1} - R_t D_t - \psi(D_{t+1}, \overline{Y}_t) \\
& + \widetilde{\beta}\, \mathbb{E}_t V(R_{t+1} D_{t+1}).
\end{aligned} \tag{13}
$$

The first line of this value function captures the firm's output. The borrowing decision influences output by altering the fraction χ of workers subject to monopsony power, given labor inputs across worker types and tasks: $L_{H,t}$, $L^c_{L,t}$, and $L^m_{L,t}$. The second line shows how borrowing impacts the firm's total wage bill, again through changes in the share of workers χ subject to monopsony power. The third line represents the direct effect of borrowing on the firm's available resources and the associated borrowing costs. Finally, the fourth line captures the effect on the firm's continuation value in the subsequent period.

The first-order condition associated with this problem is

$$
1 + (1-\alpha) Y_t \left[\frac{\varphi}{1+\varphi} + \ln\left(\frac{L^m_{L,t}}{L^c_{L,t}} \right) \right] \chi'(D_{t+1}) = \psi_D\left(D_{t+1}, \overline{Y}_t\right) + \widetilde{\beta} R_{t+1}. \tag{14}
$$

The left-hand side shows the benefit for the firm of issuing an extra unit of debt, which corresponds to one extra unit of resources in the current period plus the gain in terms of monopsonistic power in the labor market. The right-hand side measures the cost of issuing one extra unit of debt, which is the direct cost related to financial frictions plus the interest rate that the firm needs to pay at maturity, where $\psi_D(\cdot,\cdot)$ denotes the derivative of the cost function with respect to the quantity of debt issued. Since entrepreneurs are risk-neutral, their marginal utility of consumption is constant in all periods.

By taking the ratio of the labor market equilibrium conditions across the two subsets of type-L tasks, we can further simplify the previous expression to derive the firm's debt supply curve. This curve provides a relationship between the firm's optimally chosen debt level and the interest rate

$$
1 + \left(\frac{1-\alpha}{1+\varphi} \right) Y_t \left[\varphi - \ln(1+\varphi) \right] \chi'(D_{t+1}) = \psi_D\left(D_{t+1}, \overline{Y}_t\right) + \widetilde{\beta} R_{t+1}. \tag{15}
$$

In Section 4.3, we discuss in detail the key properties of this debt supply curve.

3.3 Government

The government levies type-specific lump-sum taxes on households and issues debt D^g_{t+1} subject to the budget constraint

$$
D^g_{t+1} = R_t D^g_t - (T_{H,t} + T_{L,t}). \tag{16}
$$

In our baseline specification, we assume that the government does not levy any taxes ($T_{H,t} = T_{L,t} = 0\ \forall t$), the initial debt level is zero ($D_0^g = 0$) and thus government debt remains zero throughout ($D_t^g = 0\ \forall t$).

3.4 Market Clearing and Equilibrium

The market-clearing condition for the goods market is that output produced must equal the sum of the consumption of the two types of worker-households and the entrepreneurs

$$Y_t = C_{H,t} + C_{L,t} + C_{E,t}, \tag{17}$$

where for the entrepreneurs, consumption equals per-period profits ($C_{E,t} = \mathcal{P}_t$).

Wages for the high-type workers and the competitive segment of low-type workers equate the marginal product of labor with the marginal rate of substitution between consumption and leisure

$$(L_{H,t})^{1+\varphi} = \alpha \frac{Y_t}{C_{H,t}} \qquad \text{and} \qquad (L_{L,t}^c)^{1+\varphi} = (1-\alpha)\frac{Y_t}{C_{L,t}}. \tag{18}$$

For the monopsonistic segment of low-type workers, instead, wages equate the marginal rate of substitution with the marginal product of labor adjusted by a markdown that depends the elasticity of labor supply

$$(L_{L,t}^m)^{1+\varphi} = \left(\frac{1-\alpha}{1+\varphi}\right)\frac{Y_t}{C_{L,t}}. \tag{19}$$

In the presence of monopsony power, low-type workers have a desire to borrow to smooth out their income fluctuations.[6] However, if the borrowing constraint (4) binds for them, they cannot do so. Therefore, in equilibria where the borrowing constraint binds for low-type workers, high-type workers save and accumulate assets, while workers of low type hold wealth and receive interest rate income. Thus, the bond market clearing condition is

$$B_{H,t+1} = D_{t+1} + D_{t+1}^g. \tag{20}$$

Since households alternate between types, the assets acquired while of type H provide self-insurance for the next period when a household becomes of type L.

Aggregate output is equal to output produced by the representative firm

$$\overline{Y}_t = Y_t. \tag{21}$$

Equilibrium definition. Given initial conditions for $\{D_0, D_0^g, B_0, R_0\}$ and government policy $\{T_{H,t}, T_{L,t}, D_{t+1}^g\}_{t=0}^{\infty}$, an equilibrium is a sequence of quantities $\{C_{H,t}, C_{L,t}, C_{E,t}, L_{H,t}, L_{L,t}^c, L_{L,t}^m, Y_t,$

[6] We consider allocations where the labor income share accruing to high-type workers is weakly higher than one half, $\alpha \geq 0.5$.

$D_{t+1}, B_{t+1}, T_t\}_{t=0}^{\infty}$ and prices $\{W_{H,t}, W_{L,t}^c, W_{L,t}^m, R_{t+1}\}_{t=0}^{\infty}$ such that households maximize utility subject to their budget constraint (i.e., equation (2)-(3)), entrepreneurs maximize profits subject to their technology and the labor supply of workers (i.e., equation (13)), all markets clear (see above), and the government budget constraint holds (i.e, equation (16)).

4. Steady State and Multiple Equilibria

This sections characterizes the steady state of the model, highlighting the possibility of multiple equilibria and discussing the underlying mechanisms driving the multiplicity. After choosing specific functional forms for monopsony power and the cost of issuing debt, we calibrate the model parameters and explore the quantitative properties of the multiple steady-state equilibria. We then analyze how shifts in the debt supply affect the equilibrium interest rate and empirically verify these theoretical predictions. Finally, we investigate the effects of asset purchase programs on equilibrium interest rates in the model.

4.1 The Steady State

A deterministic steady state of this economy is an equilibrium in which all variables are constant and there is no uncertainty. We thus omit time subscript below to simplify notation. The Euler equation of type-L workers pins down the multiplier $\mu_L > 0$, since their borrowing constraint always binds. Conversely, type-H workers are on their Euler equation

$$1 = \beta R \frac{C_H}{C_L}, \tag{22}$$

and their borrowing constraint is slack ($\mu_H = 0$).

Consumption of type-L workers is equal to their labor income, augmented by wealth and interest income accrued from savings accumulated in the previous period when they were type-H workers. Using their budget constraint, this consumption level is given by

$$C_L = (1-\alpha)\left[1 - \frac{\varphi}{1+\varphi}\chi(D)\right] Y + RD. \tag{23}$$

Similarly, consumption of type-H workers equals their labor income net of savings

$$C_H = \alpha Y - D. \tag{24}$$

The labor income of type-H workers is proportional to their contribution to total output, determined by the share α. In contrast, type-L workers earn less than the competitive benchmark of $(1-\alpha)$ of output. This lower labor income arises because a fraction χ of type-L workers is subject to firms' monopsonistic power in the labor market. The term $\varphi\chi D/(1+\varphi)$ captures the extent of the wage markdown resulting from monopsony.

The household demand for bonds follows from substituting the consumption levels of type-L workers, given by (23), and type-H workers, given by (24), into the Euler equation of type-H workers (22)

$$\beta R = \frac{(1-\alpha)\left[1 - \frac{\varphi}{1+\varphi}\chi(D)\right]Y + RD}{\alpha Y - D}. \tag{25}$$

This expression for the bond demand is central to our results, and we discuss its properties in detail in the following subsection.

The steady-state firms' asset supply curve follows closely from the supply curve in (15)

$$1 + \left(\frac{1-\alpha}{1+\varphi}\right)\left[\varphi - \ln(1+\varphi)\right]\chi'(D)Y = \psi_D(D,Y) + \widetilde{\beta}R. \tag{26}$$

Consumption of the entrepreneurs is equal to monopsony profits, net of interest payments on debt and of borrowing costs

$$C_E = (1-\alpha)\left[\frac{\varphi}{1+\varphi}\chi(D)\right]Y - (R-1)D - \psi(D,Y). \tag{27}$$

Imposing the above results for consumption levels into the labor market clearing conditions determines hours worked by each type of worker

$$L_H = \left(\frac{\alpha Y}{\alpha Y - D}\right)^{\frac{1}{1+\varphi}}, \quad L_L^c = \left[\frac{(1-\alpha)Y}{(1-\alpha)Y + RD}\right]^{\frac{1}{1+\varphi}}, \quad \text{and} \quad L_L^m = \left(\frac{1}{1+\varphi}\right)^{\frac{1}{1+\varphi}} L_L^c. \tag{28}$$

In the next subsection we explain how the properties of workers' asset demand may give rise to multiple steady-state equilibria in this model.

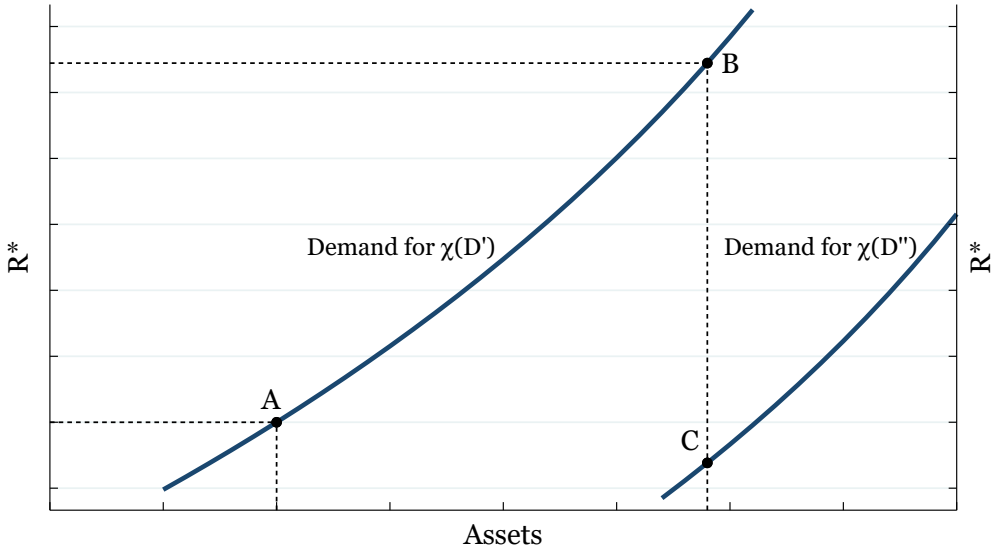
4.2 Steady-State Multiplicity, Monopsony, Income Fluctuations, and Asset Demand

Households' asset demand (25) plays a crucial role in generating the potential for multiple steady state equilibria. The impact of higher corporate debt on the interest rate along this demand for bonds is, in general, ambiguous.[7] On the one hand, higher debt allows workers to better smooth consumption over time, exerting upward pressure on the interest rate. On the other hand, higher corporate debt increases firms' monopsonistic power in the labor market, depressing the labor income of type-L workers. This amplifies workers' income fluctuations, raises their demand for insurance, and exerts downward pressure on the interest rate.

Figure 7 illustrates workers' asset demand and the impact of monopsony power on it. Consider an initial debt-interest rate pair at point A, assuming a constant degree of monopsony power $\chi = \chi(D')$. Under this assumption, the demand curve exhibits a positive slope. If type-H households acquire

[7] Throughout this analysis, we refer to corporate debt simply as "debt," since we abstract for the moment from government debt, and since households face a zero borrowing constraint and thus cannot issue debt.

Figure 7 Steady State Demand for Debt



Note. This figure plots the steady state asset demand (25) for two different values of the degree of monopsony power, $\chi(D')$ and $\chi(D'')$.

more assets, they transfer additional resources to the type-L state, causing the equilibrium interest rate R to rise. Therefore, if households purchase more debt and firms issue debt without increasing monopsony power, the economy transitions from point A to point B, characterized by higher debt and a higher interest rate. We refer to this mechanism as the *insurance effect*, consistent with standard models.

However, in our framework, higher corporate debt issuance increases firms' monopsonistic power, reducing consumption in the type-L state. This reduction shifts workers' asset demand downward, an effect we call the *monopsonistic effect*. Hence, rather than moving from point A to point B, the economy shifts from point A to point C.

Consequently, the equilibrium impact of increased corporate debt on the interest rate R is ambiguous. If the insurance effect dominates, the asset demand curve remains positively sloped. Conversely, if the monopsonistic effect prevails, the asset demand curve becomes negatively sloped. The monopsonistic effect dominates when the increase in monopsony power due to higher corporate debt issuance is sufficiently large.

A necessary condition for multiple equilibria to exist is that, at some debt-interest rate combination, the monopsonistic effect outweighs the insurance effect, causing the asset demand curve to be negatively sloped. When both debt demand and supply curves are negatively sloped, multiple equilibria can arise. Conversely, if debt demand is upward-sloping and debt supply in downward-sloping, as standard, a unique equilibrium exists.

Can multiple equilibria occur? The answer is affirmative. We identify a simple parametrization of the model under which multiple equilibria emerge. We present this parametrization in the next

subsection. Importantly, however, the existence of multiple equilibria does not rely on this specific calibration. Rather, what matters is that monopsony power $\chi(D)$ increases sufficiently strongly with debt issuance D over a certain range of debt levels.

4.3 Functional Forms, Parametrization, and Quantitative Properties of Steady States

In this section, we impose functional forms and parameter values for the key functions $\chi(D)$ and $\psi(D)$, as well as all other parameters in the model. In particular, $\chi(D)$ governs how debt affects firms' monopsony power, while $\psi(D)$ shapes the cost of bond issuance and the asset supply curve. We then calibrate the model to match the quantitative properties of the equilibrium to standard empirical targets.

Two opposing forces operate on the demand for debt, the monopsonistic and the insurance effect, as discussed in the previous section. The functional form of $\chi(D)$ plays a key role in shaping the magnitude of the monopsonistic effect, and thus the shape of the demand function (25). We postulate a flexible formulation for the way in which debt affects the monopsonistic power of firms, given by

$$\chi(D) = \frac{\gamma_1 D^{\gamma_2}(1+D)}{1+\gamma_1 D^{\gamma_2}(1+D)}, \tag{29}$$

where γ_1 and γ_2 are positive parameters.

In addition to $\chi(D)$, the shape of the supply curve (26) depends on the functional form for the cost of issuing debt

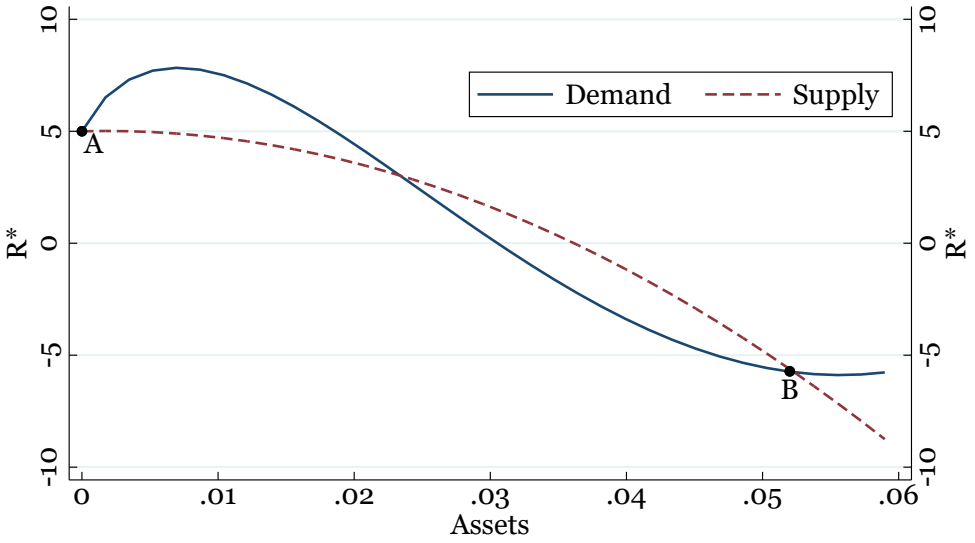
$$\psi(D, \overline{Y}) = [\delta_1 \chi(D) + \delta_2 D^2 + \delta_3 D^3]\overline{Y} \tag{30}$$

The first term "undoes" the effects of $\chi(D)$ on the supply of bonds. The remaining terms amount to a convex adjustment cost. We choose δ_1, δ_2 and δ_3 to characterize the shape of the supply curve.

We calibrate the model at quarterly frequency. The discount factor of entrepreneurs ($\widetilde{\beta} = 0.9877$) implies an annualized real interest rate equal to 5% when debt is zero. We then impose that households are more impatient than entrepreneurs ($\beta < \widetilde{\beta}$) to ensure that workers of type-L are always against the borrowing constraint. Assuming a 8% annualized discount rate gives $\beta = 0.9804$. Replacing (23) and (24) with $D = 0$ into the Euler equation for type-H workers (22) pins down an implied value for α, which turns out to be equal to 0.5018. We further choose an inverse Frisch elasticity of labor supply (φ) equal to 3, which corresponds to an intermediate value between micro and macro estimates. Finally, we set the parameters that govern the function $\chi(\cdot)$, γ_1 and γ_2, equal to 25.95 and 1.366, respectively, and the parameters of the bond issuance cost function $\psi(\cdot,\cdot)$, δ_1, δ_2 and δ_3, equal to 0.2035, 0.0387 and -10.7913, respectively.

Multiple steady-state equilibria emerge in this economy, as the parametrization above implies a strong effect of firms' bond issuance on their monopsony power, leading to a steep downward-sloping segment of the bond demand curve. Consequently, bond demand and supply intersect at

Figure 8 Steady State Equilibria in the Debt Market



Note. The figure plots R^* as a function of assets (D). The solid blue line is the demand for bonds. The dashed red line is the supply of bonds. The points A and B denote two stable steady state equilibria in the debt market. A third, unstable equilibrium is also possible.

three interest rate-debt pairs, corresponding to three steady-state equilibria. Two of these equilibria are stable, while one is unstable. Figure 8 illustrates the intersection of steady-state bond demand and supply, with A and B denoting the two stable equilibria. We discuss the properties of these stable equilibria below.

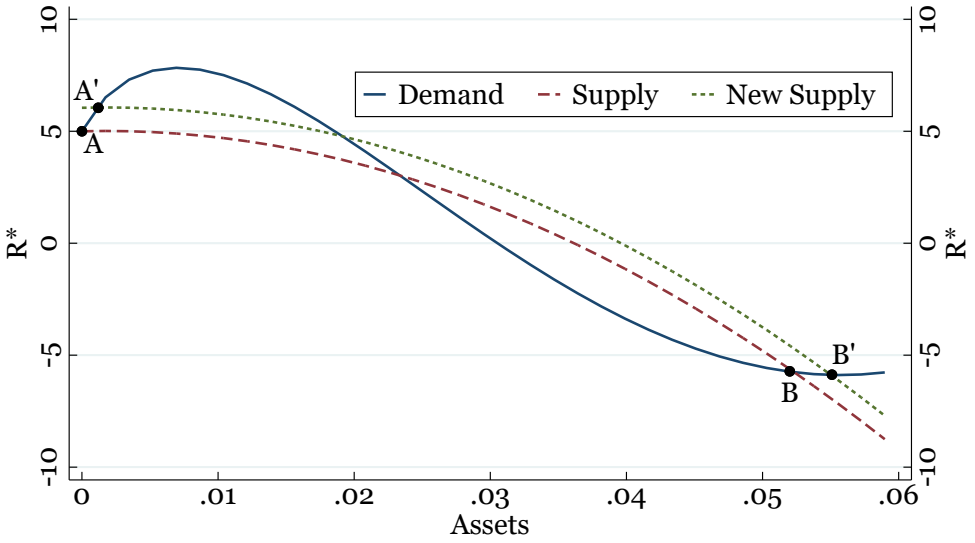
The two stable equilibria differ markedly in several respects. In equilibrium A, debt is low (normalized to zero) and the real interest rate is relatively high (5%), corresponding to the inverse of the discount factor of the entrepreneurs. At zero debt, firms have no monopsony power in the labor market, and wages are equal to the marginal product of labor for all households. As a result, the only source of household income fluctuations arises from the difference in labor income shares. Indeed, evaluating consumption of the two worker types, (23) and (24), when $D = 0$ gives

$$C_L = (1-\alpha)Y \qquad \text{and} \qquad C_H = \alpha Y.$$

Furthermore, unless firms' monopsony power rises sharply with debt issuance when debt is near zero, the households' bond demand curve exhibits a conventional positive slope in the vicinity of this equilibrium.

In contrast, in equilibrium B, firms issue a positive amount of debt, which households of type H purchase, while households of type L hold maturing claims against firms acquired in the previous period. Under our calibration, the steady-state debt level in this equilibrium B equals 0.05. When debt is sufficiently high, its issuance significantly increases firms' monopsony power. As a result, asset purchases by type-H workers exacerbate income and consumption fluctuations rather than

Figure 9 A Debt Supply Shock



Note. The figure plots a shift in the supply of debt (from red dashed to green dotted line). The new stable equilibria are points A' and B'.

smoothing consumption through self-insurance. In this region, the monopsonistic effect dominates over the insurance effect. Consequently, the real interest rate in this equilibrium is low (-5.7%), with type-H households enjoying higher income and consumption than type-L households, whose average wage is 23% below their marginal product of labor due to firms' labor market power.

4.4 Shifts to the Supply of Debt

Our goal in this section is to validate the model by testing a key prediction against the data. While directly proving the existence of multiple equilibria is challenging, we can examine an observable implication: the slope of bond demand before and after the Global Financial Crisis. Specifically, our model predicts that the relationship between bond demand and interest rates differs across the two steady-state equilibria, with a positive slope near the low-interest-rate equilibrium and a negative slope near the high-interest-rate one. Consistent with this prediction, we find empirically that before 2008, the slope of bond demand was positive, whereas after 2008, it turned negative. This structural change provides empirical support for our model and highlights a fundamental shift in post-crisis financial market dynamics.

We illustrate the implications of an increase in the supply of bonds in the model in Figure 9. We obtain the shift in the supply curve by lowering the discount factor of entrepreneurs $\widetilde{\beta}$ from 0.9877 to 0.9851.[8]

[8] Alternatively, the same shift in the supply curve could be achieved by introducing a proportional subsidy on the interest rate for debt issuanceâsuch as through favorable tax treatmentâfinanced by a lump-sum tax on entrepreneurs to maintain budget neutrality for the government.

Consider initially the high-interest-rate equilibrium at point A. If the economy remains in the vicinity of this equilibrium following a shift in debt supply, the interest rate rises. For low levels of debt, the standard insurance effect dominates: higher debt issuance by firms enables workers to better smooth consumption fluctuations, leading to a higher interest rate. However, for sufficiently high debt levels, the demand curve slopes downward. As a result, near the low-interest-rate equilibrium at point B, an increase in bond supply reduces the real interest rate. While the model does not inherently select between the two equilibria, Figure 9 highlights a testable implication: the effect of increased debt issuance on the real interest rate differs across the two steady-state equilibria.

Our empirical strategy to shed light on the possibility of multiple equilibria is to study how a shock to firms' debt issuance affects the equilibrium real interest rate R_t^* using data from the non-financial corporate sector. For this purpose, we create an instrumental variable that exploits the large degree of heterogeneity in leverage across COMPUSTAT firms, allowing us to identify an exogenous increase in firm debt. The sample covers the period 1997q1-2019q4. Following Gabaix and Koijen (2024), we construct a Granular Instrumental Variable (GIV) by using variation across firms and over time of large firms' outstanding debt. Specifically, we first extract firm-level idiosyncratic debt innovations from our large panel of US corporations. Second, we construct the GIV by computing the difference between a size-weighted and an equal-weighted average of these firm-level innovations. Third, after checking that the GIV satisfies the appropriate requirements, we run local projections to estimate how R_t^* responds to exogenous shifts in firms' debt issuance.

The first step of our approach consists of isolating idiosyncratic changes in firm-level debt by estimating the regression

$$\Delta D_{i,t} = \alpha_i + \alpha_{sct,t} + \epsilon_{i,t}, \tag{31}$$

where $D_{i,t}$ is debt of firm i at time t, α_i is a firm fixed effect controlling for time-invariant firm characteristics and $\alpha_{sct,t}$ is a sector-time fixed effect based on the first two digits of the SIC classification. The estimated residuals $\hat{\epsilon}_{i,t}$ capture movements in firm-level debt that cannot be explained by sector-specific common factors or individual fixed effects.[9]

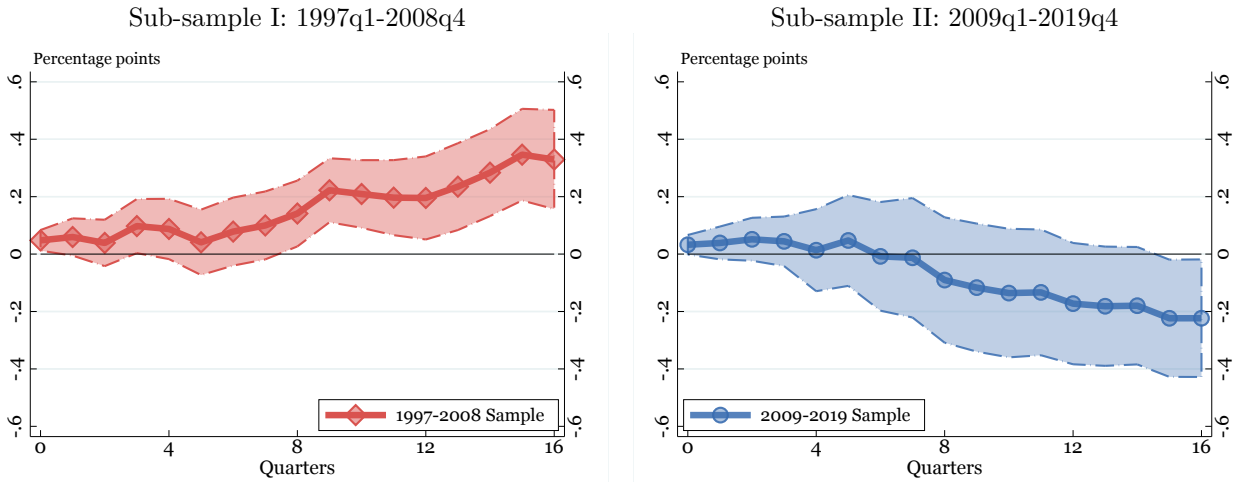
In the second step, we construct the granular instrument by taking the difference between the size-weighted average and the equal-weighted average of the firm-level idiosyncratic debt innovations $\hat{\epsilon}_{i,t}$

$$\mathrm{z}_t = \sum_{i=1}^{N_t} w_{i,t-1}\hat{\epsilon}_{i,t} - \frac{1}{N_t}\sum_{i=1}^{N_t}\hat{\epsilon}_{i,t} \tag{32}$$

where N_t is the total number of firms in each period and $w_{i,t}$ is the weight of firm i at time t, so that both weights add up to one in all periods (i.e., $\sum_i w_{it} = \sum_i (1/N_t) = 1 \ \forall t$). In our baseline specification, we use weights based on firms' total assets, which satisfy standard granularity assumptions (see Appendix C for details).

[9] An alternative approach would be to run a principal component analysis on the panel of firms and use the variation not explained by the first few components as a proxy for idiosyncratic firm-level variation. Given the unbalanced nature of our panel, we favor the fixed-effect approach.

Figure 10 The Response of R^* to a Debt Issuance Shock



Note. Dynamic response of R_t^* to an exogenous increase in firm debt identified using a granular instrumental variable approach (Gabaix and Koijen, 2024) in a local projection specification (Jorda, 2005). The weights are computed with total assets. The local projection specification controls for one lag of the instrument, one lag of the dependent variable, and one lag of GDP growth. The sample period is 1997q1-2008q4 for the left panel, and 2009q1-2019q4 for the right panel.

Finally, the third step is to estimate the effects of a shock to firms' debt issuance on the equilibrium real interest rate by means of a local projection specification

$$R^*_{t+h} - R^*_{t-1} = \alpha^h + \alpha^h_q + \beta^h z_t + \sum_{\ell=1}^{P} \gamma^h X_{t-\ell} + \nu_{t+h} \tag{33}$$

where R_t^* is the estimated 30-year-forward short-run equilibrium interest rate from the DSGE model of Del Negro et al. (2017), α^h is a constant, α^h_q is a quarterly dummy to capture seasonality effects, $X_{t-\ell}$ is a vector of controls that includes real GDP growth, lags of R_t^*, and lags of the granular instrument, and ν_{t+h} is a residual.[10]

The two panels of Figure 10 show the impact of an exogenous increase in firms' debt issuance on the equilibrium real interest rate up to 16 quarters (that is, the coefficient β^h with $h = 0, ..., 16$), for two sub-samples of roughly equal length.[11] For the first sub-sample (left panel), which covers the period from 1997 until the financial crisis of 2008, higher corporate debt issuance raises the equilibrium real interest rate. This response aligns well with the standard intuition of the effects of an increase in supply. As firms issue more debt, its price should fall and the return should increase. This adjustment is consistent with a positively sloped households' demand for assets, as depicted in Figure 9 when the equilibrium moves from A to A'.

The right panel of Figure 10 shows the response of the equilibrium real interest rate to an

[10] In robustness exercises, we consider alternative 'macro' measures of R_t^*, including those by Laubach and Williams (2003) and Lubik and Matthes (2015), as well as a measure derived from term structure models, i.e. a 10-year real forward rate.

[11] Appendix D shows that in the full sample (1997-2019), an asset supply shock leads to a mild increase of R_t^*.

exogenous increase in firms' debt issuance in the second sub-sample, which runs from 2009 to 2019. In this case, the sign of the response flips compared to the pre-crisis sub-sample. An increase in firms' debt issuance now leads to a drop in R_t^*. This response to an outward shift of the supply schedule is inconsistent with a positively-sloped demand for assets. Instead, the demand curve must be negatively sloped, at least locally, as in Figure 9 when the equilibrium moves from B to B'.

Interpreted through the lens of the model, the empirical results suggest a structural shift in the relationship between debt issuance and the equilibrium real interest rate after the Global Financial Crisis. Before 2008, the economy fluctuated around a high-interest-rate equilibrium, such as point A, where higher debt issuance raised the real interest rate, consistent with an upward-sloping asset demand curve. After 2008, the economy transitioned to a low-interest-rate equilibrium, similar to point B, where increased debt supply lowered the real interest rate due to a downward-sloping asset demand curve. The next section explores potential drivers of this shift from a high- to a low-interest-rate equilibrium.

4.5 Steady-State Effects of Asset Purchase Programmes

Having empirically validated the model's predictions on the debt–interest rate relationship, we now examine the implications of government policy shifts within the model. Our focus is on the impact of large-scale asset purchases, such as quantitative easing, on equilibrium outcomes. We first outline how quantitative easing operates within our framework. We then present the steady-state results, highlighting the impact of quantitative easing effects on the equilibrium interest rate.

Consider a government that purchases debt issued by firms by raising resources from taxation on both households.[12] We denote by B^G the amount of corporate debt purchased by the government. This exercise illustrates the implications of a fiscal authority that permanently holds assets vis-à-vis the corporate sector, and compares them with a baseline setting under which government asset holdings are zero. In equilibrium, the steady-state consumption of type-L workers becomes

$$C_L = (1-\alpha)\left[1 - \frac{\varphi}{1+\varphi}\chi(D)\right] Y + RB^P - T_L, \tag{34}$$

where B^P represents private asset holdings and T_L denotes taxes for type-L workers. Similarly, for type-H workers, consumption is

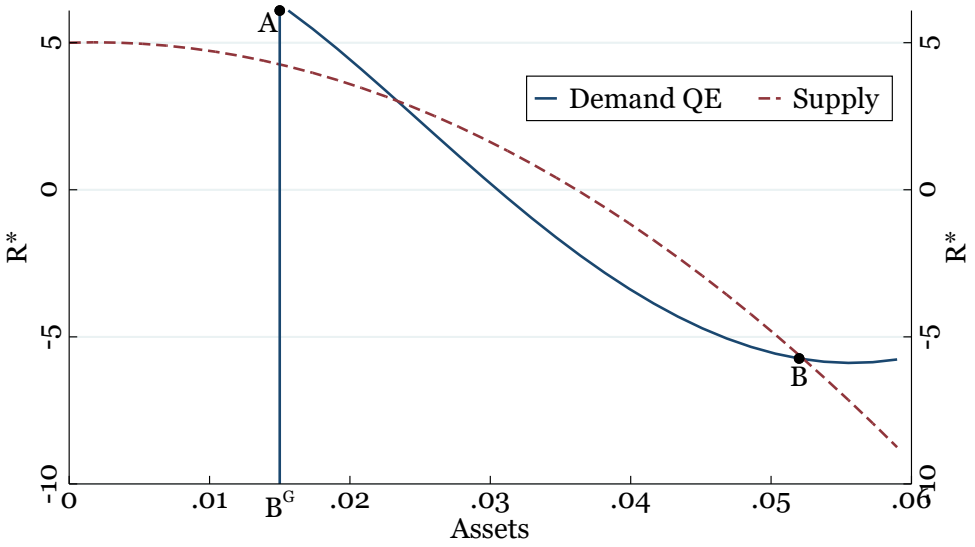
$$C_H = \alpha Y - B^P - T_H, \tag{35}$$

where T_H denotes their taxes. The government's steady-state budget constraint is

$$(R-1)B^G = -T, \tag{36}$$

[12] Purchases of private-sector issued assets accounted for a relatively small fraction of QE-related asset purchases. However, this exercise also captures in a simple way the QE-induced rise in demand for corporate debt, as investors sought higher yields in response to lower returns on government debt caused by central bank purchases of government securities, and through the reduction in corporate risk that such programmes generated (Krishnamurthy and Vissing-Jorgensen, 2011).

Figure 11 Asset Purchase Programme



Note. The figure plots the effects of a fiscal authority permanently increasing its purchases of corporate debt to B^G. The red dashed line is the bond supply, while the blue line is the shifted bond demand, where B^G is the minimum amount of corporate debt H households must hold. If B^G moves beyond the unstable equilibrium, point A disappears, and the economy converges to point B.

where total tax revenue is $T = T_L + T_H$. For simplicity, we assume that the government only taxes type-H households to finance its purchases and transfers the returns on its asset holdings to type-L workers, so that

$$T_H = B^G \qquad \text{and} \qquad T_L = -RB^G. \tag{37}$$

Under these tax rules, the private demand for corporate debt remains unchanged relative to the baseline scenario. Notably, this fiscal rule is equivalent to a government issuing public debt to purchase corporate debt, provided that type-H households fully absorb the public debt issuance.

Figure 11 illustrates the impact of this steady-state asset purchase programme. In this setup, type-H households indirectly hold at least B^G in corporate debt through government intervention. Consequently, asset holdings below B^G are no longer feasible, and the lowest-debt equilibrium shifts to the new point A in Figure 11. In this equilibrium, firm-issued debt is positive and equal to B^G, while the interest rate is lower than in the low-debt equilibrium of the baseline model.[13] The key mechanism is that increased government demand prompts firms to issue more debt, which in turn strengthens their monopsony power in the labor market. Greater monopsony power increases wage markdowns for low-type workers, amplifying their income fluctuations. Ultimately, government asset purchases impose a negative externality on workers by lowering their labor income and increasing its

[13]Since the asset demand curve slopes upward at low debt levels in the baseline setting, the low-debt equilibrium under government asset purchases features a lower interest rate if asset purchases are sufficiently large, which is the case considered here.

volatility.

A sufficiently large government purchase of corporate debt can eliminate the high-interest-rate/low-debt equilibrium. In Figure 11, if B^G exceeds the debt level of the unstable equilibrium, the intersection of asset demand and supply at point A vanishes, leaving only the low-interest-rate, high-debt equilibrium at point B. The next section examines the economy's dynamic equilibrium, showing that even smaller asset purchases—insufficient to eliminate the high-interest-rate steady-state equilibrium—can still push the economy toward the low-interest-rate steady state. This occurs because government purchases shrink the range of asset levels that can sustain a high-interest-rate equilibrium, making it less likely for the economy to remain there.

This experiment highlights a possible, unintended consequence of asset purchase programmes, as suggested in Schnabel (2024). However, by abstracting from both their positive effects and other potential costs, our model does not provide a comprehensive evaluation of quantitative easing programmes. Instead, our objective is to demonstrate that unconventional monetary policy can interact with structural features of the economy in ways that lead to unintended and persistent changes in equilibrium outcomes.

Can asset purchase programmes fully rationalize the post-GFC volatility in R^*? The answer is no. While our model allows for multiple steady states, it does not yet explain the mechanism that drives the transition between them. What causes the observed volatility? To address this question, we now analyze the dynamic equilibria of the model economy, relaxing the assumption that household asset purchases must be constant over time. We show that both sunspot equilibria and policy interventions can generate the fluctuations in R^* in line with the data, providing a potential explanation for the post-GFC volatility in equilibrium interest rates.

5. Equilibrium Interest Rate Dynamics

In this section, we characterize the dynamic equilibria of the model. First, we discuss the properties of the model that give rise to multiple equilibiria, and thus to a role for sunspot shocks in determining interest rate and debt levels. Second, we analyze a range of scenarios for sunspot shocks and government policies that can rationalize the post-Global Financial Crisis experience of low and volatile equilibrium real interest rates.

5.1 Dynamic Equilibria, Multiplicity, and Sunspots

Our economy allows for dynamic equilibria that differ from steady states. In these dynamic equilibria, households' expectations about their next-period consumption play a crucial role in determining the households' bond demand and, therefore, the equilibrium real interest rate. Just as multiple steady-state equilibria are present, multiplicity of equilibria can also arise in this dynamic setting. As a result, the realization of a sunspot shock that coordinates households' expectations about next-period consumption can potentially determine consumption and the interest rate in each period. In what

follows, we first describe an algorithm that allows us to characterize dynamic equilibria in the model economy. Next, we show that multiple dynamic equilibria are possible if the economy is expected to be in steady state from the subsequent period onward, giving rise to the potential for sunspot shocks to select among such multiple equilibria. Then, we introduce a process for sunspot shocks and characterize the sunspot equilibrium. In the next section, we analyze the quantitative predictions of this economy with sunspot equilibria.

5.1.1 Dynamic Equilibria

We characterize the dynamic equilibria as follows. First, we determine output, consumption, employment, and wage levels consistent with households' and firms' optimality given households' wealth, for all possible choices about bonds carried to the next period. Second, we characterize how households' expectations pin down the households' bond demand—i.e., the real interest rate associated with households' optimality for any choice of household savings, given household wealth. Third, we characterize firms' bond supply, which is a constant function in every period and closely related to the one in the steady-state setting. Finally, we characterize dynamic equilibria as the intersection of bond demand and supply. We show that for any level of initial wealth that households hold, multiple equilibria may arise, depending on the realization of the sunspot shock that coordinates households' expectations about next-period consumption.

First, output produced in the economy is a function of households' initial wealth $R_t B_t$ and choice of next-period bonds B_{t+1}, which we obtain from the solution of a static system of equations. We denote this relationship between output, wealth, and saving as $Y_t = Y(B_{t+1}, R_t B_t)$. Given the households' budget constraint and equilibrium in the labor market, we can also determine a similar function for consumption of the high-type household, that is, $C_{H,t} = C_H(B_{t+1}, R_t B_t)$.[14]

Second, we characterize households' bond demand, given their expectation about the next-period policy function for the consumption of the L-type household, as a function of next-period wealth $R_{t+1}B_{t+1}$, which we denote as $C_L^*(R_{t+1}B_{t+1})$. Using the consumption functions of the high and low-type household into the high-type household Euler equation at time t (5), we obtain

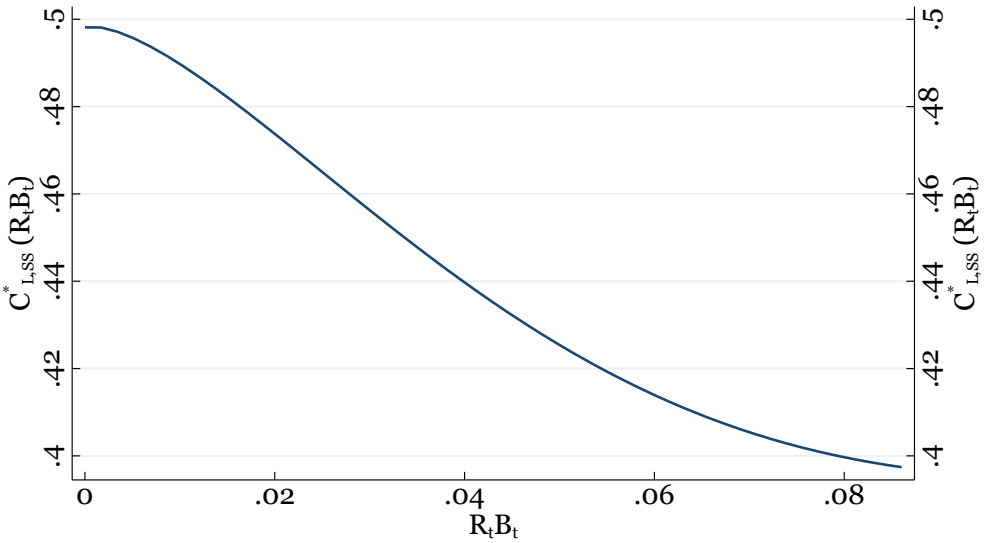
$$\frac{1}{C_H(B_{t+1}, R_t B_t)} = \beta R_{t+1} \mathbb{E}_t \left[\frac{1}{C_L^*(R_{t+1}B_{t+1})} \right]. \tag{38}$$

The solution of the non-linear equation above determines R_{t+1} as a function of $R_t B_t$ and B_{t+1}, which corresponds to the bond demand $R^d(B_{t+1}, R_t B_t)$.

Third, we determine the equilibrium choice for bonds by combining the household demand for bonds $R^d(B_{t+1}, R_t B_t)$ with the supply by firms. The supply of bonds is unchanged relative to the steady state, except for the dependence of Y_t on wealth and savings, and it is given by (26). The equilibrium interest rate and bond issuance are the values for R_{t+1} and B_{t+1} that jointly satisfy bond

[14] Appendix F.2 outlines in full the derivation of these two functions.

Figure 12 Initial Guess for Consumption Policy Function



Note. The figure plots an initial guess for the low-type consumption policy function $C^*_{L,ss}(R_{t+1}B_{t+1})$ based on the steady-state solution.

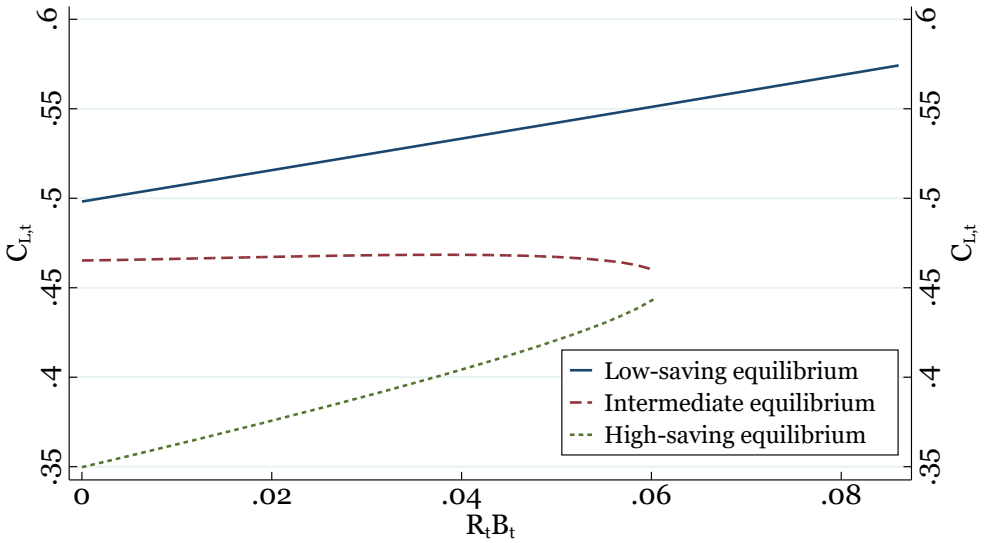
demand and supply, (38) and (26), imposing the market-clearing condition for the bond market (20) and that output and consumption of the high-type households are determined by $Y(B_{t+1}, R_tB_t)$ and $C_H(B_{t+1}, R_tB_t)$. The intersection pins down the equilibrium choice for bonds as function of initial wealth, $B_{t+1} = B^*(R_tB_t)$.

5.1.2 Equilibrium Multiplicity

Multiple equilibria are possible for any given level of initial wealth R_tB_t. To illustrate why this is the case, consider first the case in which households expect the equilibrium choice of bonds in the following periods to satisfy $B_{t+2} = B_{t+1}$, that is, households anticipate savers in the following period to behave identically to savers in the current period. We know that this guess is correct if, in the following period, the economy is in one of the multiple steady states equilibria. The above guess for the bond policy functions implies a guess for the consumption policy function of the low-type household, which we denote as $C^*_{L,ss}(R_tB_t)$ and plot in Figure 12.

A non-monotonic bond demand emerges in this economy if households' expect next-period consumption to follow the steady-state policy function $C^*_{L,ss}(R_{t+1}B_{t+1})$. Hence, multiple intersections between the bond demand and supply may occur for some levels of initial wealth, and multiple equilibria may thus arise. Figure 13 displays the policy functions for bonds and low-type household consumption corresponding to each of the multiple equilibria, as a function of initial wealth. The presence of multiple equilibria in the above example highlights the possibility that the unique policy function $B_{t+2} = B_{t+1}$ is not, in general, correct.

Figure 13 Consumption Policy Function(s) Given Initial Guess



Note. The figure plots the policy functions for consumption of the low-type household that correspond to each of the multiple equilibria in the market for bonds, given the initial guess for next-period consumption of the low-type household itself.

5.1.3 Sunspot Shocks

Suppose that in the presence of multiple equilibria, a sunspot shock coordinates household expectations about next-period policy functions. Specifically, we assume that the sunspot shock x_t takes two possible realizations $\{x_G, x_B\}$, where x_G stands for a good equilibrium and x_B for a bad equilibrium. The sunspot shock follows a Markov process whose transition matrix is

$$\begin{bmatrix} \pi & 1-\pi \\ 1-\pi & \pi \end{bmatrix},$$

with $\pi \in [0,1]$, where the diagonal entries correspond to the probability of remaining in the same state over two periods and the off-diagonal elements correspond to the probability of moving to a different state.

When multiple equilibria are possible, if the good realization of the sunspot shock occurs, the equilibrium where consumption of the L-type household is the highest is selected. Conversely, if the bad realization of the sunspot shock occurs, the equilibrium where consumption of the L-type household is the lowest is selected. The sunspot shock thus coordinates households' expectations about next-period policy functions, and its realization determines the equilibrium choice for bonds. We set the persistence of this sunspot process π to 0.9725.

We define two couples of policy functions, for consumption of the low and high-type households, conditionally on the two possible realizations of the sunspot shock, $C_{H,x}(R_tB_t)$ and $C_{L,x}(R_tB_t)$.

Formally, we solve for the fixed point of the functional equation in the policy functions

$$\frac{1}{C_{H,x_G}} = \beta R_{x_G,t+1}\left[\pi\frac{1}{C_{L,x_G}} + (1-\pi)\frac{1}{C_{L,x_B}}\right] \tag{39}$$

and

$$\frac{1}{C_{H,x_B}} = \beta R_{x_B,t+1}\left[\pi\frac{1}{C_{L,x_B}} + (1-\pi)\frac{1}{C_{L,x_G}}\right], \tag{40}$$

where $R_{x,t+1}$ denotes the interest rate between period t and $t+1$ when the realization of the sunspot shock at t is given by x. The two Euler equations above, conditional on the sunspot realization, define a couple of policy functions for next-period assets also conditional on the sunspot, $B'_{pf,x}$.[15] Figure 14 presents the policy functions for consumption from the sunspot equilibrium.

Finally, Figure 15 presents equilibrium interest rates and changes in the interest rate from a simulation of this model economy, highlighting the potential for sunspot shocks to give rise to substantial fluctuations in interest rates. Our model with sunspots, however, predicts a degree of volatility in R^* that exceeds what was observed prior to the Global Financial Crisis. How can we reconcile the pronounced fluctuations predicted by the model with the relatively stable period before 2008? We provide two suggestive explanations for the structural change in the volatility of R^*. First, we can interpret the Global Financial Crisis as a contraction in households' borrowing constraints.[16] In this interpretation, the stable interest rates prior to the crisis correspond to a period when the household borrowing constraint was slack, allowing for only a high-interest-rate equilibrium in the asset market in the model. The contraction of the borrowing constraint associated with the crisis introduces the possibility of multiple equilibria. Second, another explanation for the increase in the volatility of R^* is a rise in firms' labor market power. If monopsony power χ were low and stable, households' asset demand would be upward sloping, preventing the emergence of multiple equilibria. However, an increase in firms' monopsony power could alter the shape of asset demand, leading to the possibility of multiple steady-state equilibria.

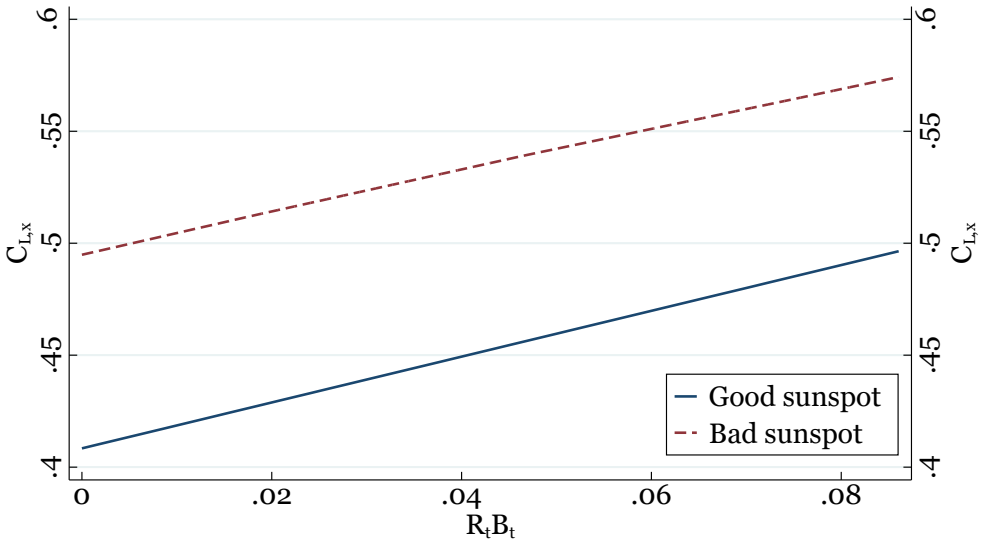
5.2 Volatile Interest Rates and Multiple Equilibria

In this section, we discuss three scenarios that can rationalize the experience of low and volatile interest rates after the Global Financial Crisis, in line with the empirical evidence documented in Section 2. The first scenario considers a fall in interest rates generated by an adverse sunspot shock that coordinates households' expectations around the low-interest-rate, high-debt equilibrium. In addition, we study two changes in government policy that may have been partly responsible for the observed interest rate dynamics. The first is an asset purchase program, whereby the public sector

[15] A full characterization of the equilibrium requires that the policy functions for consumption and asset accumulation are consistent with goods and labor market clearing in each period and for each sunspot shock realization. Appendix F.3 outlines the solution method for the dynamic equilibrium with sunspot.

[16] The 2008 financial crisis and subsequent policies are often modeled as a tightening of household borrowing constraints (Eggertsson and Krugman, 2012; Guerrieri and Lorenzoni, 2017)

Figure 14 Sunspot Equilibrium: Consumption Policy Function(s)



Note. The figure plots the policy functions for consumption of the low-type household associated to the good and bad realization of the sunspot shock, respectively.

purchases a given amount of bonds issued by firms, funding these asset purchases through taxation on households. We show that this scenario is compatible with a reduction in the equilibrium real interest rate and an increase in monopsony power by firms, in line with our steady-state results. The second case is an increased issuance of government debt, with receipts redistributed to households. In this scenario, consumption risk-sharing across households improves, leading to a rise in the interest rate. Figure 16 jointly displays the three simulated economies.

5.2.1 A GFC Sunspot

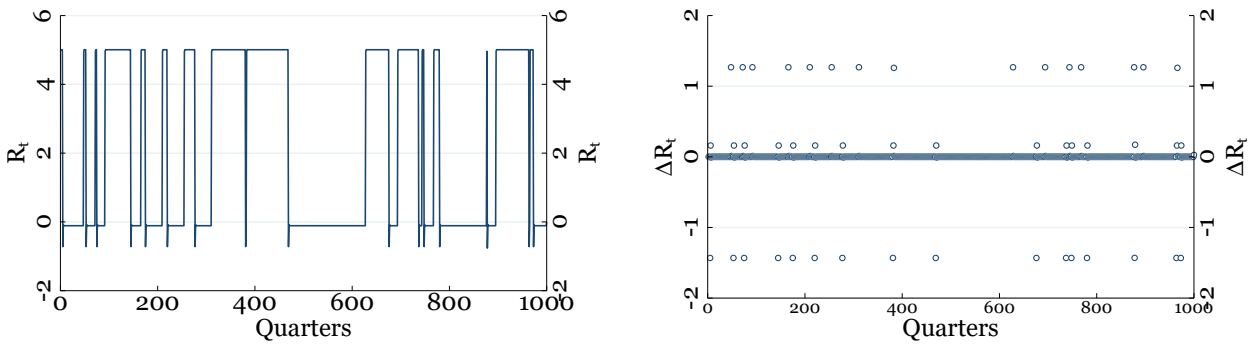
A negative realization of the sunspot shock process can in our model account for a contraction of the equilibrium real interest rate similar to the one observed after the Global Financial Crisis. When the sunspot shock realization is negative, the annualized equilibrium interest rate is five percentage points lower than under the optimistic realization. If this adverse realization persists for 48 periods, our model can rationalize the twelve years of exceptionally low interest rates that followed the Global Financial Crisis. In our calibration, the probability that the pessimistic sunspot shock persists for twelve years is 26%.[17]

5.2.2 Asset Purchase Programmes

Asset Purchase Programmes can influence the dynamics of R^*. In Section 4.5, we discussed how constant government purchases of firm-issued assets can eliminate the high-interest-rate steady-state

[17] The persistence of the sunspot process is 97.25%, so the probability of observing the pessimistic realization for at least 48 quarters equals $0.9725^{48} = 26\%$.

Figure 15 Sunspot Equilibrium - Simulation



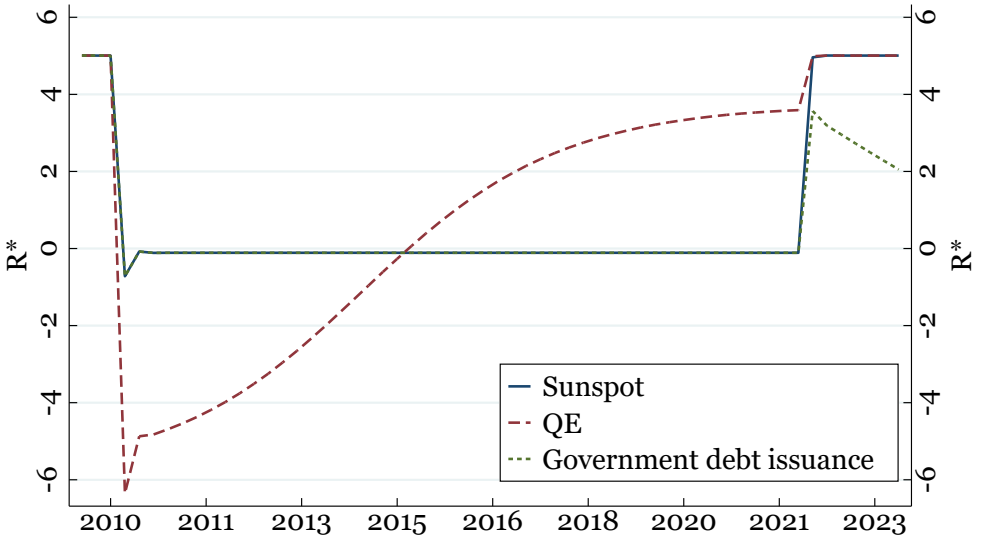
Note: The figure plots the simulated values of the real interest rate and of its changes from the solution of the model economy with sunspots.

equilibrium. Here, we show that temporary asset purchases can rationalize the sharp decline in the equilibrium interest rate observed in the context of the Global Financial Crisis.

First, we assume that the government announces an expansion in corporate asset purchases in the first quarter of 2010. The program follows the structure outlined in Section 4.5 but is set to conclude in the last quarter of 2021. During this period, the economy operates under the optimistic sunspot equilibrium. Hence, absent the asset purchase program, the interest rate would remain at 5%. Figure 16 displays the path of interest rates associated with this scenario. Asset purchases lead to an immediate and sharp decline in the equilibrium interest rate. By taxing households to finance the purchase of firm-issued assets, the government indirectly induces households to save. This, in turn, strengthens firms' monopsony power in the labor market, increases income risk, and further lowers interest rates. If the asset purchase program is expected to be persistent, the resulting decline in interest rates may be substantial. Anticipating an extended period of low consumption due to low labor income and high firms' monopsony power associated with high corporate debt issuance, households increase their demand for assets, further driving the interest rate decline. Effectively, the government eliminates the high-interest-rate equilibrium and forces the economy to converge toward the low-interest-rate steady state (point B in Figure 8). Over time, as the asset purchase program unwinds, the equilibrium interest rate gradually rises toward the high-interest-rate equilibrium.

We analyze two additional scenarios with different assumptions regarding the duration of the asset purchase program. In the first, the government initially announces a program lasting N periods but, upon reaching N, extends it by another N periods, until the program lasts for 12 years in total. Figure 17 illustrates this scenario for N corresponding to 6 and 4 years, respectively, alongside the case in which the government commits to a program lasting 12 years and does not renege on this commitment. When the government commits to purchasing corporate debt for an initial period and then extends it, the decline in the equilibrium interest rate is more moderate than when the government announces the full duration upfront. The interest rate declines on impact upon the initial announcement, then reverts toward the high-interest-rate equilibrium before declining again when

Figure 16 R^*-Dynamics: Post-GFC Experience

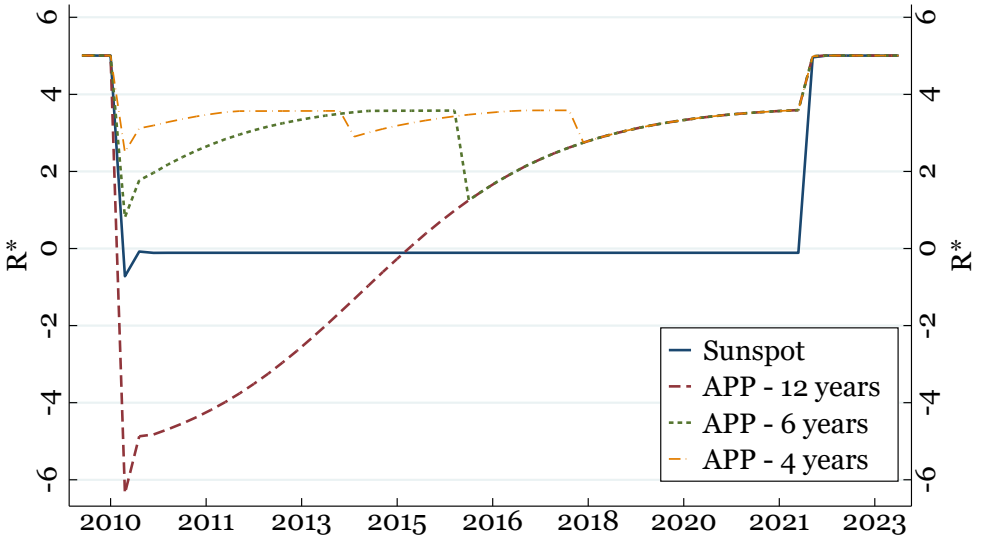


Note. The figure plots the simulated path of R^* post-GFC under three scenarios. The sunspot scenario (solid blue line) represents a fall in interest rates generated by an adverse sunspot shock. The second scenario (dashed red line) is an asset purchase program, whereby the public sector purchases a given amount of bonds issued by firms, funding these asset purchases through taxation on households. The third (dotted green line) is an issuance of government debt, with receipts redistributed to households.

the program is extended. Qualitatively similar dynamics emerge for announcements of 6 and 4 years, with a larger decline for longer announced durations.

Next, we consider a scenario where the government initially commits to a six-year asset purchase program and subsequently renews it each quarter, unexpectedly, each time announcing that the program would last for six-years. After 12 years from the initial announcement, the government eventually and unexpectedly exits the program. Figure 18 illustrates the interest rate dynamics in this scenario. The interest rate declines upon the initial announcement of the program, and it remains low throughout the entire 12-year period. In this scenario, households are consistently surprised by the actual length of the asset purchase program. This uncertainty reflects the ambiguity surrounding the duration of similar programs following the GFC. Even policymakers themselves, revealed through the Summary of Economic Projections (SEP), had different views on the persistence of policy at the lower bound. In January 2012, when the SEP first contains Federal Funds Target rate projections, 3 of the 17 individual policymakers expected rates to have been increased already by 2013 (one expected +25bps and two expected +75bps), but four members didn't expect any lift off until 2015, and two until 2016. And for market participants, using Survey of Professional Forecasters (SPF) forecast data for 3-month Treasury Bill rates, expectations of low interest rates in 2010 were consistent with a relatively short stay at the lower bound, but expectations for the duration of the ZLB period, and by association QE purchases, were gradually increased. Interestingly, when the Fed reduced interest rates in 2020 following the onset of the Covid pandemic, SPF forecasts were immediately consistent

Figure 17 R^*-Dynamics: Asset Purchase Programmes



Note. The figure plots the simulated path of R^* under different assumptions regarding the duration of the asset purchase programme. The dotted green and dashed yellow lines represent scenarios where the government initially announces an asset purchase programme of length N, later extending it for another N periods until the total duration reaches 12 years, with N corresponding to 6 and 4 years, respectively. The dashed red line depicts the case in which the government commits upfront to a 12-year programme and adheres to this commitment. The solid blue line represents the path of interest rates under a pessimistic sunspot shock.

with a much longer period at the lower bound.

Regardless of the specific trajectory of R^*, a key takeaway is that even a short-term policy can significantly influence the steady-state interest rate. In particular, a corporate asset purchase program can eliminate the high-interest-rate equilibrium and shift the economy toward a low-interest-rate regime. Thus, in our model, unconventional monetary policy can have lasting consequences.

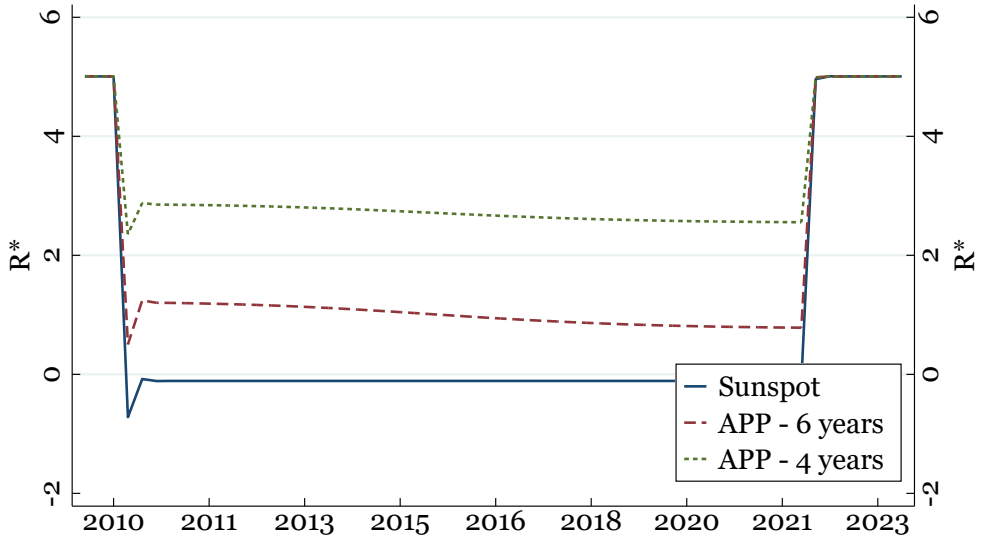
What, then, was the ultimate cause of the significant drop in interest rates observed during the Global Financial Crisis? Our framework suggests two possible explanations: a negative sunspot shock shifting savers' expectations, the implementation of asset purchases programs, or a combination of both.

After the COVID pandemic, equilibrium interest rates have started to rise again from their historically low levels. What drives this increase in R^*? Once again, more optimistic realizations of sunspot shocks may be a contributing factor. In the next subsection, we focus on the role of policy and explore how expansionary fiscal policy can contribute to a higher R^*.

5.2.3 Government Debt

Government debt has risen substantially in the United States after the COVID pandemic, spurred by the direct effects of the recession on government deficits, and by stimulus policies enacted to contrast

Figure 18 R^*-Dynamics: Recurrently Extended Asset Purchase Programmes



Note. The figure plots the simulated path of R^* in a scenario where the government repeatedly extends the asset purchase programme unexpectedly. The dashed red line represents the case where the government initially commits to a six-year programme but subsequently renews it each quarter, each time announcing an additional six-year duration. The dotted green line represents the case where the announced length of the programme is of four years. The solid blue line represents the path of interest rates under a pessimistic sunspot shock.

the adverse consequences of the pandemic. Here, we address the possibility that expansionary fiscal policy contributed substantially to the recent rise in R^*. We find that in our framework, a sizable expansion in government debt can contribute to an increase of the equilibrium real interest rate similar to the one observed in the United States over the years following the COVID pandemic.

Consider a scenario in which the government issues a positive amount of debt, denoted as D^G_{t+1}, rebates receipts from debt issuance to H-households, and thereafter keeps the level of government debt constant, setting taxes on H households to finance interest payments on debt.The issuance of government debt allows H-households to save through a financial instrument that is different from corporate debt, and thus to smooth out their income fluctuations without increasing the severity of firms' monopsony power. Hence, the increase in public debt facilitates the redistribution of consumption across high and low-type households, which in turn can drive an increase in R^*.

We consider a scenario in which the fiscal expansion occurs after an extended period of time in which the economy experienced a pessimistic realization of the sunspot shock. Specifically, we consider a pessimistic realization of the sunspot shock that lasts for 12 years, as in our baseline scenario, followed by the announcement of an increase in government debt, which will remain elevated for four years. The dotted green line in Figure 16 illustrates the interest rate dynamics associated with this rise in public debt.

The announcement of higher government debt leads to an immediate rise in the interest rate. The interest rate rises because, given the issuance of government debt, H-households can now save by

purchasing government debt instead of corporate debt. As a result of the lower issuance of corporate debt, firms' labor market power diminishes, increasing income of type$-L$ households. Anticipating higher future incomes, type$-H$ households reduce their current savings, further reinforcing the upward impact on R^*.

The period over which public debt remains elevated is crucial to determine the quantitative impact of fiscal policy on the equilibrium interest rate. A permanent increase in public debt could eliminate the low-interest-rate equilibrium. This occurs because a rise in public debt effectively shifts the household demand for debt upward. If public debt reaches a sufficiently high level, the demand for debt will lie above its supply by firms, preventing the existence of an equilibrium in which firms issue a positive amount of corporate debt. However, also for a temporary increase in government debt, the longer is the fiscal expansion projected to last, the greater is the initial rise in R^*.

The impact of government debt on the equilibrium interest rate in this framework depends crucially on the adverse effect of corporate debt on household income fluctuations. Higher government debt raises interest rates not only by allowing households to save more but also by enabling them to do so without relying on firm-issued debt. This prevents the unintended consequence of corporate debt purchases of lowering some workers' incomes and widening household income fluctuations.

6. Concluding Remarks

The equilibrium real interest rate, commonly known as R^*, is generally considered as a key reference point for monetary policy. On average, the policy rate should be equal to the equilibrium real interest rate plus the inflation target. Conventional wisdom maintains that real factors determine a unique equilibrium real interest rate which the monetary authority should target. We develop a model with multiple equilibrium real interest rates. In our framework, government purchases of private assets can select the equilibrium real interest rate.

Finally, we conclude our dynamic analysis by addressing a broader question: Can our model rationalize the recent experience of equilibrium interest rates after the Global Financial Crisis? We believe the answer is affirmative. We attribute the decline in R^* around the GFC to shifts in expectations or policy changes. Moreover, we can rationalize the recent increase in R^* by attributing it to fiscal policy or, once again, to shifts in expectations. Other long-term forces–such as demographics, inequality, and slowing productivity growth–are likely to have also influenced R^*. Our analysis focuses on the short-run fluctuations in this key variable, and our mechanism helps explain the sudden drops in R^* that are not fully accounted for by long-term trends.

Importantly, in our framework, short-term policies influence R^*. This makes it particularly challenging for central banks and policymakers to use R^*as a guiding variable. In fact, policy that is guided by R^* in an attempt to stabilize the short run interest rate may, in turn, influence R^* itself. This creates a policy endogeneity, where policymakers who attempt to react to fluctuations in R^* can modify its trajectory, and thus can never observe it in the state it was in before their intervention.

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Appendix for:
Monopsony, Income Risk and R^* Multiplicity

by Ambrogio Cesa-Bianchi, Sergio de Ferra, Andrea Ferrero, Alex Kohlhas, Michael McMahon, Federica Romei, Giovanni Rosso

A. Data Sources

A.1 Firm-level data

The baseline dataset is derived from Compustat, focusing on US firms for 1997 to 2019. Our main variables of interest are

1. 'Selling, General, and Administrative Expenses' (`xsga`), divided by the number of employees (`emp`) to obtain a proxy for salary costs per worker (wages)
2. 'Staff Expenses - Total' (`xlr`), divided by the number of employees (`emp`) to obtain an alternative proxy for salary costs per worker (wages)
3. Total assets (`atq`) to proxy for firm size
4. Total debt (`dlcq+dlttq`)
5. Leverage, defined as the ratio of total debt to total assets.

Following standard practices in the literature (Ottonello and Winberry, 2020), we perform the following cleaning steps:

1. Drop duplicates (proper duplicates, that is same id and value)
2. Only keep firms incorporated in the US
3. Drop COVID period (i.e. post 2019q4)
4. Drop financial firms (SIC code $\in$ [6000, 6799])
5. Drop observations with negative assets
6. Drop observations that fall above/below the top/bottom 0.5 percent of observations for each variable.

A.2 Macro data

We obtain macroeconomic data from Federal Reserve Economic Data (FRED). Specifically, we download:

1. Real GDP (`GDPC1`)
2. PCE Price Index (`PCEPI`)
3. Vix index (`VIXCLS`)

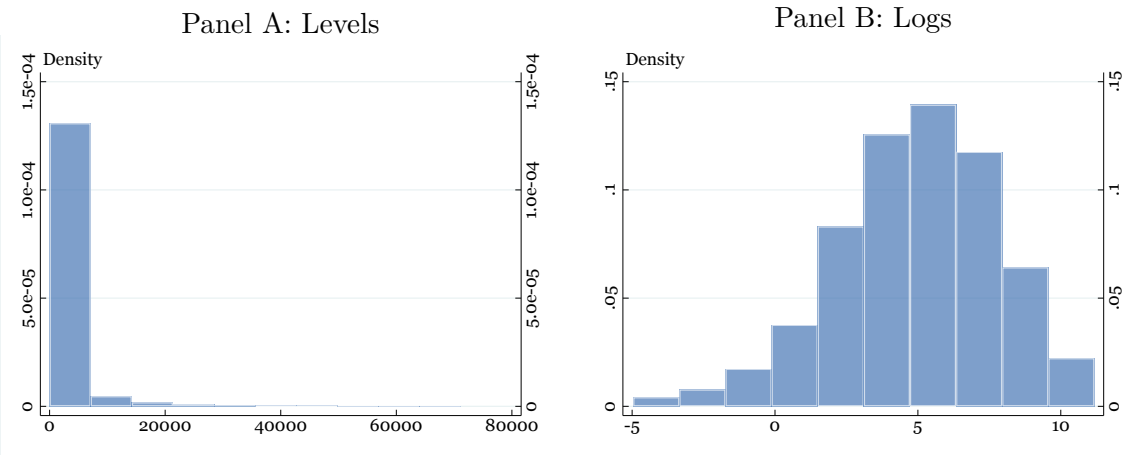
B. Stylized Facts

This section reports additional information about the data.

Figures B.1, B.2, B.3, and B.4 report the empirical distributions of our main variables of interest, namely *Total Assets*, *Total Debt*, *Selling, General, and Administrative Expenses*, and *Leverage* in Compustat quarterly.

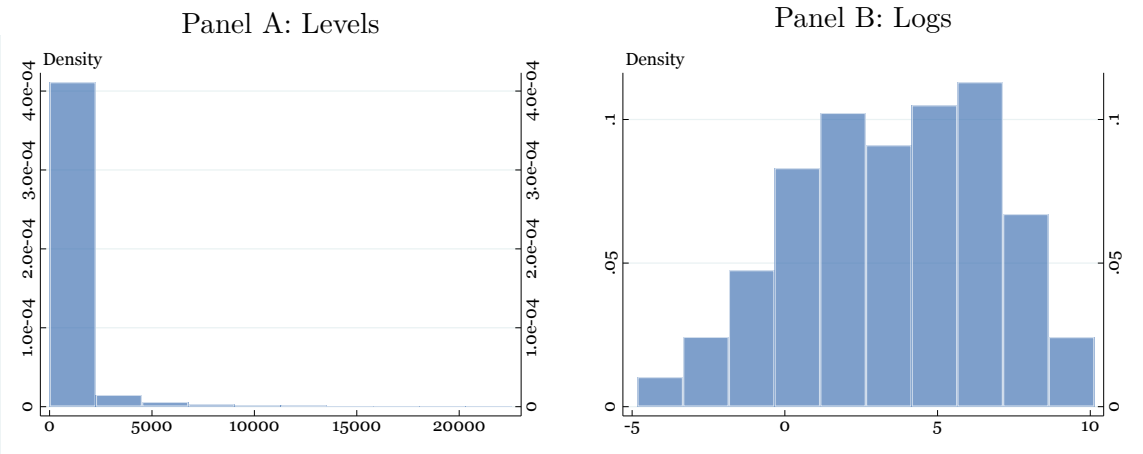
Figures B.5 and B.6 report a comparison between Compustat's `xsga` (Selling, General, and Administrative Expenses) and `xlr` (Staff Expenses). The figures show a strong similarity between the two measures. The distribution of firm-year observations is very similar, both when considering "between" and "within" firm information. The chart suggests that using `xsga` is suitable for the analysis, especially given the advantage that `xsga` is available for a much larger sample of firms (15,000 vs. 3,000) and at a quarterly frequency.

Figure B.1 Total Assets



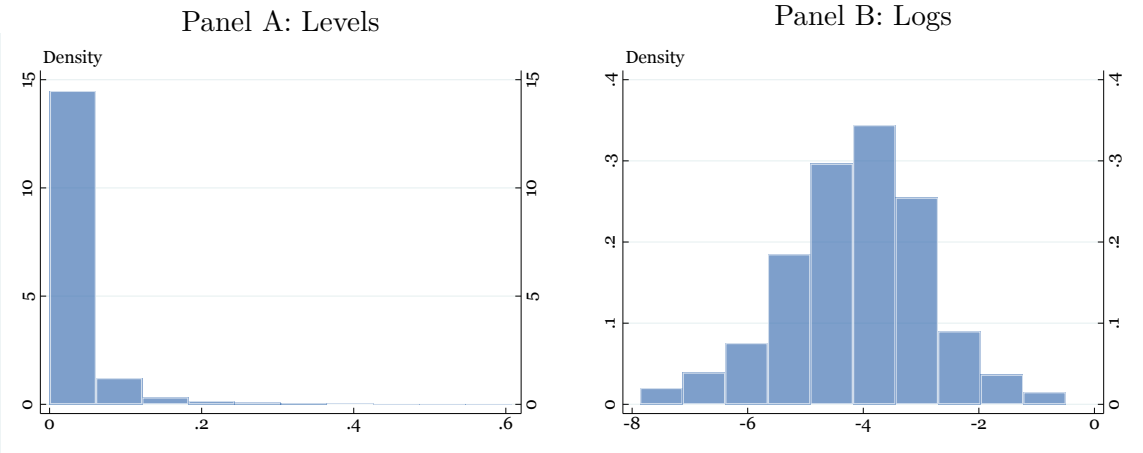
Note. This figure plots the distribution of total assets in our sample, in levels (Panel A) and in logs (Panel B). Sample period 1997q1 to 2019q4.

Figure B.2 Total Debt



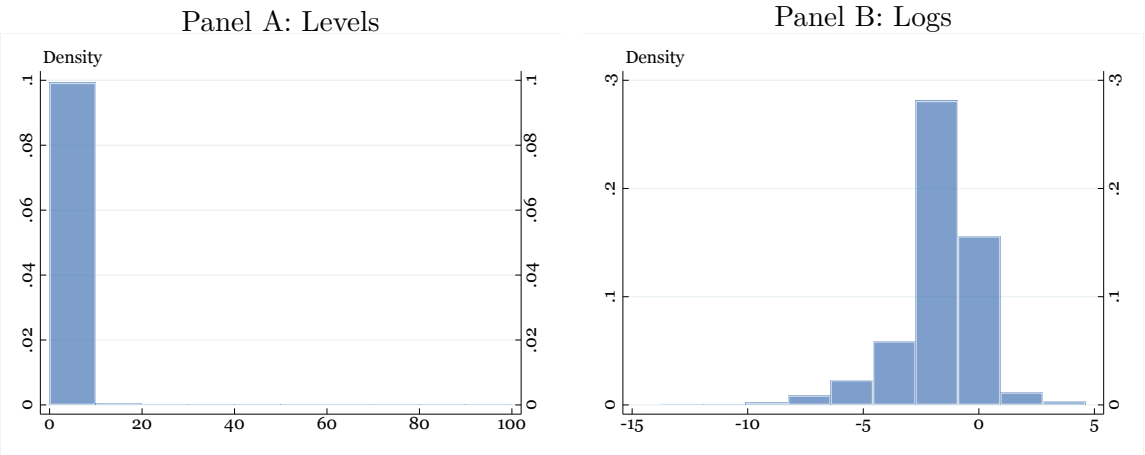
Note. This figure plots the distribution of debt in our sample, in levels (Panel A) and in logs (Panel B). Sample period 1997q1 to 2019q4.

Figure B.3 Salary Costs



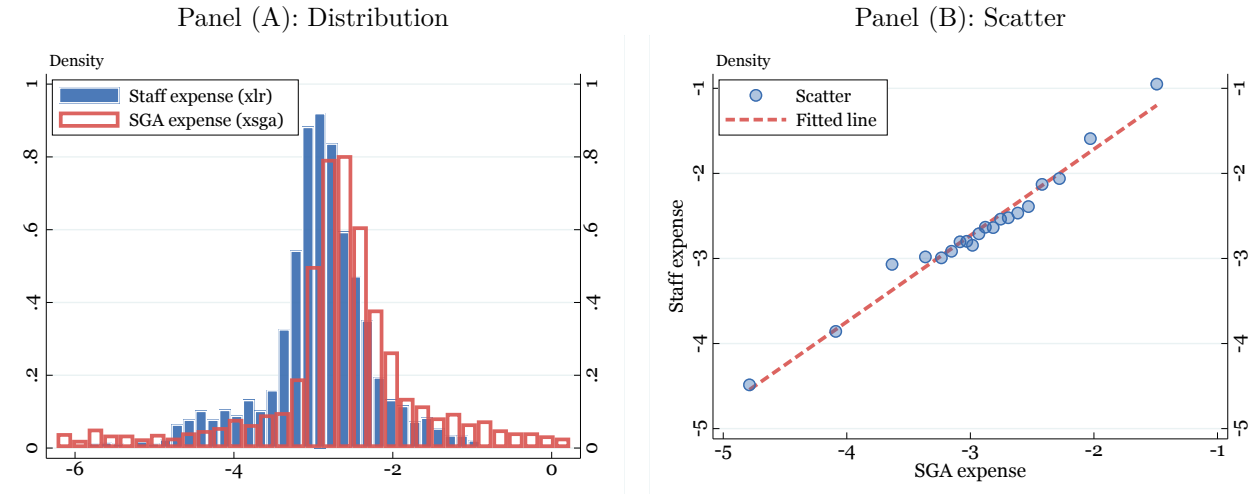
Note. This figure plots the distribution of debt in our sample, in levels (Panel A) and in logs (Panel B). Sample period 1997q1 to 2019q4.

Figure B.4 Leverage



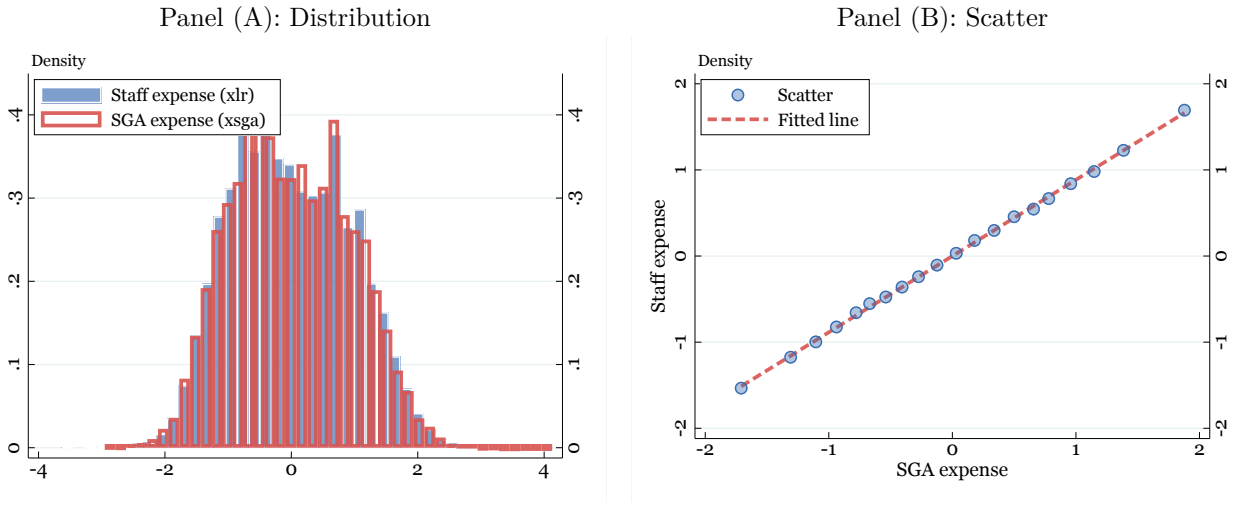
Note. This figure plots the distribution of debt in our sample, in levels (Panel A) and in logs (Panel B). Sample period 1997q1 to 2019q4.

Figure B.5 SGA Expenses vs. Staff Expenses: Between



Note. Comparison between Compustat's `xsga` (Selling, General, and Administrative Expenses) and `xlr` (Staff Expenses) in the cross-section of firms. Each observation represents the average values of `xsga` and `xlr` for a firm over time.

Figure B.6 SGA Expenses vs. Staff Expenses: Within



Note. Comparison between Compustat's `xsga` (Selling, General, and Administrative Expenses) and `xlr` (Staff Expenses) in the cross-section of firms. Each observation represents the yearly values of `xsga` and `xlr` standardized at the firm level (i.e. $(x - \mu_x)/\sigma_x$, where μ_x and σ_x are the firm-level average and standard deviation of x).

C. Granular Instruments

To explain the methodology, we employ the simple example used by Gabaix and Koijen (2024). Think of the following system, where to keep consistency with Gabaix and Koijen (2024), we write in terms of households' capital supply and firms capital demand:

$$R_t = \psi D_{St} + \varepsilon_t \tag{C.1}$$

$$D_{it} = \phi^d R_t + \eta_t + u_{it} \tag{C.2}$$

where $D_{St} = \sum_i S_i D_{it}$ with S_i representing the weight of firm $i \in \{1, ..., N\}$ and with $\sum_i S_i = 1$. Each firm's log demand D_{it} depends on the real interest rate R_t as in (C.2), with demand elasticity ϕ^d, and some shocks. The real interest rate, in turn, depends on aggregate demand D_{St}, which is the size-weighted demand, with a sensitivity ψ that is the inverse of the supply elasticity. We impose that $\psi\phi^d \neq 1$, which ensures the existence of a unique solution of our system (C.1) – (C.2). The econometrician observes S_i, R_t, and D_{it}.

Our object of interest is ψ, the slope of households' capital supply curve, which tells us how the interest rate R_t is responding to an exogenous increase to firms' debt issuance. We cannot estimate ψ (and ϕ^d for that matter) by OLS as ε_t and η_t are typically correlated, implying that D_{St} is correlated with ε_t in (C.1) and R_t with η_t in (C.2).

Following Gabaix and Koijen (2024), we construct the GIV as the size-weighted average outcome, $D_{st} = \sum_i S_i D_{it}$, minus the equal-weighted average outcome, $D_{Et} = (1/N) \sum_{i=1}^N D_{it}$:

$$z_t := D_{\Gamma t} = D_{St} - D_{Et}. \tag{C.3}$$

Given that

$$D_{st} = \phi^d R_t + \eta_t + u_{St}, \qquad D_{Et} = \phi^d R_t + \eta_t + u_{Et} \tag{C.4}$$

the GIV is also

$$z_t = u_{\Gamma t} = u_{St} - u_{Et} \tag{C.5}$$

and it is made only of idiosyncratic shocks. Given the exogeneity condition

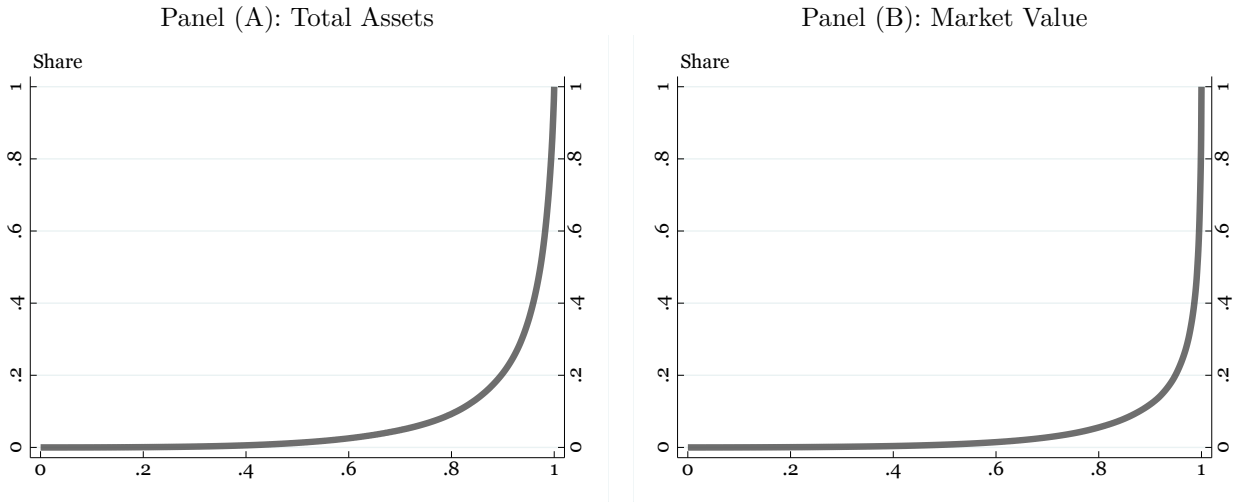
$$u_t \perp \eta_t, \varepsilon_t \tag{C.6}$$

we have $\mathbb{E}[u_t \varepsilon_t] = 0$, and hence $\mathbb{E}[z_t \varepsilon_t] = 0$. Using (C.1), this gives $\mathbb{E}[(R_t - \psi D_{s_t}) z_t] = 0$, and thus $\psi = \mathbb{E}[R_t z_t] / \mathbb{E}[B_{st} z_t]$. Its empirical counterpart is the estimator $\psi_T^e = \sum_{t=1}^T R_t z_t / \sum_{t=1}^T D_{st} z_t$.[18]

[18] Remember that, for a simple model with one endogenous variable $R = a + bD_{St} + e$, this is the formula of the 2SLS estimator. To see that, take the covariance of all terms with the instrument z, which gives $Cov(R, z) = Cov(a, z) + bCov(D_S, z) + Cov(e, z) = bCov(D_S, z)$. Then, you get $b^{IV} = Cov(R, z)/Cov(D_S, z)$. This is the same expression as you have in matrix notation, i.e. $b^{IV} = (z'D_S)^{-1}(z'R)$, where remember that, for example, $(z'D_S) = \sum_1^T z_t D_{St}$, is the sum of cross products for D_S and z from which the mean is subtracted given that the regression has an intercept.

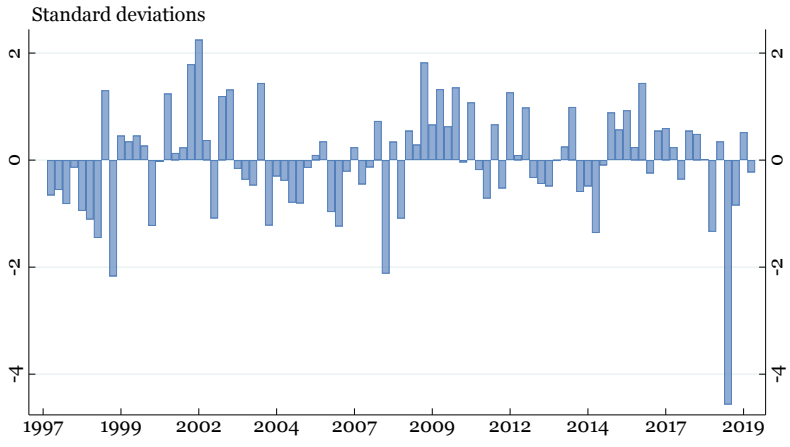
For the instrument to be relevant, there has to be heterogeneity in the share/size distribution. Trivially, if there were no difference between share-weighted and equally weighted firm-level shocks, z_t would display no variation and the would likely be poor. Figure C.1 reports the Lorentz curves for firms' total assets and market value. With such a skewed distribution, idiosyncratic shocks can become 'granular' and have aggregate effects (Gabaix, 2011), making our data a natural application of the GIV methodology. The series of granular shocks is reported in Figure C.2.

Figure C.1 Lorentz Curves



Note. This figure plots the Lorentz curves for assets (left) and market value (right).

Figure C.2 The Granular Instrument



Note. This figure plots the evolution of the granular instrument. Sample period 1997q1 to 2019q4.

D. Robustness

This section reports the robustness of our main empirical results. We conduct several exercises to ensure the reliability of our findings, including using different sample selection criteria, varying the time periods analyzed, and employing alternative measures of R^*.

Tables D.1 and D.2 demonstrate that our results on the relationship between wages and leverage are robust to using Compustat's `xlr` (Staff Expenses) instead of `xsga` (Selling, General, and Administrative Expenses). To verify this, we first check whether our results using `xsga` hold in the smaller (and at annual frequency) sample of firms for which `xlr` is available, as shown in Table D.1. We then re-run our specification using `xlr` instead of `xsga`, with the results presented in Table D.2. The findings are very similar to those reported in our baseline analysis.

Tables D.3 and D.4 report the relationship between wages and leverage in a sample of firms that includes those in the financial sector and only includes safe firms (proxied by firms above the median firm size in the cross-section of firms). The tables show that the strong positive relationship between wages and firm size documented in the main text is robust to different sample selection choices.

Figure D.1 reports the estimates from the baseline local projections specification employing alternative measures of R^*, namely the 'macro' measures by Laubach and Williams (2003) and Lubik and Matthes (2015); as well as a measure of R^* derived from term structure models, i.e. a 10-year real forward rate. In each panel, the left chart reports the dynamic response of R^* over the full sample (i.e. 1997q1 to 2019q4, in gray); and the right chart reports the dynamic response of R^* over the two sub-samples as in the main text, namely 1997q1 to 2008q4 (in orange) and 2009q1 to 2019q4 (in blue).

Figure D.2 reports the estimates from the baseline local projections specification (XX) employing alternative sample selection criteria and different econometric specifications. Specifically, Panel A *No Seasonal Dummies* excludes seasonal dummies from the estimation; Panel B *Market Value Weights* employs firms' market value instead of total assets to compute the granular instrument; Panel C *Including Financials* uses a sample of firms that includes those in the financial sector; Panel D *Safe Firms* uses a sample of safe firms, proxied by firms above the median firm size in the cross-section of firms.

Table D.1 Wages and Leverage (Annual, `xsga`)

	(1)	(2)	(3)	(4)
Total Assets	0.48***	0.46***	0.36***	0.37***
	(0.02)	(0.02)	(0.01)	(0.01)
Total Assets × Leverage		-0.03***		-0.01***
		(0.00)		(0.00)
Sector × Time FE	yes	yes	yes	yes
Firm FE	no	no	yes	yes
Observations	81,152	81,152	79,595	79,595
R-squared	0.65	0.66	0.94	0.94

Note. Robust standard errors (clustered two-way, at the year and firm level) are reported in parentheses, with (0.00) indicating a value lower than 0.005. *** p<0.01, ** p<0.05, * p<0.1. Coefficients corresponding to the constant, fixed effects, and controls (log number of employees and log leverage) are not reported.

Table D.2 Wages and Leverage (Annual, `xlr`)

	(1)	(2)	(3)	(4)
Total Assets	0.32***	0.32***	0.25***	0.26***
	(0.02)	(0.02)	(0.03)	(0.03)
Total Assets × Leverage		-0.03***		-0.01*
		(0.00)		(0.00)
Sector × Time FE	yes	yes	yes	yes
Firm FE	no	no	yes	yes
Observations	6,809	6,809	6,575	6,575
R-squared	0.58	0.59	0.92	0.92

Note. Robust standard errors (clustered two-way, at the year and firm level) are reported in parentheses, with (0.00) indicating a value lower than 0.005. *** p<0.01, ** p<0.05, * p<0.1. Coefficients corresponding to the constant, fixed effects, and controls (log number of employees and log leverage) are not reported.

Table D.3 Wages and Leverage: Including Financials

	(1)	(2)	(3)	(4)
Assets	0.47***	0.45***	0.35***	0.35***
	(0.03)	(0.02)	(0.01)	(0.01)
Assets × Leverage		-0.03***		-0.01***
		(0.00)		(0.00)
Sector × Time FE	yes	yes	yes	yes
Firm FE	no	no	yes	yes
Observations	345,454	345,454	344,915	344,915
R-squared	0.62	0.63	0.92	0.92

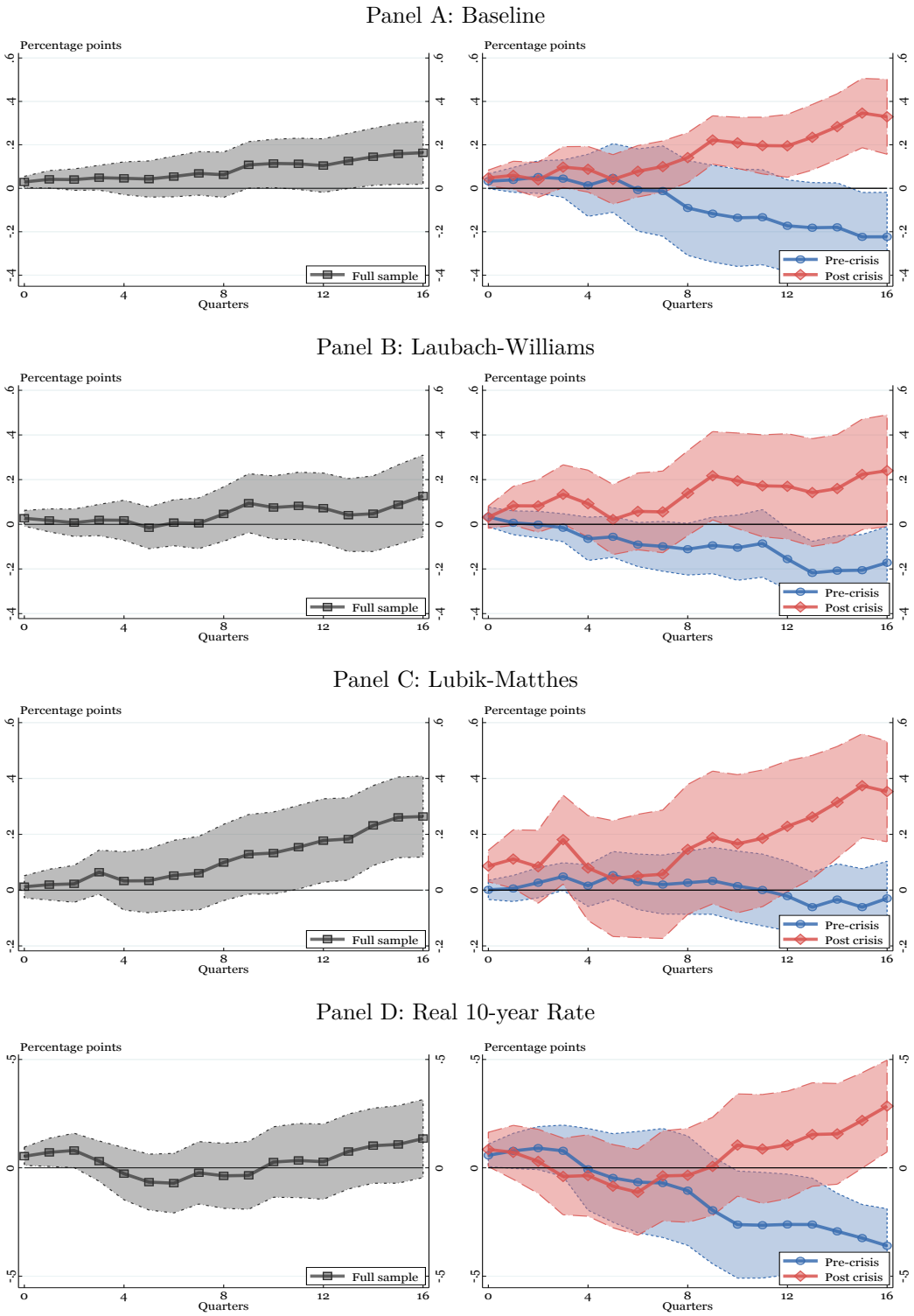
Note. Robust standard errors (clustered two-way, at the year and firm level) are reported in parentheses, with (0.00) indicating a value lower than 0.005. *** p<0.01, ** p<0.05, * p<0.1. Coefficients corresponding to the constant, fixed effects, and controls (log number of employees and log leverage) are not reported.

Table D.4 Wages and Leverage: Large Firms

	(1)	(2)	(3)	(4)
Assets	0.60***	0.59***	0.42***	0.41***
	(0.03)	(0.03)	(0.01)	(0.01)
Assets × Leverage		-0.01		-0.00
		(0.01)		(0.00)
Sector × Time FE	yes	yes	yes	yes
Firm FE	no	no	yes	yes
Observations	159,102	159,102	158,824	158,824
R-squared	0.65	0.65	0.95	0.95

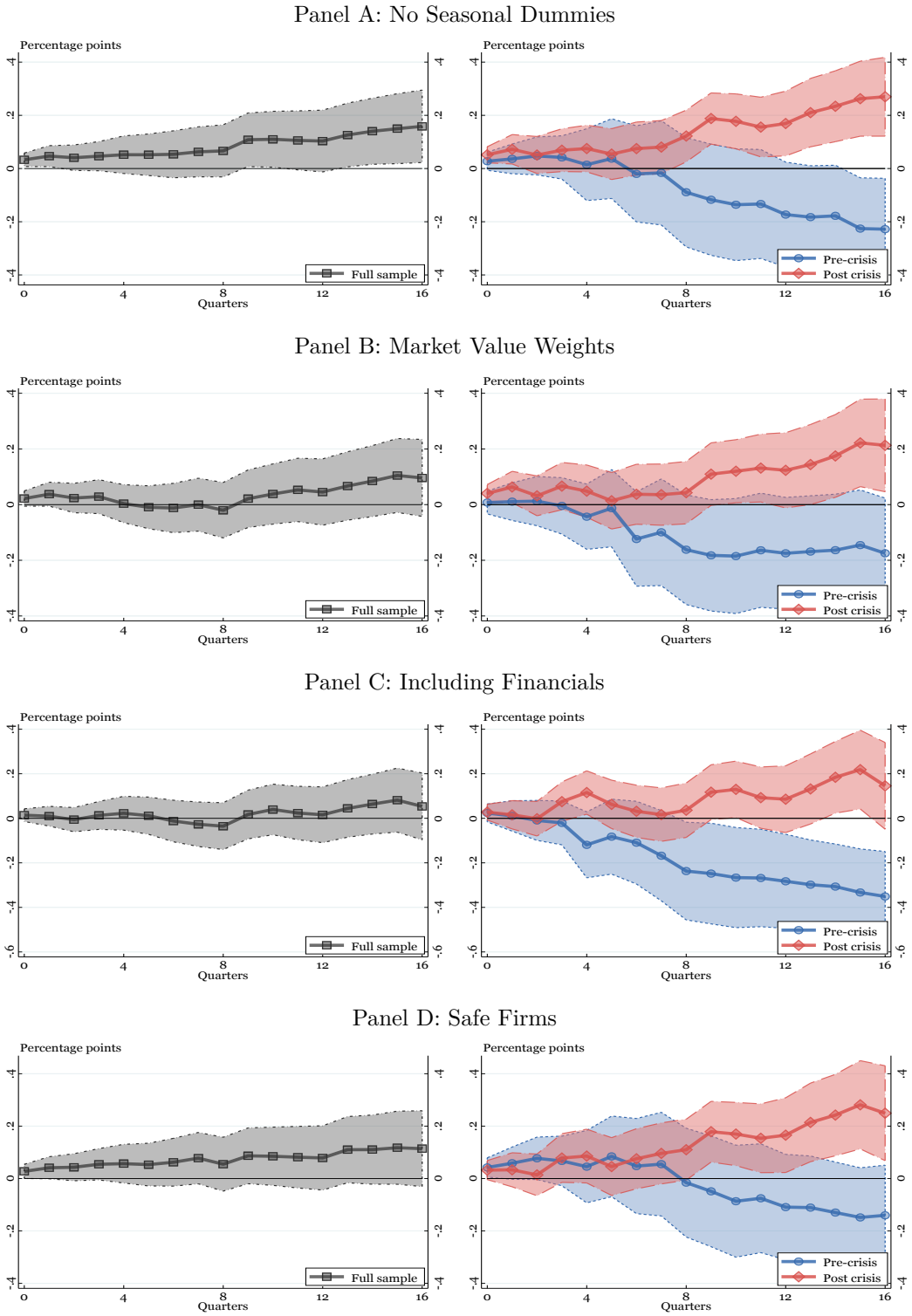
Note. Robust standard errors (clustered two-way, at the year and firm level) are reported in parentheses, with (0.00) indicating a value lower than 0.005. *** p<0.01, ** p<0.05, * p<0.1. Coefficients corresponding to the constant, fixed effects, and controls (log number of employees and log leverage) are not reported.

Figure D.1 GIV LP Robustness: Alternative R^* Measures



Note. This figure plots the evolution of leverage blabla. Sample period 1997q1 to 2019q4.

Figure D.2 GIV LP Robustness: Other Specifications



Note. This figure plots the evolution of leverage blabla. Sample period 1997q1 to 2019q4.

E. Empirical analysis of consumption risk

In this section we explore the dynamic response of consumption risk to an increase in corporate debt.

E.1 Data

The analysis in this section relies on data from the Consumption Expenditure Survey (CEX), administered since 1980 by the Bureau of Labour Statistics (BLS) which uses it as an input to compute CPI weights. The CEX collects quarterly detailed information on a nationally representative sample of households' expenditure using a rotating panel design. The 'interview' component of the CEX consists of a rotating panel where each household is surveyed quarterly over 5 quarters (data on the first interview are not published, as it is preparatory; post 2015 the interviews are only 4). Information provided pertains to expenditure over the previous three months. We follow Blundell, Pistaferri and Saporta-Eksten (2018) in constructing a measure of non-durable consumption as the sum of expenditure on "food at home, food away from home, alcohol and tobacco, utilities, maintenance and repairs, education, housing services, financial services, clothing, health, entertainment, cash contributions, transportation, and other nondurables". We focus on the 1997-2015 sample.

E.2 Construction of consumption risk and dynamic response

Construction of consumption risk measure. We construct a measure of consumption risk as the standard deviation of the quarterly (quarter-on-quarter) change in log consumption at the household level. That is, we generate change in log non-durable consumption as

$$\Delta c_{i,t} = \log c_{i,t} - \log c_{i,t-3} \tag{E.1}$$

where $c_{i,t}$ is the non-durable consumption of household i in the last quarter t in which it appears in the sample and $c_{i,t-3}$ is the consumption in the first quarter in which it appears in the sample. Then, in every quarter t there is a cross-sectional distribution of $\Delta c_{i,t}$, with households entering and exiting the sample. An example of this cross-sectional variation is in Figure E.1, comparing the distribution of changes in log consumption for 2007q1 and 2007q3. We compute an aggregate measure of consumption risk by taking the standard deviation consumption changes over time:

$$\Delta CR_t = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\Delta c_{i,t} - \Delta c_t\right)^2} \tag{E.2}$$

where Δc_t is the cross-sectional average of $\Delta c_{i,t}$ at time t. Figure E.2 plots this quarterly measure from 1997q1 to 2015q4.

Estimation of dynamic response. To estimate the effects of a shock to firms' debt issuance on

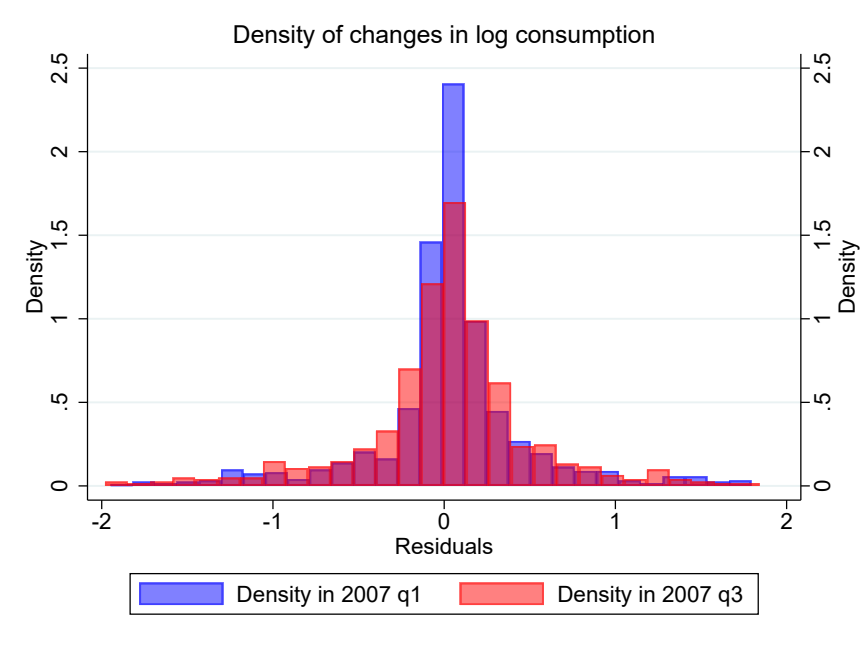
households' consumption risk, we employ the following local projection specification:

$$CR^*_{t+h} - CR^*_{t-1} = \alpha^h + \alpha^h_q + \beta^h \epsilon_t + \sum_{\ell=1}^{P} \gamma^h X_{t-\ell} + \nu_{t+h} \tag{E.3}$$

where α^h is a constant; α^h_q is a quarter-dummy to capture seasonality effects; ϵ_t is the granular instrument; $X_{t-\ell}$ is a vector of controls, including real GDP growth, lags of CR^*, and lags of the granular instrument described in section 2; and ν_{t+h} is a residual, and CR^* is the quarterly measure of consumption risk.

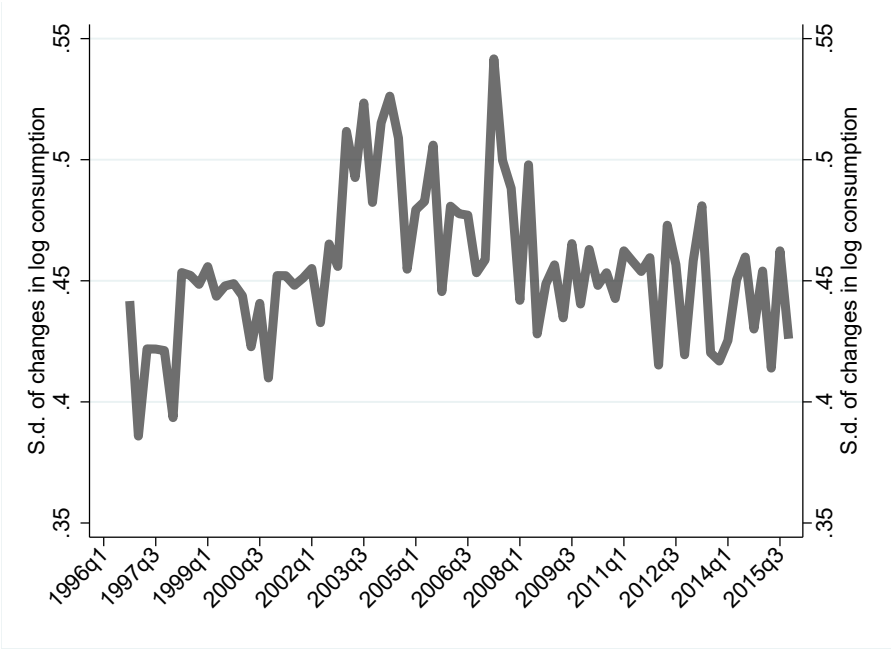
Figure E.3 shows the impact on consumption risk of an exogenous increase in firms' debt issuance, for the period 1997-2015. We observe evidence of an increase in consumption risk in response to an increase in corporate debt, in agreement with the model's central mechanism.

Figure E.1 Changes in household log consumption



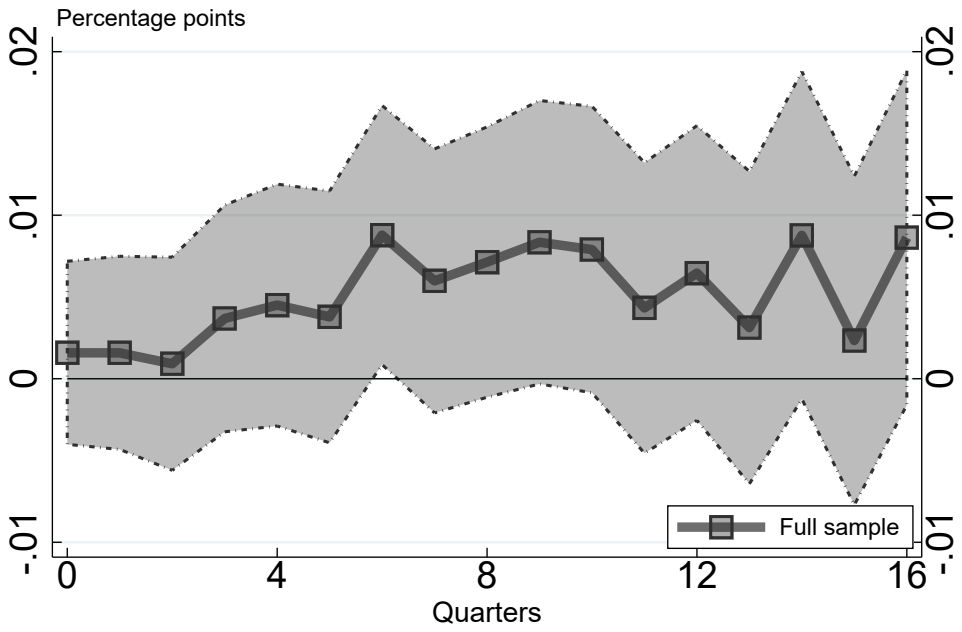
Note. This figure plots the distribution of changes in households nondurable consumption between the last three months they appear in the sample and the first quarter they appear.

Figure E.2 Time series of consumption risk



Note. This figure plots the cross-sectional s.d. of changes in log consumption, as detailed in equation (E.2).

Figure E.3 The response of consumption risk to a debt issuance shock



Note. Dynamic response of consumption risk to an exogenous increase in firm debt identified using a granular instrumental variable approach (Gabaix and Koijen, 2024) in a local projection specification (Jorda, 2005). The weights are computed with total assets. The local projection specification controls for one lag of the instrument, one lag of the dependent variable, and one lag of GDP growth. Sample period is 1997q1 to 2015q2.

F. Derivations

F.1 Firms' Problem

The problem of the firm is to maximize the discounted stream of profits, subject to the (7), and the first-order condition for household labor supply (6) for inputs in whose market the firms is monopsonist, i.e. for $i \in (0, \chi(D_t))$. Formally, this problem is:

$$\begin{aligned}\max_{L_{H,t}(i), L_{L,t}(i), D_{t+1}} \; & Y_t - \int_0^1 W_{H,t}(i) L_{H,t}(i)\, di - \int_0^{\chi} W_{L,t}(i) L_{L,t}(i)\, di \\ & - \int_{\chi}^1 L_{L,t}(i)^{1+\varphi} C_{L,t} + D_{t+1} - D_t R_t - \psi\left(D_{t+1}\right).\end{aligned} \tag{F.1}$$

We can use the labour supply condition (6) for the L households to get the wage ratio as a function of the L labour ratio:

$$\frac{W_{L,t}^m}{W_{L,t}^c} = \left(\frac{L_{L,t}^m}{L_{L,t}^c}\right)^{(\varphi)}. \tag{F.2}$$

From the firms' labour demand, we can also derive the wage ratio as a function of the L labour ratio:

$$\frac{W_{L,t}^m}{W_{L,t}^c} = \left(\frac{L_{L,t}^c}{(1+\varphi) L_{L,t}^m}\right) \tag{F.3}$$

We can use (F.2) and (F.3) to find the L-household labour ratio as a function of the parameters:

$$\left(\frac{L_{L,t}^m}{L_{L,t}^c}\right) = \left(\frac{1}{1+\varphi}\right)^{\frac{1}{1+\varphi}}. \tag{F.4}$$

Therefore we can write equation (F.5) as:

$$1 + (1-\alpha) Y_t \frac{1}{1+\varphi} \left[\varphi - \ln\left(1+\varphi\right)\right] \chi'\left(D_{t+1}\right) = \psi'\left(D_{t+1}\right) + \beta R_{t+1} \tag{F.5}$$

F.2 Combination of Optimality Conditions to derive Output as Function of Wealth and Saving

We outline below how to obtain output Y_t as function of housheold wealth $R_t B_t$ and saving B_{t+1}, i.e. the function $Y_t = Y(B_{t+1}, R_t B_t)$.

First, combine firm's labor demand (10), (12) and (11) with households' budget constraints to

yield households' consumption as function of output, wealth, and saving:

$$C_{H,t} = \alpha Y_t - B_{t+1}, \tag{F.6}$$

$$C_{L,t} = (1-\alpha)\left[1 - \frac{\varphi}{1+\varphi}\chi(D_{t+1})\right] Y_t + R_t B_t. \tag{F.7}$$

Second, combine household labor supply (6) with the labor demands, to yield employment as function of total output and the above-determined consumption:

$$L_{H,t} = \left(\frac{\alpha Y_t}{C_{H,t}}\right), \tag{F.8}$$

$$L^c_{L,t} = \left(\frac{(1-\alpha)Y_t}{C_{L,t}}\right), \tag{F.9}$$

$$L^m_{L,t} = \left(\frac{(1-\alpha)Y_t}{(1+\varphi)C_{L,t}}\right). \tag{F.10}$$

Third, plug these expressions into the production function (7), to yield a non-linear equation for output as function of the bond choices and of the initial household wealth:

$$Y_t = L_{H,t}^{\alpha} {L^m_{L,t}}^{(1-\alpha)\chi} {L^c_{L,t}}^{(1-\alpha)[1-\chi]} \tag{F.11}$$

$$Y_t = \left(\frac{\alpha Y_t}{C_{H,t}}\right)^{\alpha} \left(\frac{(1-\alpha)Y_t}{C_{L,t}}\right)^{(1-\alpha)} \left(\frac{1}{1+\varphi}\right)^{(1-\alpha)\chi} \tag{F.12}$$

$$1 = \frac{\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}\,(1+\varphi)^{-(1-\alpha)\chi}}{C_{H,t}^{\alpha} C_{L,t}^{1-\alpha}}, \tag{F.13}$$

which simplifies to:

$$[\alpha Y_t - B_{t+1}]^{\alpha}\left[(1-\alpha)\left[1 - \frac{\varphi}{1+\varphi}\chi\right] Y_t + R_t B_t\right]^{1-\alpha} = \alpha^{\alpha}(1-\alpha)^{(1-\alpha)}\,(1+\varphi)^{-(1-\alpha)\chi}. \tag{F.14}$$

Finally, solve the above expression non-linearly for Y_t as function of B_{t+1} and $R_t B_t$, which we denote as $Y_t = Y(B_{t+1}, R_t B_t)$.

In turn, this function can be used to determine the consumption levels of the two households, as well as the employment levels of the two types of workers, as function of the bond choices and of the initial wealth of the households: $C_{H,t} = C_H(B_{t+1}, R_t B_t)$, $C_{L,t} = C_L(B_{t+1}, R_t B_t)$, $L_{H,t} = L_H(B_{t+1}, R_t B_t)$, $L^c_{L,t} = L^c_L(B_{t+1}, R_t B_t)$, $L^m_{L,t} = L^m_L(B_{t+1}, R_t B_t)$,

Note that in the above equations we have implicitly imposed that bonds purchased by households equal bonds issued by firms, $B_{t+1} = D_{t+1}$. Hence, choices for asset purchases B_{t+1} affect equilibrium variables also through their impact on monopsony power, via the function $\chi(D_{t+1})$.

F.3 Solution for Dynamic Sunspot Equilibrium

We outline in what follows our solution method for the equilibrium in the dynamic model economy with sunspot. We proceed by backward induction.

First, consider a guess for the households' guess about the next-period policy function for consumption of the low type, and associated marginal utility of consumption. We use as initial guess the policy function associated with the steady-state choice for asset accumulation, $C_{L,ss}$. We initially guess that households expect this policy function to characterize equilibrium in the next period independently of the current period sunspot realization.

Second, solve for the multiple equilibria implied by the above guess for next-period consumption. Specifically, solve the Euler equation

$$\frac{1}{C_H} = \beta R_{t+1} \frac{1}{C_{L,ss}} \tag{F.15}$$

for equilibrium B_{t+1}. As discussed in Section 5, multiple equilibria for B_{t+1} and R_{t+1} may be consistent with the solution to the equation above for given initial wealth $R_t B_t$. We impose that if the good (bad) sunspot realizes, the equilibrium of the model economy is, for each level of initial wealth, the one associated with the maximum (minimum) level for low-type consumption. We thus define new, sunspot conditional guesses for the low-type consumption policy function: $C_{L,x,guess}$.

Third, proceed backwards by one period and, given the stochastic process for the sunspot (**??**) and the guess for the next-period, sunspot conditional, policy functions for low-type consumption, form expectations for the next-period marginal utility of consumption. Given these expectations, solve for a couple of bond demand functions, conditional on the current realization of the sunspot that are each consistent with the Euler equation:

$$\frac{1}{C_{H,x}} = \beta R_{t+1} \mathbb{E}_t \left[\frac{1}{C_L} \right]. \tag{F.16}$$

Find the intersection of the bond demands with the bond supply, and obtain equilibrium asset purchases and interest rate conditional on the sunspot realization. Update the guess for the policy function for low-type consumption conditional on the sunspot.

Fourth, proceed backwards until convergence of the policy functions for consumption.