The Macroeconomic Implications of US Market Power in Safe Assets*

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Abstract

The US government is the dominant supplier of global safe assets and faces a downward sloping demand for its debt. In this paper, we ask if the US exercises its market power when issuing debt and study its macroeconomic consequences. We develop a model of the global economy in which US public debt generates a non-pecuniary value for its holders, analyze the equilibrium in which the US government is the monopoly provider of this safe asset, and contrast this case with the one in which the US government acts as a price taker. We use variation in estimated demand elasticities for US debt during high- and low-volatility regimes to empirically distinguish between these two models and find that the data reject the price-taking behavior in favor of the monopoly one. We then quantify the distortions due to market power and find that it generates a significant underprovision of safe assets, a sizable markup in the convenience yield, and large welfare benefits for the US to the detriment of the rest of the world. Finally, we study the implications of increasing competition in safe assets from other sovereigns and private institutions.

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1 Introduction

The past few decades have seen an increasingly large demand for safe assets fueled by the rapid growth of high-saving emerging economies. These safe assets are produced by a small number of advanced economies that have the institutional capability to do so. One consequence of the relatively small number of safe-asset issuers is that they have the ability to exert market power. As argued by Farhi and Maggiori (2018), this ability can lead to scarcity in the global supply of safe assets and distortions in the international monetary system. In recent history, the most prominent example of such a safe-asset producer is the US government. A large empirical literature that builds on Krishnamurthy and Vissing-Jorgensen (2012) has documented a downward sloping demand for US Treasuries that reflects the value that investors have for these assets' safety, liquidity, and collateral properties.

In this paper, we ask if the US internalizes this downward sloping demand curve and exploits its market power when issuing debt. We then study the macroeconomic implications of US market power in safe assets. We develop a model of the global economy in which the US is the sole provider of a safe asset with a non-pecuniary benefit. The monopoly equilibrium is associated with a scarce supply of US debt and a spread between its return and that of other safe assets—what the literature refers to as a convenience yield, which reflects both this non-pecuniary value and monopoly rents. This model has different implications for how changes in demand elasticities for US debt affect equilibrium outcomes relative to a model in which the US acts as a price taker. We then measure these elasticities in the data and exploit variation in them during high- and low-volatility regimes, to empirically distinguish between the two models. We find that the data reject the price-taking behavior in favor of the monopoly model, because the latter can better account for increases in yields during these periods of high global volatility with increases in markups. We then use our model to quantify the macroeconomic distortions due to market power. We find that this market power generates a significant underprovision of global safe assets, accounts for a sizable share of the observed convenience yield, and gives rise to large welfare benefits for the US. Finally, we also use our model to study the implications of increased competition in the market for safe assets.

We consider a dynamic model of international borrowing and lending with two countries: the US and the rest of the world. In our model, agents can trade two types of safe assets: public debt issued by the US and capital. We enrich this setting with two key features. First, following the recent theoretical literature on the convenience yield, US public debt provides a non-pecuniary benefit to its holders. This benefit can capture a variety of mechanisms studied in the literature, including the expansion in output associated with the ability to use such assets as collateral or the ease with which they can be traded in secondary markets. Due to this non-pecuniary benefit, in equilibrium, the US issues external debt at low interest rates and invests in other foreign assets with higher returns, thereby operating as a world banker (Gourinchas and Rey, 2007a). Second, the US is the sole provider of this type of asset, and hence, enjoys monopoly power in its provision. As a result, the equilibrium convenience yield, which in the model corresponds to the spread between the return on US debt and safe capital, is a combination of both a non-pecuniary value and a markup. We show that this markup is completely determined by the elasticity of demand for US debt. In contrast, if the US is a price taker, this markup is zero. In addition, the presence of a monopolist in this market implies an underprovision of such assets relative to a benchmark in which the US is a price taker. We show that the degree of underprovision also depends on this demand elasticity.

Motivated by the theoretical predictions, we ask whether the data support the model with market power (i.e., the one in which the US government acts strategically) over a price-taking benchmark. As is well understood from the industrial organization literature, price and quantity data are insufficient to distinguish between price-taking and strategic behavior by the US government when marginal costs are unobservable. We use the insight of Bresnahan (1982) to argue that rotations in the demand curve for US Treasuries (i.e., changes in demand elasticities) can help us test whether price-taking or strategic behavior by the US provides a better representation of the data. We follow the firm conduct literature and use the test developed by Rivers and Vuong (2002) to formally test between the price-taking and monopoly models. To do so, we enrich the demand structure estimated in prior literature to include a demand rotator. We use a regime indicator of high and low global volatility as our measure of a demand rotator and find that the data reject the price-taking behavior in favor of the monopoly model. This is because the monopoly model can better account for increases in the convenience yield during high-volatility periods by increases in markups. We also reach similar conclusions when we pursue a complementary exercise that tests between price-taking and strategic behavior by using variations in the estimated elasticity of demand that arise from the changing composition of US debt holders.

The empirical results suggest that policymakers take into account that interest rates may rise if they issue more debt. We find narrative support for this in a variety of contemporary and historical episodes. One recent example pertains to the Clinton administration's efforts to reduce the deficit. In *The Clinton Administration's Vision for Economic Development* (Tyson, 1993), Laura Tyson, the Chair of President Clinton's Council of Economic Advisers, writes "This [the deficit reduction program] reflects our basic rationale that, when the government reduces its borrowing, interest rates fall and the private sector can borrow more." In a recent interview (Childs and Goldstein, 2021), she also describes how Clinton was worried about rising interest rates if the federal deficit was not reigned in. In a historical example, Alexander Hamilton, the first Secretary of the Treasury, writing in a report on public credit (Hamilton, 1790), highlights the value of "properly funded" public debt;

> It is a well known fact, that in countries in which the national debt is properly funded, and an object of established confidence, it answers most of the purposes of money...The benefits of this are various and obvious...Thirdly. The interest of money will be lowered by it; for this is always in a ratio, to the quantity of money, and to the quickness of circulation. This circumstance will enable both the public and individuals to borrow on easier and cheaper terms.

We then use our estimates along with other aggregate moments to conduct a quantitative analysis of the monopoly model. We find that there is a significant underprovision of global safe assets, with safe-asset supply in the monopoly case being almost half of that in the case when the US acts as a price taker. Additionally, the convenience yield in the monopoly model carries a markup of approximately two-thirds, and is one and a half times that in the price-taking model. We also find that this market power brings sizable welfare benefits to the US while causing large welfare losses to the rest of the world. In this sense, our analysis quantifies a notion of "exorbitant privilege" stemming from the ability of the US to issue large amounts of debt at low interest rates.

In our next exercise we aim to understand the effects of increasing safe-asset competition on the global economy. This exercise is motivated by the recent efforts to create alternative safe assets, both by other governments and the private financial sector. Examples of the former efforts are the initiatives to create a supranational safe asset at the European Union level (Zettelmeyer and Leandro, 2018), and the efforts by the Chinese government to establish itself as a safe-asset issuer and a reserve currency country (Clayton, Dos Santos, Maggiori, and Schreger, 2022). In the private financial sector, creating alternative safe assets has been achieved through increased securitization (Gorton, Metrick, Shleifer, and Tarullo, 2010; Sunderam, 2015). We use our model to assess the macroeconomic impacts of transitioning to an economy in which there is increased competition for safe assets that are substitutable with US government debt. We consider competition from two sources: other sovereigns and the financial sector. We model the former by considering an extension of our model in which N symmetric countries Cournot compete for the provision of safe assets. Our baseline monopolist model corresponds to the case in which $N = 1$, and we consider the effects of transitioning to an economy with a larger N. An economy with $N = 2$ features a global steady-state supply of such assets that is approximately two times larger than the baseline economy with monopoly provision, which implies that the steady-state issuance of US debt is roughly unchanged. However, borrowing costs increase, and there are significant redistributive effects in terms of welfare. As N further increases, the aggregate supply of safe assets and the borrowing costs for the US increase further.

We model competition arising from the financial sector by extending our model to include a competitive fringe. An important distinction is whether this competition arises from domestic or foreign firms. We find that the case of the foreign fringe closely resembles the model with Cournot competition. However, in the case of domestic competition, because the US government internalizes the profits from the domestic fringe, there is less competition for safe assets, implying higher markups, lower safe-asset quantities, and smaller welfare losses for the US. One interesting result we find is that while the aggregate supply of safe assets substantially increases because of increased competition, the US public-debt-to-GDP ratio is fairly stable across the different counterfactuals.

Related Literature

Our paper is related to a literature in international finance that studies safe assets and the global economy. Maggiori (2017), Gourinchas, Govillot, and Rey (2017), and He, Krishnamurthy, and Milbradt (2019) develop macroeconomic theories of the determination of safe assets.[1] A closely related paper is Farhi and Maggiori (2018), which develops a model of the international monetary system. In their model, the shortage in the global supply of safe assets arises because of the presence of market power. Building on their insights, our model features an economy that enjoys market power because of its ability to supply a safe asset that provides a fundamental non-pecuniary value. We contribute to this literature by providing empirical support for the idea that the US exercises its market power and quantifying its macroeconomic implications.

A related literature focuses on the special role of US public debt and the dollar demand. This literature builds on the work of Krishnamurthy and Vissing-Jorgensen (2012), which documents a downward sloping demand for US Treasuries and the presence of a convenience yield that reflects the additional safety and liquidity attributes of US Treasuries. Subsequent work has studied the implications for the term structure and sustainability of US public debt (Greenwood, Hanson, and Stein, 2015; Blanchard, 2019; Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2019; Mian, Straub, Sufi et al., 2021; Brunnermeier, Merkel, and Sannikov, 2022) and international safe assets and exchange rates (Du, Im, and Schreger, 2018; Krishnamurthy and Lustig, 2019; Koijen and Yogo, 2020; Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2020c; Jiang, Krishnamurthy, Lustig, and Sun, 2021b).[2]

[1]See Holmstrom and Tirole (1997); Krishnamurthy and Vissing-Jorgensen (2015); Lenel (2017); J Caballero and Farhi (2018); Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2020b); Gorton and Ordonez (2021) for contributions in the closed-economy literature.

[2]A related literature has studied the evolution of real yields on public debt from a historical perspective (Payne, Szőke, Hall, and Sargent, 2022; Rogoff, Rossi, and Schmelzing, 2022).

Motivated by these facts, a set of papers develop macroeconomic models to study the global implications of the special role of US debt (e.g., Engel and Wu, 2018; Jiang, Krishnamurthy, and Lustig, 2020a, 2021a; Valchev, 2020; Kekre and Lenel, 2021; Devereux, Engel, and Wu, 2022). Our theory shares this idea that US debt generates special benefits to its holders. We contribute to this literature by modeling the behavior of the US government when its debt generates non-pecuniary benefits to US debt holders. Our analysis suggests that these benefits endow the US with market power in safe assets, which accounts for a sizable component of the convenience yield and gives rise to significant underprovision of safe assets. In this sense, our paper quantifies the welfare benefit of the "exorbitant privilege" (Gourinchas and Rey, 2007b,a) that the US enjoys because of its ability to issue large amounts of safe debt at low interest rates.

Finally, a recent literature studies the effects of increasing competition in global safe-asset markets. Clayton et al. (2022) develop a theory to study how countries compete to become safe-asset issuers by building reputation. Geromichalos, Herrenbrueck, and Lee (2022) study imperfect competition in a model in which assets' liquidity premia are determined endogenously. Our analysis complements this literature by providing empirical support for the strategic behavior of the US government and studying the effects of increasing competition for the US and the rest of the world in a quantitative model.

The rest of the paper is organized as follows. Section 2 presents the model and characterizes the prices and allocations in the monopoly and competitive equilibria. Section 3 presents the empirical test of US government behavior. In Section 4 we conduct a quantitative analysis of the model. We conclude the paper in Section 5.

2 Model

We consider a model of international borrowing and lending with two countries: the US and the rest of the world. In our model, agents can trade two types of safe assets: public debt issued by the US and capital. We enrich this setting with two key features. First, following the recent theoretical literature on the convenience yield, US public debt provides a non-pecuniary benefit to its holders. This benefit captures the value associated with the high degree of liquidity of this asset, its ability to serve as collateral, or both. Second, building on Farhi and Maggiori (2018), the US is the sole provider of this type of asset, and hence, enjoys monopoly power in its provision.

2.1 Environment

The two countries are denoted by the US and RoW. The environment is deterministic, and time is discrete, infinite, and denoted by $t = 0, 1, 2, ...$ Each country consists of households, competitive final-goods producers, and competitive capital-goods producers. In addition, there is a government in the US with the ability to issue public debt. We first describe the problem of agents in the RoW. In addition to choosing consumption and investment, the representative RoW household can purchase debt issued by the US government. US public debt is valuable as a means of inter-temporal smoothing and also provides a "non-pecuniary" value. Purchasing b^*_{t+1} units of US debt in period t generates $f_{t+1}\left(b^*_{t+1}\right)$ units of the consumption good in period $t+1$, where f is an increasing and concave function.[3] In Appendix B, we show that such a non-pecuniary value can arise because US debt can serve as collateral to finance investment projects. In addition, we discuss an alternative benefit function which is single-peaked. The single-peaked assumption is motivated by work in monetary theory and captures the benefits that arise because of the favorable liquidity properties of US debt, i.e., its usefulness in facilitating transactions (see, for example, Lagos, Rocheteau, and Wright, 2017 and references therein).

The problem for the representative RoW household is

$$\max_{\left\{c^*_t, k^*_{t+1}, b^*_{t+1}\right\}_{t\geqslant 0}} \sum_{t=0}^{\infty} \beta^t u\left(c^*_t\right)$$

subject to

$$c^*_t + k^*_{t+1} + b^*_{t+1} \leqslant w^*_t + \left(1 - \delta + r^*_{K,t}\right) k^*_t + f_t\left(b^*_t\right) + \left(1 + r_t\right) b^*_t,$$

$$b^*_{t+1} \geqslant 0,$$

and standard non-negativity constraints. Here c^*_t and k^*_{t+1} denote consumption and capital choices in period t, respectively; $r^*_{K,t}$ denotes the return on RoW capital; r_t denotes the return on US public debt; and w^*_t denotes wages. We also assume that households are endowed with one unit of time and supply labor inelastically.

There are also RoW capital-goods producers who rent capital from RoW and US households, produce a composite capital good, and rent it to final-goods producers in the RoW. The problem for the representative capital-goods producer is

$$\max_{\left\{k^*_{US,t}, k^*_{RW,t}\right\}} R^*_t K^*_t - r_{K,t} k^*_{US,t} - r^*_{K,t} k^*_{RW,t},$$

[3] With some abuse of terminology, we refer to the benefit function $f(b)$ as a "non-pecuniary" benefit, even though we model it as extra resources appearing in the budget constraint. There is an equivalent formulation in which the function enters directly into preferences without wealth effects.

where K_t^* is generated using a CES technology,

$$K_t^* = \left[\sigma\left(k_{RW,t}^*\right)^{\frac{\theta-1}{\theta}} + (1-\sigma)\left(k_{US,t}^*\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}.$$

Here, R_t^* is the rental rate of the foreign capital composite, $k_{US,t}^*$ is the capital rented from US households, $k_{RW,t}^*$ is the capital rented from RoW households by the RoW capital producer, and $r_{K,t}$ and $r_{K,t}^*$ are their respective returns.

The problem for the final-goods producer is

$$\max_{K_t^*, L_t^*} A_t^* K_t^{*\alpha} L_t^{*1-\alpha} - R_t^* K_t^* - w_t^* L_t^*.$$

We next turn to the problem of the US. US households choose consumption and capital to maximize their expected utility. They also supply labor inelastically. We state their problem in Appendix B. We assume that the US government can issue debt to RoW households and levies taxes on US households in order to finance debt repayment. These taxes are distortionary and generate resource costs. Recall that US debt generates a non-pecuniary benefit for RoW households. In our baseline model we assume that the US is the monopoly provider of such an asset. In Appendix B we show that the Ramsey problem for the US government is

$$\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t,s^t \geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + k_{t+1} - b_{t+1} = w_t - \chi_t(b_t) + (1 - \delta + r_{K,t}) k_t - (1 + r_t(b_t)) b_t,$$

where b_t is the debt issued by the US government, and, with some abuse of notation, $r_t(b_t)$ is the inverse demand function for US debt. We also show in Appendix B that the distortionary cost associated with debt repayment is captured by the function $\chi_t(b_t)$. More generally, this function captures the costs of expanding the size of the government's balance sheet. We assume that χ is a positive, increasing, and convex function whenever $b_{t+1} > 0$, and zero otherwise. The capital-goods producer in the US solves

$$\max_{\{k_{US,t}, k_{RW,t}\}} R_t K_t - r_{K,t} k_{US,t} - r_{K,t}^* k_{RW,t},$$

where K_t is generated using a CES technology

$$K_t = \left[\sigma(k_{RW,t})^{\frac{\theta-1}{\theta}} + (1-\sigma)(k_{US,t})^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}},$$

while the final-goods producer solves

$$\max_{K_t, L_t} A_t {K_t}^{\alpha} {L_t}^{1-\alpha} - R_t K_t - w_t L_t.$$

An allocation is this economy is given by $\mathbf{x}_t = (x_t^*, x_t)$, where

$$x_t^* = \left(\left\{ c_t^*, k_{t+1}^*, b_{t+1}^*, k_{US,t}^*, k_{RW,t}^*, L_t^* \right\}_{t,s^t} \right),$$

and similarly for x_t.

We can now define an equilibrium for this environment.

Definition 1. A monopoly equilibrium is an allocation $\{\mathbf{x}_t\}_{t \geqslant 0}$ and prices $\left\{ R_t, R_t^*, r_{K,t}, r_{K,t}^*, w_t, w_t^* \right\}$ such that

1. given prices, the allocation $\{x_t\}$ solves the maximization problems for the US;
2. given prices, the allocation $\{x_t^*\}$ solves the maximization problems for the RoW;
3. markets clear:

$$b_t = b_t^*,$$

$$k_t = k_{US,t} + k_{US,t}^*$$

$$k_t^* = k_{RW,t} + k_{RW,t}^*$$

and

$$L_t^* = L_t = 1.$$

2.2 Equilibrium Characterization

In this section we show how this model guides our empirical and quantitative exercises. We start by analyzing a special case of our model in which the US and RoW capital are perfect substitutes in the production function (i.e., $\theta = \infty$). We define the convenience yield in the model as the spread between the returns on US capital and US public debt, $\mathcal{S}_t \equiv (r_{K,t} - \delta) - r_t^{US}$. This model-based definition is consistent with the definition of the convenience yield used in the literature and in the empirical analysis, which is defined to be the spread between the US safe corporate debt and US public debt. This is because in the model, we can interpret the return on capital as the return on safe corporate debt.[4]

[4]Formally, our model is equivalent to one in which firms own the capital stock and borrow from households in order to make investments. In this model the return on firm debt is identical to the return on capital in our model.

Next, we show that both the US and RoW problems can be rewritten so that the choice of debt solves a static problem. To do so, we define $a_{t+1} \equiv k_{t+1} - b_{t+1}$ as the net asset position of the US (and similarly for the RoW). Given this change of variable and using the fact that $b_{t-1} = b^*_{t-1}$, the problem for the US government can be written as

$$\max_{\{c_t, a_{t+1}, b^*_t\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$\begin{aligned} c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t})\, a_t \\ + \mathcal{S}_t(b^*_t)\, b^*_t - \chi(b^*_t). \end{aligned}$$

This formulation recasts the choice of debt as a standard static monopoly problem where the relevant price is the convenience yield and the cost is given by χ. The first-order conditions from this problem imply

$$\mathcal{S}_t(b^*_t) = \chi'(b^*_t) - \mathcal{S}'_t(b^*_t)\, b^*_t. \tag{1}$$

An implication of the US and RoW capital being perfect substitutes is that $r^*_{K,t} = r_{K,t}$ for all t. Using this result, one can rewrite the RoW problem with a similar change of variable. The first-order conditions from the RoW problem imply that

$$\mathcal{S}_t(b^*_t) = f'_t(b^*_t). \tag{2}$$

Thus, because of the non-pecuniary benefit that US debt provides over capital, the return on US debt is lower than that of capital. One can use these conditions to show that the spread and debt level in the monopoly equilibrium are, respectively,

$$\mathcal{S}^{ME}_t = \frac{1}{[1 - \mu_t]} \chi'\left(b^{ME}_t\right) \tag{3}$$

and

$$b^{ME}_t = f'^{-1}\left(\mathcal{S}^{ME}_t\right). \tag{4}$$

Since the US is a monopolist, the convenience yield features a *markup* μ_t where

$$\begin{aligned} \mu_t &\equiv \frac{\mathcal{S}'_t(b^*_t) - \chi'_t(b^*_t)}{\mathcal{S}_t(b^*_t)} \\ &= -\frac{f''(b^*_t)}{f'(b^*_t)} b^*_t, \end{aligned} \tag{5}$$

where the last line follows from (1) and (2).

In contrast, consider an environment in which the US acts as a price taker in the market for safe assets. The problem for the RoW is unchanged, while the problem for the US is

$$\max_{\{c_t, a_{t+1}, b_t\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t + \mathcal{S}_t b_t - \chi(b_t),$$

where the US takes the convenience yield as given. It is straightforward to see that the convenience yield in the competitive equilibrium is given by

$$\mathcal{S}_t^{CE} = \chi'\left(b_t^{CE}\right), \tag{6}$$

where the equilibrium level of debt is

$$b_t^{CE} = f'^{-1}\left(\mathcal{S}_t^{CE}\right). \tag{7}$$

The following lemma immediately follows from comparing the two monopoly and price-taking equations.

Lemma 1. *The monopoly equilibrium features a higher spread and an underprovision of safe assets compared to the case in which the US acts as a price taker.*

A direct implication of the lemma is that the existence of safe-asset underprovision depends on whether the US behaves strategically. The degree of underprovision then depends crucially on the markup μ_t. The markup is completely pinned down by the elasticity of demand, $\mu_t = \varepsilon_{D,t}^{-1}$, where

$$\varepsilon_{D,t} \equiv \frac{db_t^*}{d\mathcal{S}_t}\frac{\mathcal{S}_t}{b_t^*} = -\frac{f'(b_t^*)}{f''(b_t^*)\, b_t^*}.$$

We summarize the above arguments in the lemma below.

Lemma 2. *In the model in which the US and RoW are perfect substitutes* ($\theta = \infty$) *and the US behaves as a monopolist, the convenience yield markup is* $\mu_t = \varepsilon_{D,t}^{-1}$*, where* $\varepsilon_{D,t}$ *is the elasticity of demand for US debt.*

Consider instead the model in which the RoW and US capital are no longer perfect substitutes. We show in the appendix that the above analysis continues to hold in the steady state of this model.

There are two key takeaways from this section. First, to ascertain whether there is underprovision of safe assets requires us to test if the US behaves strategically. Second, if the US behaves strategically, the degree of underprovision of safe assets depends on the elasticity of demand. In the following section, we will use the model and data to provide support for the strategic-behavior assumption and also measure the degree of underprovision of safe assets.

3 Empirical Analysis

In this section, we formally test if the data support the monopoly model over the model in which the US acts as a price taker. For the test we use the insight of Bresnahan (1982) that rotations in the demand curve (through changes in demand elasticities) can help identify strategic from competitive behavior. A pure rotation of the demand curve will change prices only if the agent exploits market power, through changes in markups but not if the agent is a price taker (see Figure C.1 for an illustration of this prediction). Thus, observing increases in prices when demand becomes more inelastic is an indication of strategic behavior. To implement the test, we first estimate the demand for US Treasuries. The key departure from the existing literature is that we also include a demand rotator as a dependent variable. Formally, we estimate

$$y_t = \alpha + \beta \ln b_t + \gamma \left(\ln b_t \times z_t \right) + \delta X_t + \varepsilon_{t,} \tag{8}$$

where y_t is a measure of the convenience yield, $\ln b_t$ is the log of the ratio of public debt to GDP, z_t is the demand rotator, and X_t is a vector of controls that includes z_t. In this specification, the demand semi-elasticity of prices to quantities is given by $\beta + \gamma z_t$. To obtain an estimate of the actual elasticity, we take the ratio of semi-elasticity to the average value of y_t in our sample.[5] When $\gamma = 0$, we obtain the same demand specification estimated in the literature. We also assume the following cost function, $\chi_t(b_t) = \omega_t \frac{b_t^{1+\lambda}}{1+\lambda}$, which implies that the (log) marginal cost of issuing debt is given by

$$\ln mc_t = \omega_t + \lambda \ln b_t,$$

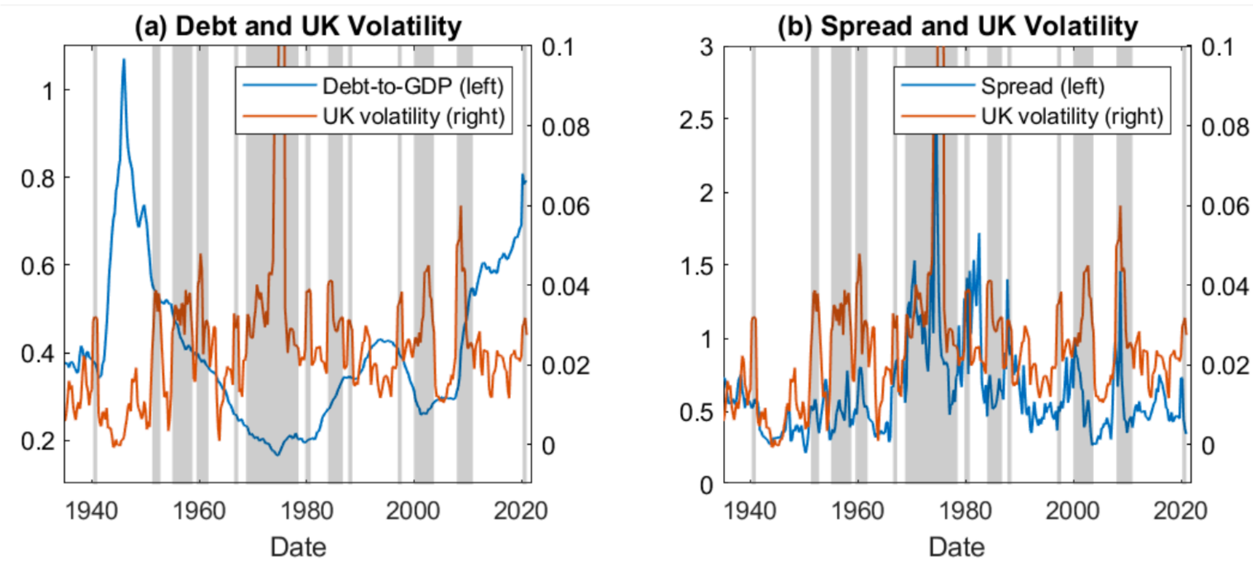
where ω_t is a marginal cost shifter. The exclusion restriction is that the random variables z_t and ω_t are independent, i.e., $\mathbb{E}\left[z_t \omega_t\right] = 0$.

The data for the demand estimation are gathered at a quarterly level from 1935 to 2020. We compute measures of convenience yields for short- and long-term US public debt. The

[5]As an alternative, one could directly measure the demand elasticity by using the log of the convenience yield as the dependent variable. We prefer our empirical specification because the observed convenience yield is negative during a small window in our sample.

short-term convenience yield is computed as the difference in the yields to maturity of short-maturity AAA corporate bonds and US Treasury Bills. The long-term convenience yield is computed as the difference in the yields of long-maturity AAA corporate bonds and US Treasury bonds. Our baseline measure of the convenience yield consists of a weighted average of the short- and long-term convenience yields, with the weights given by the average share of short- and long-term US public debt over the sample period. Our baseline measure of public debt is privately held gross federal debt. In the robustness analysis, we also conduct our empirical analysis using short- and long-term convenience yields separately, and externally held public debt. We provide details on the data sources and the construction of these and other variables in Appendix B. Panels (a) and (b) of Figure 1 depict the time series of the convenience yield and the public debt-to-GDP ratio.

Figure 1: Evolution of prices and quantities of US public debt



Notes: Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. Spread is the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. The shaded areas correspond to periods of high volatility where for at least one quarter the UK volatility measure is above the sample 75th percentile. See Appendix B for a description of the construction of all the variables.

For the demand rotator, we use a slow-moving measure of global volatility. In particular, $z_t = \mathbb{I}\left\{\tilde{z}_t \geqslant \bar{\tilde{z}}\right\}$ is a regime indicator variable that equals one when the volatility index, $\tilde{z}_t$, is higher than the sample median, and zero otherwise. Our volatility index is the standard deviation of the weekly returns of the MSCI United Kingdom Index, computed over a yearly rolling window. Since this index is available starting only in 1972, we use a projection of it based on the yearly rolling window standard deviation of monthly returns of the UK share price index for the earlier part of the sample (see Appendix B for details about the construction). Figure 1 shows the evolution of the volatility measure over time. The logic for including such a demand rotator is that there is a flight to US Treasuries during periods of high global volatility that increases the demand for public debt and makes it more inelastic. We use the regime indicator based on the standard deviation over a yearly rolling window to capture relatively slow-moving changes in volatility over which debt issuance decisions are more likely to respond to changes in demand. However, we also obtain similar results if we use an indicator variable based on the standard deviation computed over shorter rolling windows. Our baseline volatility measure is based on the UK, to capture fluctuations in global volatility that are arguably unrelated to the US. Under this rotator, the exclusion restriction implies that innovations to the supply of US debt are uncorrelated with UK volatility. In Appendix B, we discuss its validity as a demand rotator and show that it is uncorrelated with various measures of fiscal supply shocks. We also consider alternative demand rotators and obtain similar results. Finally, in the baseline specification, the vector of controls X_t includes z_t, a measure of US volatility, and the slope of the yield curve. Our results are robust to the inclusion of this set of controls.

We pursue two estimation strategies to estimate the demand for public debt and show that they both reach similar conclusions. First, we estimate (8) using ordinary least squares (OLS). Second, we pursue a complementary instrumental variables (IV) strategy with two different instruments for the supply of public debt. The first instrument is the dependency ratio of the US population. The motivation for this instrument is that variations in Social Security expenditures are affected by changes in the demographic structure of the US population. Therefore, by instrumenting public debt with changes in the dependency ratio, we are capturing a source of exogenous fluctuations in Social Security expenditures. The second instrument builds on the literature that studies the macroeconomic implications of fiscal shocks and instrument changes in the supply of US debt with a measure of news of military expenditure shocks. This measure was developed in Ramey (2011) and updated subsequently, and has been widely used to study the fiscal multipliers and the responses of macro variables to government expenditure shocks (see, for example, Barro and Redlick (2011); Auerbach and Gorodnichenko (2012); Ramey and Zubairy (2018)). In particular, the instrument consists of a variable that measures at a quarterly level the announcements of military spending as a percent of GDP. The logic behind the instrument is that these shocks are related to military events, which are unrelated to economic shocks that affect the demand for safe assets. Figure C.2 shows the evolution of the instruments over time. In Appendix B, we show that these instruments are uncorrelated with measures of global volatility and with the level of economic activity, and discuss the validity of the exclusion restriction. As part of robustness exercises described below, we also consider additional instruments.

The first two columns of Table 1 report the estimation results for the demand when we allow the semi-elasticity to depend on the demand rotator.

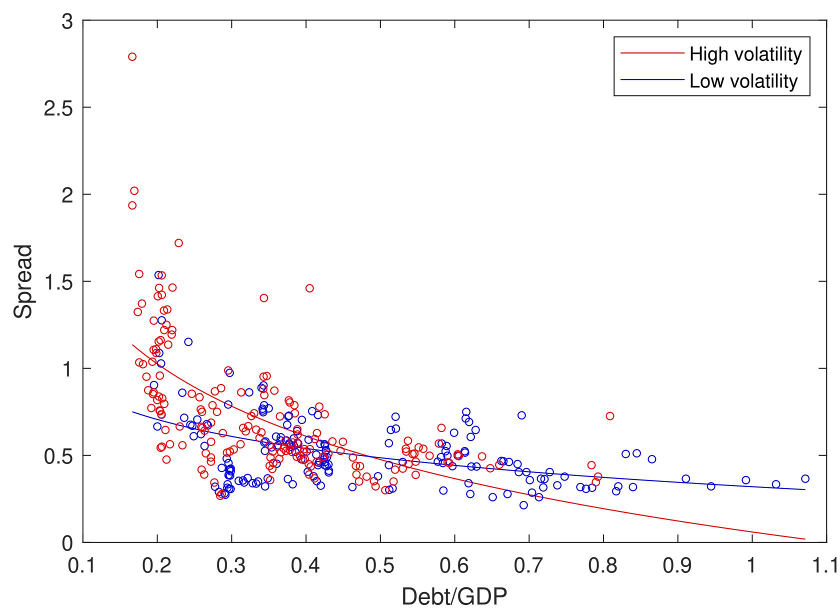
Table 1: Baseline demand estimation

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Log(debt/gdp)	-0.20***	-0.13**	-0.39***	-0.22***
	(0.04)	(0.06)	(0.03)	(0.05)
High Volatility Dummy	-0.34***	-0.14	0.04	0.09***
	(0.06)	(0.10)	(0.03)	(0.03)
Vol Dummy×Log(debt/gdp)	-0.39***	-0.23**		
	(0.06)	(0.09)		
Extended VIX	0.02***	0.02***	0.02***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Slope	-0.06***	-0.07***	-0.06***	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.14**	0.21***	-0.02	0.13**
	(0.06)	(0.07)	(0.05)	(0.06)
Observations	344	338	344	338
R-squared	0.54		0.49	
Demand elasticity, high vol	1.07	1.73	1.59	2.84
Demand elasticity, low vol	3.18	4.66	1.59	2.84
Markup, high vol	0.94	0.58	0.63	0.35
Markup, low vol	0.31	0.21	0.63	0.35

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above the sample median. The main independent variables of interest are the log of the ratio of the Treasury debt outstanding to US GDP and its interaction with the volatility dummy. Other controls include the slope of the Treasury yield curve, measured as the spread between the 10-year Treasury yield and the three-month Treasury yield, and a measure of US volatility based on the VIX data. See the main text for further details, and Appendix B for a description of the construction of all the variables. The estimation method is ordinary least squares (OLS) for columns 1 and 3, and instrumental variables (IV) for columns 3 and 4. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

The OLS estimates of β and γ are both negative and statistically significant. The point estimates imply that a 10% increase in the supply of government debt leads to a decrease in the convenience yield of 20 basis points in low-volatility periods and 59 basis points in high-volatility periods. Given the sample average for the convenience yield, the implied demand elasticities are $\varepsilon_D^L = 3.18$ and $\varepsilon_D^H = 1.07$ during low- and high-volatility periods, respectively (see the last rows of Table 1). In other words, the demand curve is more inelastic in periods of high volatility. This can be seen in Figure 2, which shows the convenience yields and debt levels for high- and low-volatility episodes. Column 2 reports the estimates from the IV method, which uses both instruments simultaneously. In this specification, the point estimates for β and γ are also negative and statistically significant, and imply demand elasticities of 4.66 and 1.73 during low- and high-volatility periods, respectively. The similarity between the OLS and IV estimates suggests that most of the variation in the debt-to-GDP ratio can be attributed to supply shocks. In Appendix C, we report the output of the first-stage regressions, which estimate the log of public debt on each of the instruments and the set of controls used in the main regressions. The last two columns of Table 1 report the estimates of the demand specification when we drop the demand rotator. The average estimated elasticities are 1.59 and 2.84 in the OLS and IV specification, respectively, within the range of the estimates in prior literature (see, e.g., Krishnamurthy and Vissing-Jorgensen (2012); Greenwood et al. (2015); Jiang et al. (2021b); Mian et al. (2021); Krishnamurthy and Li (2022)). We will use an average of these point estimates (i.e., 2.2) in the quantitative analysis of our model.

Figure 2: Safe-asset demand in times of high and low volatility



Notes: Spread is the difference between corporate bond yields and Treasury bond yields, both measured in percentage units. Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. High (resp., low) volatility periods are periods with the UK volatility measure above (resp., below) the sample median. The lines of best fit are obtained from regressing Spread on the log of Debt/GDP. See Appendix B for a description of the construction of all the variables.

We now test the validity of the competitive and monopoly models by comparing their relative fit of the data. Formally, we use a model selection test to distinguish between these two models. We build on the literature in industrial organization that uses the model selection test in Rivers and Vuong (2002) (RV) to test between different models of firm conduct (Backus, Conlon, and Sinkinson, 2021; Duarte, Magnolfi, Sølvsten, and Sullivan, 2021). Under our structural model and the assumed parametric cost function, we can use equations (3) and (6) to express the log of innovations to the marginal costs as

$$\ln \omega_t = \ln \mathcal{S}_t - \xi \ln \mu_t - \lambda \ln b_t, \tag{9}$$

where $\xi = 1$ under monopoly and $\xi = 0$ under perfect competition. Recall that under the true model, we have the moment condition $\mathbb{E}[\tilde{z}_t \omega_t] = 0$. Following RV, we can define the sample analog of a measure of lack of fit for a model m using a generalized method of moments (GMM) objective function, as

$$Q_m \equiv \left| \sum_{t=1}^{T} \frac{1}{T} \tilde{z}_t \omega_t \right|,$$

where T is the total number of periods in our sample, and ω_t is obtained from (9) using observed data for $\mathcal{S}_t$ and b_t, and estimated data for μ_t. Given this measure, the RV test statistic is

$$T^{RV} = \frac{\sqrt{T}\,(Q_1 - Q_2)}{\sigma_{RV}},$$

where $\sigma_{RV}/\sqrt{T}$ is the asymptotic standard error of the difference $(Q_1 - Q_2)$. The RV results show that T^{RV} has a standard normal distribution. This implies that we can reject the null hypothesis in favor of model 1 at the 5% significance level if T^{RV} is smaller than –1.96, and we can reject the null hypothesis in favor of model 2 if T^{RV} is larger than 1.96.

We implement this test in our framework, where Q_1 is the lack of fit for the price-taking model and Q_2 is the equivalent for the monopoly model, for different values of λ, the elasticity of the marginal cost function. In Table 2, we display the test statistics for our baseline model and different values of the elasticity of the cost function, λ.[6]

[6] In Table B.4 in Appendix B we display the F-statistic proposed by Duarte et al. (2021) to diagnose weak testing instruments. The F-statistic rejects the presence of weak instruments in almost all cases.

Table 2: Conduct tests for different cost elasticities

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. OLS								
	3.47	-1.11	-4.72	-6.45	-7.25	-8.23	-8.4	-8.44
	(0.04)	(0.27)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. IV								
	-3.99	-6.24	-7.08	-7.49	-7.73	-8.21	-8.37	-8.43
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: This table shows the results of the RV statistical test comparing the fit of the monopoly and price-taking models for different values of the cost elasticity, λ. Values lower than -1.96 reject the price-taking model in favor of the monopoly model. OLS (ordinary least squares) and IV (instrumental variables) are the methods for estimating the demand for public debt. P-values are in parentheses. See the main text for further details.

Under both the OLS and IV specifications, the test rejects the price-taking model in favor of the monopoly model, for various values of λ. A visual inspection of the results of the test is illustrated in Figure C.3, which shows the estimated innovations to marginal cost under both models. The convenience yield tends to increase in periods of high volatility, such as the mid-1970s, the early 2000s, and the Global Financial Crisis. These increases can be partly accounted for by the estimated rising markups in the monopoly model, whereas they can be explained only by increases in marginal costs in the price-taking model. The latter introduces correlation between innovations to marginal costs and the demand rotator, which makes the moment condition less likely to hold.

In Appendix D we describe an alternative method for inferring the conduct of the US government based on the same observables. This approach relies on backing out the implied value of the conduct parameter ξ, using equation (9) evaluated at high and low elasticity periods. The inferred values of ξ are close to one, implying that the monopoly model is a good representation of the data.

The effects of simultaneous demand shifts and rotations. One potential source of concern is that high-volatility regimes are also associated with shifts in the demand, in addition to rotations. Indeed, our demand estimation results suggest that this is the case, since the estimated partial derivative of the convenience yield with respect to the volatility measure is positive (see Table 1). Recall that our methodology to differentiate between the two models relies on rotations in the demand curve changing prices and quantities if the US acts strategically, but not when it acts as a price taker. If rotations are also accompanied by shifts in demand, then prices and quantities can change even in the price-taking model. In that model, both prices and quantities should increase in high-volatility periods in response to the demand shifting outwards (see Figure C.4). However, as Figure

1 shows, high-volatility periods are associated with high prices and low debt levels. For instance, debt-to-GDP ratios were particularly low during high-volatility periods such as the 1970s oil crisis and the early 2000s dotcom crisis. These observed dynamics of debt prices and quantities make it even more challenging for the price-taking model to explain the data in the presence of demand shifts. This is also reflected in the results of the RV test, which uses information on both prices and quantities, and favors the monopoly model for any elasticity of the cost function, λ. It is worth noting, however, that the opposing movement in prices and quantities is not necessary to reject the price-taking behavior in the presence of demand shifts. As suggested by equation (9), even if prices and quantities increase in high-volatility periods, the test could favor the monopoly model if the increase in prices is more than that predicted by a movement along the marginal cost curve.

The case of exogenous debt rules. One possibility is that the US government follows exogenous debt rules, which would imply a perfectly inelastic supply of debt. In our model, this case is approximated in the limit where $\lambda \to \infty$. In this case, neither shifts nor rotation in demand would have any effect on quantities. However, as we see from Figure 1 and Table C.2, the level of debt is negatively correlated with our measure of volatility. Table C.2 also shows the correlation of the volatility measure with the trend and cyclical component of public debt. The low correlation of the volatility measure with the cyclical component suggests that debt rules may be a good representation of the data at short-run frequencies, while the negative correlation of volatility with the trend component suggests a more elastic supply of debt at longer frequencies.

3.1 Robustness Analysis

In this section we assess the robustness of the main empirical results to the use of alternative approaches to identifying demand rotations and other specifications for estimating the demand for US public debt.

Alternative rotators. We first consider demand rotators that are based on alternative measures of global volatility. We estimate the demand for public debt and the conduct test using a rotator of volatility regimes with a measure of US stock market volatility. In this case, the test reaches similar conclusions as in our baseline analysis, but does so by using price and quantity dynamics from high-volatility episodes that are different from those in our baseline exercise, with the UK volatility variable, for example, the aftermath of the Great Depression (see Figures B.2 and B.3).[7] Next, we consider a rotator based on the volatility of the Hong Kong stock market index. Finally, we consider alternate constructions of the baseline UK-based volatility measure. In particular, we use regime indicators based on a standard deviation of the MSCI United Kingdom Index returns

[7]This is because there is a low correlation, of 25%, between US and UK volatility.

computed over six-month and two-year rolling windows (instead of the one-year rolling window used in the baseline); we consider regime indicators in which high-volatility periods correspond to those in which the standard deviation of the MSCI United Kingdom Index is greater than its 66th and 75th percentiles (instead of the sample median), and also consider a regime indicator based on a residualized measure of UK volatility (residualized from a projection based on US volatility). Table B.5 shows the demand estimates for these alternative rotators, which imply a more inelastic demand in periods of high volatility. Table B.6 shows the test statistics for these rotators, which reject the price-taking in favor of the monopoly model. See Appendix B for further details about these exercises.

Second, we use an alternative rotator that is based on the shifting composition of the holders of public debt. This approach exploits the facts that the composition of public-debt investors has shifted over time and that different types of investors have different demand elasticities (Krishnamurthy and Vissing-Jorgensen, 2007). We divide the investors in US public debt into two groups: foreign investors, which are mostly comprised of official investors (such as foreign central banks) and domestic investors, which are mostly comprised of domestic financial institutions and mutual funds. In Appendix B, we estimate the demand elasticity for each group separately and find that the demand curve for foreign investors is more inelastic (see Table B.7). Since the 1970s there has been a large increase in demand for Treasuries from foreign investors, which implies that the average demand elasticity weighted by the share of the two investor types has been decreasing. We use this time variation in the estimated average elasticity to compute the RV conduct test and find that it rejects the price-taking in favor of the monopoly model for most values of the supply elasticity. In this case, the monopoly model can better account for the observed increase in long-term convenience yields that started at roughly the same time as the increase in foreign investors' participation (see Figures B.4 and B.5), through an increase in markups.

Other robustness analyses. The empirical results are also robust to the set of controls used in the demand estimation, to how we measure the convenience yield and public debt, to the time sample used in the estimation, and to the use of alternative instruments for the supply of public debt. Tables B.8, B.9, B.11, and B.12 report the demand estimates with and without the demand rotator, and Tables B.10 and B.13 report the corresponding test statistics. We include the volume of bank deposits as an additional control, to capture the presence of a substitutable safe asset that has similar liquidity properties (see, e.g., Nagel, 2016; Krishnamurthy and Li, 2022). We also conduct the empirical exercises excluding the set of controls. For alternative measures of the convenience yield, we use the short- and long-term convenience yields as dependent variables. For public debt, we also consider using the ratio of debt to trend-GDP—to avoid capturing movements driven by actual GDP—and external debt as a dependent variable. For the time sample, we consider a postwar sample and a sample that excludes periods in which the zero lower bound binds. As an alternative instrument, we use a measure of government expenditure shocks developed by Blanchard and Perotti (2002). This measure consists of the component of current government spending that is not explained by a set of controls, which include lagged values of taxes, output, and government spending (see Appendix B for further details). We also consider using the military news and dependency ratio instruments separately. The demand estimates are fairly stable across these specifications and imply more inelastic demand in periods of high volatility. The test results are also stable and reject the price-taking model in favor of the monopoly one. To summarize, our empirical analysis suggests that the monopoly model in which the US internalizes its market power when issuing debt yields a better representation of the data than the price-taking model. Consistent with prior literature, we also estimate the demand for public debt to be inelastic. This implies sizable distortions due to market power, as we will see in the next section.

4 Quantitative Analysis

In the previous section, we provided empirical support for the model in which the US behaves strategically and exploits its market power when issuing debt. In this section, we use this model along with the empirical estimates to quantify the macroeconomic implications of this market power.

As a first step, we use our empirical elasticity measure to decompose the average convenience yield across our sample into a non-pecuniary component and a markup (μ). Note that this analysis requires only the estimate of the elasticity of demand and is independent of the remaining parameters of the model. Recall that the markup is just the inverse of the elasticity of demand, which in our sample is 2.2. Thus the markup accounts for approximately 45% of the convenience yield. Given an average convenience yield of 68 basis points, the markup is significant and equals 30 basis points. In contrast, in the price-taking equilibrium, the markup is zero.

To further understand the economic implications due to this market power, we calibrate our model. The model is calibrated at an annual frequency. The four externally calibrated parameters are described in Table 3. We assume a utility function of the form $u(c) = c^{1-\gamma}/(1-\gamma)$, a benefit function of the form $f(b) = \nu b^{\eta}/\eta$, and a cost function of the form $\chi(b) = \omega b^{1+\lambda}/(1+\lambda)$. The cost function is the same as the one used in the previous section. For the parameters on preferences and technologies, we use standard values in the business-cycle literature: a coefficient of relative risk aversion of $\gamma = 2$, a capital share of $\alpha = 0.3$, and a depreciation rate of $\delta = 0.1$. We follow Barro (1979) and Jiang, Sargent, Wang, and Yang (2022) and assume that $\lambda = 1$ in our baseline calibration but also consider robustness to different values.

Table 3: Externally calibrated parameters

γ	Risk aversion parameter	2
α	Capital share	0.3
δ	Depreciation rate	0.1
λ	Cost elasticity	1

The eight internally calibrated parameters are described in Table 4 and are chosen to match eight moments in the steady state. The discount factor β and the parameters associated with the benefits and cost of issuing debt, ν and ω, respectively, are calibrated to match the average convenience yield, the interest rate on US debt, and its debt position. In particular, β is determined using the average convenience yield, the US interest rate, and the steady-state model equation $\beta^{-1} = r^K - \delta$, which implies that

$$\beta^{-1} = \mathcal{S} + r^{US},$$

where $\mathcal{S} = r^K - \delta - r^{US}$ is the average convenience yield, which is 0.68%, and r^{US}, the US interest rate, which is 1.%. We use an inverse elasticity of demand of 2.2—which is approximately the simple average of the estimates in columns 3 and 4 of Table 1 and is also in line with the estimates found in prior literature—which implies $\eta = 0.54$. To calibrate ω and ν, we use the above functional forms along with the model's first-order conditions in the steady state to obtain

$$\mathcal{S} = \nu b^{\eta-1}$$

and

$$\mathcal{S} = \omega b^{\lambda} + \nu (1-\eta) b^{\eta-1}.$$

Using the average convenience yield, the average debt-to-GDP ratio of 0.39, and our empirical estimate of η, we can obtain ν from the first equation. Next, we obtain ω from the second equation. The remaining parameters are related to the capital share and productivity levels target moments associated with the external balance sheet of the US and to the relative sizes of the two economies. In particular, the share parameter σ is calibrated using the degree of home bias in US private assets, measured as the ratio of k_{US}/k, which we obtain from Warnock (2002). The foreign share parameter σ^* is calibrated to match the average net foreign assets of the US in the data. We calibrate US productivity scalar so that the US GDP is normalized to 1, and we calibrate the productivity scalar of the RoW so that the steady-state model ratio of the US GDP to RoW GDP is equal to that in the data. Here the GDP of the RoW corresponds to the GDP of the EU and China during the sample period.

Table 4: Internally calibrated parameters

Full-sample calibration				
β	Discount rate	0.98	Average convenience yield	0.68%
ν	Benefit parameter	0.0045	Average US real interest rate	1.0%
ω	Cost parameter	0.0096	Average US debt-GDP ratio	0.39
σ	US own capital share	0.92	US home bias	0.8
σ^*	RoW own capital share	0.79	US NFA	−0.05
A	US productivity	0.82	Normalized US GDP	1
A^*	RoW productivity	0.94	Ratio of RoW GDP/US GDP	1.1

We can now use our model to quantify the distortions due to market power, by comparing the baseline economy to a counterfactual one in which the US acts as a price taker. Table 5 displays the safe-asset levels, spreads, and interest rates in both economies. Our baseline calibration suggests that the level of safe-asset underprovision due to market power is significant. The safe-asset supply is one-half times larger in the counterfactual when the US acts as a price taker. Moreover, the spreads in the price-taking case are almost 20% larger in the monopoly case. In Table C.3 we show how these results depend on alternative parameterizations of the demand and cost elasticities. As the table shows, the effects are significant in all cases.

Table 5: Macroeconomic distortions due to market power

	ME	CE
Total safe assets/GDP	0.39	0.59
Convenience yield	0.68%	0.57%
Interest on public debt	0.97%	1.09%

Notes: The steady-state equilibrium values of macroeconomic variables. ME refers to the baseline monopoly equilibrium in which the US exercises market power. CE refers to a competitive equilibrium in which the US acts as a price taker.

We next use our model to quantify the welfare implications of the benefits to the US of having access to the technology for creating these safe assets. To do so, we study the transition from the monopoly steady state to an economy in which there is no special role for US assets (i.e., $f = 0$). We also consider the transition to an equilibrium in which the US acts as a price taker.

Table 6: Welfare implications of market power in safe assets

	No special role	CE with special role
US welfare	-0.21%	-0.08%
RoW welfare	-0.34%	$+0.10\%$

Notes: No special role corresponds to an economy in which the benefit and cost functions are both zero. CE with special role corresponds to the competitive equilibrium in which the US acts as a price taker. Welfare changes are expressed in permanent consumption equivalence terms considering the whole transition period starting from the baseline monopoly equilibrium.

Table 6 documents a significant welfare gain to the US from having access to this technology, almost half of which is due to market power. Clearly, the RoW also benefits from this technology but prefers an environment in which the US acts as a price taker. Table C.4 shows the results for alternative parameterizations of the demand and cost elasticities. One can interpret these welfare gains as a measure of "exorbitant privilege" (Gourinchas et al., 2017). Our measure focuses on the gains from the special role of US debt and abstracts from risk-premium considerations. Introducing such premia would increase these benefits.[8]

4.1 Safe-asset Competition

Next, we use our model to understand the effects of increasing competition in the market for safe assets. We consider competition from two different sources: other sovereigns and private institutions. We model the former case as a Cournot game, and the latter as a monopolist competing against a competitive fringe.

4.1.1 Competition from Sovereigns

We model sovereigns as "large" players and consider an extension of our model in which N symmetric countries Cournot compete for the provision of the safe asset. To focus on the effects of competition, we keep the sizes of the RoW and the total suppliers of the safe asset constant and equal to those in the baseline model. Our baseline model corresponds to the case in which $N = 1$. In such an environment, the problem for the US is

$$\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t,s^t \geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

[8] In a recent paper, Atkeson, Heathcote, and Perri, 2022 argue that a broader notion of exorbitant privilege that includes all types of private foreign assets and liabilities has been decaying over time.

subject to

$$c_t + k_{t+1} - b_{t+1} = w_t - \chi_t(b_t) + (1 - \delta + r_{K,t})\, k_t - (1 + r_t(b_t + B_t))\, b_t,$$

where B_t is the level of safe assets provided by the other countries. The rest of the environment is unchanged.

Here, the markup and the level of safe-asset provision depend on the level of competition, which is captured by N. To see this, consider the analytical model we analyzed earlier with perfectly substitutable capital and recall the expressions (3) and (4). The following lemma characterizes the equilibrium outcomes.

Lemma 3. *When* N *countries Cournot compete for the provision of the safe asset, the equilibrium quantity of safe assets and the spread are given by*

$$\mathcal{S}_t^{CN} = \frac{1}{[1 - \mu_t^{CN}]} \chi' \left(\frac{b_t^{CN}}{N} \right) \tag{10}$$

and

$$b_t^{CN} = f'^{-1}\left(\mathcal{S}_t^{CN}\right), \tag{11}$$

respectively, where $\mu_t^{CN} = (N \varepsilon_{D,t})^{-1}$.

All proofs are in the Appendix A.1. It follows directly from the lemma that the total quantity of safe assets will be higher and spreads lower when $N > 1$. However, the effect on the US issuance of debt is unclear. In a symmetric equilibrium, the US issues b^{CN}/N. Since both the numerator and denominator are increasing, the effect of increasing N is ambiguous. We now show that US issuance always increases as we move from a monopoly to a duopoly but decreases with N after that.

Lemma 4. *Suppose that f is concave and has constant elasticity. Then US safe-asset provision increases as N goes from 1 to 2 but decreases for all N thereafter.*

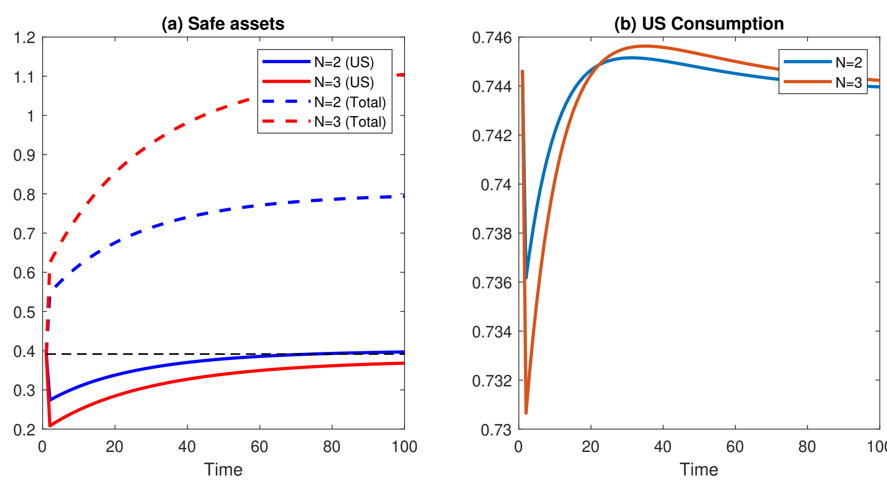
When the first competitor arrives, its effect on increased competition more than offsets the fact that the same demand can now be satisfied by more competitors, thus increasing the issuance of US debt. As the number of competitors increases, the additional effect on competition is smaller and the latter effect is dominant.

We now study the effects of increased competition in a quantitative version of our model with imperfect substitution of capital. Note that Lemmas 3 and 4 apply to the steady state of this model. To study the transition, we assume that at date zero, there is an unanticipated increase in the number of competitors N. We consider different values for N. As mentioned in the introduction, this exercise is motivated by the increase in the private provision of safe assets and the desire in some countries to introduce an indigenous safe asset that can rival US Treasuries. The calibration is identical to that in the previous section.

In Figure 3 we plot the transition path for the quantity of safe assets and US consumption. Table 7 documents the change in convenience yields, interest rates, and welfare changes as a consequence of this transition. In Appendix C (Figure C.5), we plot the transition path for other variables, including RoW consumption. We observe a significant increase in the equilibrium quantity of safe assets and decrease in spreads. Note that the equilibrium quantity of safe assets is larger than in the case in which the US acts as a price taker because of the assumption of increasing marginal costs. As more countries contribute to the provision of safe assets, the marginal cost for each country decreases, which results in a larger aggregate quantity.

During the transition, the US issuance of debt falls sharply, leading to a consumption drop which recovers over time as the economy converges to the new steady state. In line with Lemma 4, the US issuance of debt is larger in the new steady state. However, an interesting result here is that owing to the non-monotonicity result described in Lemma 4, as N increases, the steady-state level of US debt is not very different from that in the monopoly case. Of course, the US now faces a much higher interest rate and its welfare decreases significantly as N increases. In contrast, the RoW is much better off when there is more competition.

Figure 3: Transition path due to increased competition



Notes: This figure shows the path of macroeconomic variables in response to increasing the number of safe-asset issuers to N from the steady state of an economy with a single safe-asset issuer. US indicates safe assets produced by the US only; total includes safe assets produced by all Cournot competitors in the economy.

Table 7: The effects of increasing competition

	ME	Cournot		Fringe	
		N = 2	N = 3	Foreign	Domestic
a. Steady-state variables					
Total safe assets	0.39	0.80	1.13	0.90	0.83
US public debt	0.39	0.40	0.38	0.41	0.33
Convenience yield	0.69%	0.50%	0.43%	0.47%	0.49%
Interest on public debt	0.97%	1.16%	1.23%	1.18%	1.17%
b. Welfare					
Steady State					
US welfare	–	−0.12%	−0.11%	−0.15%	−0.94%
RoW welfare	–	+0.96%	+1.71%	+1.18%	+1.04%
Transition					
US welfare	–	−0.13%	−0.18%	−0.15%	−0.05%
RoW welfare	–	+0.16%	+0.26%	+0.20%	+0.18%

Notes: This table reports key macroeconomic variables under different competition arrangements. Panel A shows the steady-state values of these macroeconomic variables. Panel B reports the welfare change expressed in permanent consumption equivalence terms. The first two rows indicate the welfare change if the economy instantaneously jumped to the new competitive steady state. The last two rows show the results when the transition period is considered.

4.1.2 Competition from Financial Intermediaries

Unlike how we modeled sovereigns, we model financial intermediaries as a competitive fringe. These intermediaries are owned by households. Using a similar argument to the one presented earlier, we can write the problem of the consolidated household-intermediary pair as

$$\max_{\{c_t, a_{t+1}, b_t\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$\begin{aligned} c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t})\, a_t \\ + \mathcal{S}_t(b_t)\, b_t - \chi_F(b_t), \end{aligned}$$

where χ_F is the cost of issuing safe assets for the intermediary. An important assumption is whether these intermediaries, or households, correspond to the ones from a third country or the US. In the former case, the US government will be in direct competition with these intermediaries; in the latter, the US government would like to consolidate market power.

First consider the case in which the households reside in a third country. The Ramsey problem for the US government is

$$\max_{\{c_t, a_{t+1}, b_t\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$\begin{aligned} c_t + a_{t+1} &= w_t l_t + (1 - \delta + r_{K,t}) a_t \\ &\quad + \mathcal{S}_t \left(b_t + b_t^f(b_t)\right) b_t - \chi(b_t) \end{aligned}$$

where $b_t^f(b_t)$ is the level of safe assets issued by the fringe and is the solution to

$$\mathcal{S}_t \left(b_t + b_t^f(b_t)\right) = \chi_F' \left(b_t^f(b_t)\right). \tag{12}$$

As before, the demand for safe assets is determined via the first-order conditions of the RoW,

$$\mathcal{S}_t \left(b_t + b_t^f(b_t)\right) = f' \left(b_t + b_t^f(b_t)\right). \tag{13}$$

Lemma 5. *When there is competition from a foreign competitive fringe, the equilibrium spread and quantities of safe assets* $\left(b_t, b_t^f\right)$ *are given by*

$$\mathcal{S}_t^F = \frac{1}{[1 - \mu_t(b_t, b_t^f)]} \chi'(b_t), \tag{14}$$

$$b_t + b_t^f = f'^{-1}\left(\mathcal{S}_t^F\right), \tag{15}$$

and

$$b_t^f = \chi_F'^{-1}\left(\mathcal{S}_t^F\right), \tag{16}$$

respectively, where the markup

$$\mu_t\left(b_t, b_t^f\right) = \left(\left(1 - \frac{f''\left(b_t + b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right)}\right) \varepsilon_{D,t}\right)^{-1} \frac{b_t}{b_t + b_t^f}.$$

The increase in competition from the fringe lowers the spread and increases the equilibrium quantities of safe assets.

Next, we consider the case in which the competition arises from US household-intermediary pairs. In this case, the Ramsey problem for the US government is

$$\max_{\left\{c_t, a_{t+1}, b_t, b_t^f\right\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + a_{t+1} = w_t l_t + (1-\delta + r_{K,t})\, a_t$$
$$+ \mathcal{S}_t\left(b_t + b^f_t(b_t)\right) b_t - \chi(b_t) + \mathcal{S}_t\left(b_t + b^f_t(b_t)\right) b^f_t - \chi_F\left(b^f_t\right),$$

and where, as before,

$$\mathcal{S}_t\left(b_t + b^f_t(b_t)\right) = f'\left(b_t + b^f_t(b_t)\right).$$

Lemma 6. *When there is competition from a domestic fringe, the equilibrium spread and quantities of safe assets* $\left(b_t, b^f_t\right)$ *are given by equations in Lemma 5 except that*

$$\mu_t\left(b_t, b^f_t\right) = \left(\left(1 - \frac{f''\left(b_t + b^f_t(b_t)\right)}{\chi''_f\left(b^f_t(b_t)\right)}\right)\varepsilon_{D,t}\right)^{-1}.$$

Relative to the case with foreign intermediaries, in this case the markup is larger and the equilibrium quantity of debt is smaller. The reason for less competition in the domestic-fringe case relative to the foreign-fringe case is that the US government directly cares about the profits of the fringe, because they are owned by households. Thus, the US maximizes the joint profits of the government and fringe, which implies that the outcomes are closer to those inthe monopoly case than they are when the fringe is owned by foreign households.

We now consider the transition from our initial monopoly steady state to the steady state with the fringe in our quantitative model. Table 7 highlights the key statistics in the transition and compares them with the monopoly and Cournot cases. There are two key takeaways. First, while the aggregate supply of debt varies considerably by type of competition, the amount issued by the US is relatively stable. Second, the welfare loss of the US in the domestic-fringe case is significantly lower relative to the other cases, because the benefits from the fringe are also internalized by the US.

5 Conclusion

In this paper, we found empirical support for the idea that the US government behaves strategically and exploits its market power when issuing debt. We quantified the distortions due to this power and found that they are sizable and give rise to a significant underprovision of global safe assets. This finding provides one interpretation of the "shortage" of safe assets highlighted by academics and policy-makers.

Motivated by the growth of private and other sovereign safe assets, we studied the effects of increasing safe-asset competition. One implication of our analysis is that increased competition will alleviate the safe-asset shortage. We also found that while the US issuance of debt is relatively unchanged, the cost of servicing this debt rises sharply. Therefore, increasing safe-asset competition can have significant implications for the sustainability of US public debt (see, for instance, Blanchard, 2019; Rogoff, 2020).

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A Theoretical Appendix

Consider the model in which the US and RoW capital are imperfect substitutes in the aggregate capital technology. We show that the results in Section 2.2 continue to hold in the steady state of this model.

Lemma 7. *In the steady state, the level of debt is given by*

$$f'\left(b^{ME}\right) = \chi'\left(b^{ME}\right) - f''\left(b^{ME}\right) b^{ME},$$

and the convenience yield is given by

$$\mathcal{S}^{ME} = \chi'\left(b^{ME}\right) - f''\left(b^{ME}\right) b^{ME}.$$

In the steady state of the price-taking equilibrium, the level of debt is given by

$$f'\left(b^{CE}\right) = \chi'\left(b^{CE}\right),$$

and the convenience yield is given by

$$\mathcal{S}^{CE} = \chi'\left(b^{CE}\right).$$

Therefore, $b^{ME} < b^{CE}$*and* $\mathcal{S}^{ME} > \mathcal{S}^{CE}$.

The proof follows directly from comparing the first-order conditions in the monopoly and price taking equilibria. Comparing the steady states reveals that in the monopoly case, the equilibrium level of debt is lower and the spread is higher.

A.1 Microfoundation for the Benefit and Cost Functions

We now derive the benefit and cost functions from a more primitive environment. We provide a microfoundation based on the ability to use Treasuries as collateral. Alternative microfoundations for the benefit function include the use of public debt to facilitate transactions (see, for example, Lagos et al., 2017 and references therein) or reduce misallocation (e.g., Woodford, 1990; Perez, 2018). We discuss the implications of the former in the next subsection.

Consider first the US. We assume that the US is populated by households who solve

$$\max_{\{c_t, k_{t+1}\}_{t\geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + k_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) k_t - T_t,$$

where T_t is the the total tax burden on private agents. The capital and final-goods producers are identical to those described in the main text. We assume that the US government can issue debt and uses taxes to pay back its debt. We assume that taxation is distortionary and results in a resource cost $\chi(\cdot)$. We also assume that existing debt and interest payments must be paid back before new debt can be issued. These assumptions imply that

$$T_t = \left(1 + r_t^{us}\right) b_t + \chi\left(\left(1 + r_t^{us}\right) b_t\right) - b_{t+1}.$$

The equations characterizing the equilibrium given these taxes are

$$u'(c_t) = \beta\left(1 - \delta + r_{K,t}^{us}\right) u'(c_{t+1})$$

and

$$c_t + k_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) k_t - T_t.$$

Thus, we can write the Ramsey problem as

$$\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t \geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + k_{t+1} + b_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) k_t + \left(1 + r_t^{us}\right) b_t - \chi\left(-(1 + r_t) b_t\right)$$

$$u'(c_t) = \beta(1 - \delta + r_{K,t+1}) u'(c_{t+1}).$$

Consider the relaxed problem where we drop the last constraint. The first-order conditions of this relaxed problem yield exactly this constraint. So, the Ramsey problem is

$$\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t \geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + k_{t+1} + b_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) k_t + \left(1 + r_t^{us}\right) b_t - \chi\left(-(1 + r_t) b_t\right).$$

This problem is identical to that in the main text except for the factor $(1 + r_t)$ in the cost function. For simplicity, we consider the formulation without this factor but show using numerical exercises that our results are unchanged.

Next, consider the RoW. As before, assume the RoW is populated by households who consume and save in capital. In addition, households have investment opportunities and need to raise funds. Let $f(x_t)$ denote the profit associated with investing x_t units in the investment opportunity. We assume that households have access to intra-period loans that need to be collateralized by safe assets. Thus, the amount that households can borrow in period t is given by

$$x_t \leqslant b_t.$$

The problem for the household in the RoW is

$$\max_{\{c_t, l_t, k_{t+1}, b_{t+1}\}_{t \geqslant 0}} \sum_{t=0}^{\infty} \beta^t u(c_t^*)$$

subject to

$$c_t^* + k_{t+1}^* + b_{t+1}^* = f(x_t^*) + (1 - \delta + r_{K,t}^*) k_t + (1 + r_t) b_t^* + w_t^* l_t^*,$$

$$x_t \leqslant b_t$$

$$b_{t+1} \geqslant 0.$$

Assuming that the collateral constraint binds, this problem is equivalent to the one in the main text.

A.2 A Single-peaked Benefit Function

One alternative microfoundaton for this non-pecuniary benefit is that US debt can help alleviate search and transaction frictions. In this case, this benefit can be interpreted as a liquidity premium. See Lagos et al., 2017 for a survey of the literature. In these models, the liquidity premium reflects the ability of assets (such as Treasury bonds) to overcome search frictions in decentralized markets. These models with liquidity frictions feature a notion of satiation: if agents hold large enough quantities of bonds, the liquidity premium will be zero.

We model this with a benefit function $g(b)$ that is concave and single-peaked, and assume that the US government can costlessly issue debt. We will deal with the case with positive marginal costs subsequently. In the zero-cost case, if the US acts as a price taker, it is straightforward to see that in equilibrium the liquidity demand will be satiated and so

$$\mathcal{S} = g'(b^*) = 0.$$

As before, if we assume that the US and RoW capital are perfect substitutes, then the problem for the US if it behaves as a monopolist is

$$\max_{b} \mathcal{S}(b)\, b.$$

Thus, the optimal choice of b solves

$$g''(b)\, b + g'(b) = 0.$$

Since g is a concave function, the above equation implies that $b^{ME} < b^*$ and the spread $\mathcal{S}^{ME} = -g''(b)\, b > 0$. There are two implications of this single-peaked benefit function worth highlighting. First, the convenience yield reflects only market-power distortions. Second, just as in our baseline model, there is an underprovision of safe assets relative to the price-taking case.

The magnitude of safe-asset underprovision will depend on the shape of $g(b)$. However, the estimation of g is different than in our baseline. Our estimation procedure in the baseline relies on exogenous cost shifters, which allowed us to identify demand; but here we cannot use the same procedure, because we assume zero marginal costs. Estimating g in such a context is outside the scope of this paper.

Finally, it is worth noting that if we assume a positive marginal cost, then we can use a similar estimation procedure as in our baseline. The reason is that in this case, even in the price-taking scenario, the equilibrium convenience yield will be positive and the quantity will be lower than the satiation point. Thus we will always be on the "increasing" part of the benefit function; so, it is reasonable to model such a situation as one with an increasing and concave constant elasticity function, as we did in our baseline.

A.3 Proofs from Section 4.1

Proof of Lemma 3

Using a similar argument to that in the baseline, we can write the problem of the US as

$$\max_{\{c_t, a_{t+1}, b_t\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$\begin{aligned} c_t + a_{t+1} = w_t l_t &+ (1 - \delta + r_{K,t})\, a_t \\ &+ \mathcal{S}_t (b_t + B_t)\, b_t - \chi(b_t). \end{aligned}$$

The first-order condition for the US is

$$\mathcal{S}_t\left(b_t + B_t\right) = \chi'\left(b_t\right) - \mathcal{S}_t'\left(b_t + B_t\right) b_t.$$

Thus, in any symmetric equilibrium, we have

$$S_t\left(b_t^{CN}\right) = f'\left(b_t^{CN}\right)$$

and

$$\mathcal{S}_t\left(b_t^{CN}\right) = \chi'\left(\frac{b_t^{CN}}{N}\right) - f''\left(b_t^{CN}\right)\frac{b_t^{CN}}{N}.$$

Therefore,

$$\mathcal{S}_t\left(b_t^{CN}\right) = \frac{1}{1-\mu_t^{CN}}\chi'\left(\frac{b_t^{CN}}{N}\right)$$

where $\mu_t^{CN} = \left(N\varepsilon_{D,t}\right)^{-1}$. Q.E.D.

Proof of Lemma 4

From the proof of Lemma 3

$$\chi'\left(\frac{b}{N}\right) - \frac{1}{N}f''\left(b\right)b = f'\left(b\right).$$

Let $z \equiv b/N$. Then totally differentiating the above equation wrt N yields

$$\chi''\left(z\right)z'\left(N\right) - f''\left(Nz\right)z'\left(N\right) - f'''\left(Nz\right)z\left(Nz'\left(N\right)+z\right) = f''\left(Nz\right)\left(Nz'\left(N\right)+z\right),$$

which implies that

$$z'\left(N\right) = z\frac{\frac{f'''(Nz)Nz}{f''(Nz)}\frac{1}{N} + 1}{\left[\frac{c''(z)}{f''(Nz)} - 1 - \frac{f'''(Nz)zN}{f''(Nz)} - N\right]}.$$

Suppose that $f = \eta_f b^\eta/\eta$. Then,

$$z'\left(N\right) = z\frac{\left(2-\eta\right)\frac{1}{N} - 1}{\left[-\frac{c''(z)}{f''(Nz)} + N + \eta - 1\right]}.$$

Note that for $N \geqslant 1$ the denominator is positive, so the sign depends on $2-\eta-N$. Thus, as N increases from 1 to 2, US safe-asset provision increases, and as N increases beyond 2, US safe asset provision decreases in N. Q.E.D.

Proof of Lemma 5

Proof. The first-order condition for the US is

$$\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)\left[1 + b_t^{f'}(b_t)\right] b_t + \mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0. \tag{17}$$

Using the (12), we have

$$\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)\left[1 + b_t^{f'}(b_t)\right] = \chi_f''\left(b_t^f(b_t)\right) b_t^{f'}(b_t),$$

and so

$$b_t^{f'}(b_t) = \frac{\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right) - \mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)}.$$

Next, using (13), we have $\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right) = f''\left(b_t + b_t^f(b_t)\right)$; thus, inserting this into the previous equation yields

$$b_t^{f'}(b_t) = \frac{f''\left(b_t + b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right) - f''\left(b_t + b_t^f(b_t)\right)}.$$

Substituting the above into (17) yields

$$\left[1 - \varepsilon_D^{-1}\left[\frac{\chi_f''\left(b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right) - f''\left(b_t + b_t^f(b_t)\right)}\right]\frac{b_t}{b_t + b_t^f(b_t)}\right]\mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0,$$

and using the definition of markup in the text of the lemma yields the result. The equilibrium quantities can be obtained from (12) and (13). Q.E.D.

Proof of Lemma 6

The first-order condition for the US is

$$\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)\left[1 + b_t^{f'}(b_t)\right]\left(b_t + b_t^f\right) + \mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0. \tag{18}$$

Using (12) and (13), we have

$$b_t^{f'}(b_t) = \frac{f''\left(b_t + b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right) - f''\left(b_t + b_t^f(b_t)\right)}.$$

Substituting the above into (18) yields

$$\left[1 - \varepsilon_{D,t}^{-1}\left[\frac{\chi_f''\left(b_t^f(b_t)\right)}{\chi_f''\left(b_t^f(b_t)\right) - f''\left(b_t + b_t^f(b_t)\right)}\right]\right]\mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0,$$

and using the definition of markup in the text of the lemma yields the result. The equilibrium quantities can be obtained from (12) and (13). Q.E.D.

B Empirical Analysis

B.1 Data Description

We use quarterly frequency data from 1935 to 2020. We first describe the construction of variables used in the baseline empirical analysis.

- *Debt-to-GDP*: Debt from 1942 to 2020 is the par value of privately held gross federal debt from the Dallas Fed. Historical debt data from 1935 to 1941 is US net interest-bearing federal debt from NBER Macrohistory database. We also compute the ratio of debt to trend-GDP, in which the trend GDP corresponds to the HP-filter trend component of the GDP.

- *AAA-Treasury*: The percentage spread between Moody's Aaa-rated long-maturity corporate bond yield and the yield on long-maturity Treasury bonds. Moody's Aaa index is from FRED. Long-maturity Treasury yields are long-term US government securities for 1935--2000 and market yield on US Treasury securities at 20-year constant maturity for 2001–2020, both from FRED.

- *CP-Bills*: The percentage yield spread between high-grade commercial paper and Treasury bills. For commercial paper rates, we use "three-month AA nonfinancial commercial paper rate" for 1997--2020 and "average of offering rates on three-month commercial paper placed by several leading dealers for firms whose bond rating is AA or equivalent" for 1971--1996. For 1935--1970, we use prime commercial paper, four–six-month maturity, from Banking and Monetary Statistics. The Treasury bill rates are three-month Treasury bills for 1971--2020 and six-month Treasury bills for 1959–1970 from FRED. For 1935–1958, we use three–six-month Treasury bills from NBER Macrohistory database.

- *Maturity-weighted convenience yield*: Our baseline measure of the convenience yield is an average of AAA-Treasury and CP-Bills spreads weighted by the maturity share of outstanding US Treasury debt. We consider the short-term share to be Treasuries with maturities less than or equal to three years, and long-term to be those with maturities longer than three years. We obtain US Treasury auction data from the US Treasury from 1980 to 2020, to construct a time series of the maturity composition of outstanding US Treasuries. Specifically, we add newly issued Treasuries, drop matured Treasuries, and keep track of maturities of still outstanding debt. Given the stability of the maturity share within this timeframe, we take the average of the weights to get a short-term weight of 0.6 and long-term weight of 0.4.

- *Demand rotator based on UK volatility*: The demand rotator is an indicator variable that equals 1 if the UK volatility index is greater than its sample median, and 0 otherwise. The UK volatility index is the standard deviation, computed over a yearly rolling window, of weekly returns of the MSCI United Kingdom Index. Because this index is available only starting in 1972, for the earlier part of the sample we use a projection based on the yearly-rolling-window standard deviation of monthly returns of the UK share price index. The MCSI UK index was obtained from Bloomberg, and the monthly share price index, from FRED. Table B.1 reports the regression estimates used for the projection. The R-squared of the regression is 0.68.

- *Slope*: The slope of the Treasury yield curve is the difference between the 10-year Treasury yield and the three-month Treasury yield. The yield on 10-year interest rates from 1953 to 2020 is from FRED, while the yield from 1935--1952 is from the NBER Macrohistory database.

- *US volatility*: We use VIX, the CBOE Volatility Index from 1990 to 2020. For 1935 to 1990, we create a historical series of VIX predicted by regressing VIX on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2020. The regression estimates are reported in Table B.1. The value-weighted S&P index was obtained from CRSP.

- *Dependency ratio*: Total population in the US aged 65 years or older divided by population aged between 15 and 65 years. The data were sourced from the Current Population Survey, Bureau of Labor Statistics.

- *Military news shocks*: We use the series constructed by Ramey (2011) and Ramey and Zubairy (2018)) of news in changes in military spending. We scale this series by nominal GDP and create a cumulative series. Since news about military expenditures are often announced before the expenditures, we allow for these shocks to affect public debt with a lag. In addition, since we are interested in instrumenting the stock of public debt, and military spending shocks affect the change in public debt, we accumulate the shocks over time to compute our instrument. In particular, the instrument for the supply of public debt is given by

$$z_t = \sum_{s=t-t_1}^{s=t-t_2} r_s,$$

where r_t is the military news shock variable constructed in Ramey (2011), t_1 is the number of lags with which military news spending affect actual spending, and $t_2 > t_1$ is the lead time at which we stop accumulating the news shocks to account for changes in the stock of public debt. We pick the appropriate t_1 and t_2 by running the first-stage regression for $(t_1, t_2) \in [0, 12] \times [4, 80]$. We choose (t_1, t_2) that maximizes the explanatory power of the first-stage regression by selecting the pair that gives the highest F-stat value:

$$b_t = \beta_0 + \beta_1 z_t (t_1, t_2) + \gamma X_t + \varepsilon_t,$$

where b_t is the log of the ratio of public debt to GDP, and X_t is a vector of controls. The pair selected is $t_1 = 40$ and $t_2 = 5$. In Figure B.1, we show this accumulation procedure for different lags and leads. The left panel shows the first-stage F-statistic and how the lags and leads were selected; the middle and right panels show that the regression coefficients are stable across the group of reasonable lags and leads.

We now describe the construction of variables used in the robustness analysis.

- *Demand rotator based on Hong Kong volatility*: This demand rotator is an indicator variable that equals 1 if the Hong Kong volatility index is greater than its sample median, and 0 otherwise. The Hong Kong volatility index is the standard deviation, computed over a yearly rolling window, of the weekly returns of the Hang Seng stock market index. This index is available at a weekly level starting in 1970.

- *Demand rotator based on US volatility*: This demand rotator is an indicator variable that equals 1 if the yearly moving average of the US volatility index, described above, is greater than its sample median, and 0 otherwise.

- *Blanchard--Perotti shocks*: To construct these shocks, we use data from Ramey and Zubairy (2018). We run the following regression to obtain the shock series, ε_t^{BP} :

$$g_t = \beta_0 + \sum_{s=1}^{4} \beta_s X_{t-s} + \varepsilon_t^{BP},$$

  where g_t is real government expenditures scaled by trend GDP; and X_t is a vector of controls containing real GDP, real government expenditures, and real government tax revenues all scaled by trend GDP. Trend GDP is a sixth-degree polynomial for the logarithm of GDP. We use the same accumulation procedure as that for military news shocks explained above.

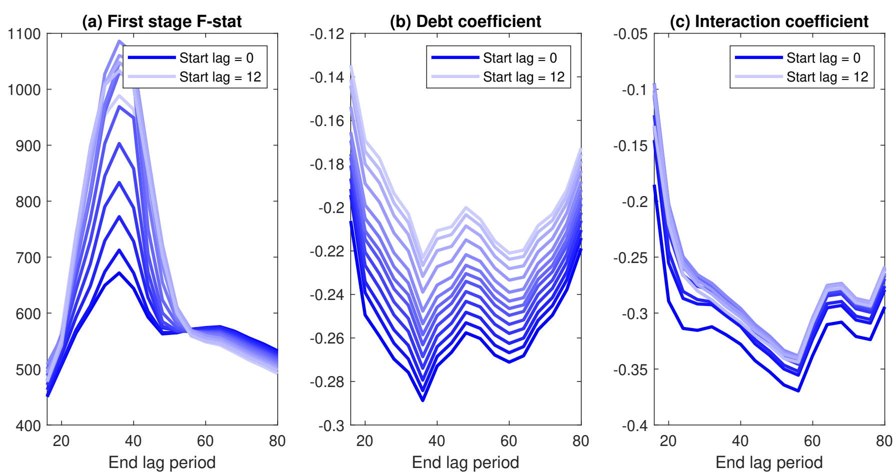
- *External public debt*: Foreign holdings of US Treasuries expressed as a share of GDP.

From 1952, the data are from the Fed's Flow of Funds. From 1940 to 1952, the data are from the US Treasury's Treasury International Capital (TIC) database.

- *Domestic public debt*: Computed as the difference between total and external public debt.

- *Bank deposits*: Computed as the sum of all checking accounts in commercial banks, savings accounts in commercial banks, and all-time deposits at banks and thrifts with balances less than $100,000. The series are downloaded from FRED, from 1959 to 2021. For data prior to 1959, the series are obtained from the FDIC historical bank dataset.

Figure B.1: Military news shock accumulations



Notes: This figure shows the sensitivity of the instrumental variables (IV) estimation output to the choice of different leads and lags for accummulating the military news shock. The left panel shows the first-stage F-statistic for the various lags and leads selected; the middle and right panels show the IV regression coefficients from the second stage.

Table B.1: Volatility measure construction

VARIABLES	MSCI UK Volatility	VIX
UK Share Price Volatility	1.00***	
	(0.05)	
S&P500 Volatility		364.42***
		(18.86)
Constant	-0.01***	8.34***
	(0.00)	(0.66)
Observations	177	124
R-squared	0.68	0.75

Notes: The dependent variables are annualized rolling four-quarter standard deviation of the weekly log stock returns on the MSCI United Kingdom Index from 1972 to 2020 and VIX, the CBOE Volatility Index from 1990 to 2020. The independent variables are annualized rolling four-quarter standard deviation of the monthly log stock returns on the UK share price index and annualized standard deviation of the weekly log stock returns on the S&P 500 index. The market cap weighted UK share price index was obtained from FRED. The value-weighted S&P index was obtained from CRSP. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

B.2 Validity of the Demand Rotator and Supply Instruments

In this section, we discuss the validity of the demand rotator. The exclusion restriction for the demand rotator is that the random variables z_t and ω_t are independent, i.e., $\mathbb{E}[z_t \omega_t] = 0$, where ω_t is a marginal cost shifter. In our context, this requires that the UK volatility measure and the regime indicator of high or low UK volatility are unrelated to fiscal supply shocks. Table B.2 shows that both measures have low correlation to various measures of fiscal supply shocks—government spending changes, corporate and individual tax rates, and a measure of government spending shocks from the Blanchard--Perotti regression.

Table B.2: Demand rotator correlations

	Gov. spending growth	Corporate tax rate	Highest ind. tax rate	Blanchard–Perotti shocks
UK volatility	0.06	0.21	0.20	0.03
UK volatility, binned	0.07	0.20	0.18	0.03
US volatility	0.13	-0.16	-0.19	-0.16
US volatility, binned	0.10	-0.10	-0.17	-0.14

Notes: UK volatility is a 1935 to 2020 historical series of annualized rolling four-quarter standard deviation of the weekly log stock returns on the MSCI United Kingdom Index predicted by regressing the series on the annualized rolling four- quarter standard deviation of the monthly log stock returns on the UK share price index from 1972 to 2020. UK volatility, binned is an indicator function for whether UK volatility is above the sample median value. US volatility is a 1935 to 2020 historical series of VIX predicted by regressing VIX on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2020. US volatility, binned, is an indicator function for whether extended VIX is above the sample median value. Blanchard–Perotti is the cumulative exogenous government expenditure shocks from the Blanchard–Perotti regression; we accumulate the military news shocks from t-4 to t-44. Government spending is US federal government spending. Highest ind. tax rate is the highest marginal personal income tax rate.

The table also shows the lack of correlation of these fiscal variables with measures of US volatility, which we use as an alternative demand rotator.

When we use instrumental variables for the demand estimation, the exclusion restriction implies that the instruments are not related to demand shocks and affect only the spread through the shocks' direct effect on debt supply. Table B.3 shows that all our instruments exhibit low correlation with various determinants of the demand for safe assets—the volatility of US and UK stock markets and GDP growth rate.

Table B.3: Instrument correlations

	UK volatility	VIX	GDP growth
Dependency	-0.12	-0.08	-0.01
Military news	-0.21	-0.24	-0.04
Blanchard–Perotti	0.03	-0.06	-0.22

Notes: UK volatility is a 1935 to 2020 historical series of the annualized rolling four-quarter standard deviation of the weekly log stock returns on the MSCI United Kingdom Index predicted by regressing the series on the annualized rolling four-quarter standard deviation of the monthly log stock returns on the UK share price index from 1972 to 2020. VIX is the CBOE Volatility Index from 1990 to 2020. GDP growth is the real US GDP growth rate. Dependency ratio is the US population aged 65 years or older divided by population aged 15 to 65 years. Military news is the cumulative news in changes in military spending scaled by GDP; we accumulate the military news shocks from t-5 to t-40. Blanchard–Perotti is the cumulative exogenous government expenditure shocks from the Blanchard–Perotti regression; we accumulate the military news shocks from t-4 to t-44.

Finally, we construct an F-statistic proposed by Duarte et al. (2021) to diagnose weak testing instruments. A testing instrument is weak (degenerate) if the predicted markups across the true model and the two models that are being tested are indistinguishable. We test for weak instruments along the power and size dimensions. An instrument is weak for power when there is a low probability of rejecting that the two tested models are equivalent when in fact they are not. An instrument is weak for size when there is a high probability of rejecting that the models are equivalent when in fact they are. For the case with a single instrument, the critical value for a worst-case size of 0.075 is 31.4, and the critical value for a maximal power of 0.95 is 31.1. Instruments with an F-statistic greater than these critical values are neither weak for size nor weak for power. The -statistics for each of the rotator instruments we use are reported in Table B.4.

Table B.4: F-statistics

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline (UK Volatility)								
	28.11	45.42	74.03	87.99	94.2	101.03	101.59	101.57
b. US Volatility								
	95.83	87.11	86.82	88.33	89.72	93.54	95.14	95.7
c. Investor composition								
	186.3	127.37	101.7	91.82	87.06	79.58	77.61	77.03

Notes: This table reports F-statistics for the strength of the RV testing instrument for different values of the cost elasticity, λ, and different testing instruments and specifications. An F-statistic greater than 31.1 is not weak for power at the 0.95 level, and an F-statistic greater than 31.4 is not weak for size at the 0.075 level. The different panels refer to different markup estimations based on alternative rotators. See the main text for further details.

B.3 Additional Empirical Results

In this section we conduct a set of additional exercises that illustrate the robustness of our main empirical results. We first analyze alternative approaches to identifying demand rotations, and then estimate other specifications for the demand for US public debt. In summary, the results reiterate our findings that the demand for US Treasuries becomes more inelastic in regimes of high volatility and that the dynamics of the prices and quantities of US debt across these regimes can be better accounted for by the monopoly rather than the price-taking equilibrium. In addition, we also estimate a demand for public debt that is inelastic, with point estimates for the elasticity that are in the range of those estimated in prior literature.

B.3.1 Alternative Rotators Based on Volatility

To begin, we consider the effects of using alternative demand rotators based on measures of global volatility. Table B.5 shows the demand estimation results using the instrumental variables approach, and Table B.6 shows the RV test results. The first alternate rotator is a regime indicator that equals 1 when the US volatility index is greater than the sample median, and 0 otherwise. The US volatility index is computed as the yearly moving average of the extended VIX (see Appendix B for details on how we compute the extended VIX). Second, we consider a regime indicator based on the yearly standard deviation of the Hong Kong stock market index (Hang Seng index) weekly returns. This variable is availableonly starting in 1970, so the estimation sample for this exercise is shorter than that in the baseline. Third, we also consider a regime indicator based on a residualized measure of UK volatility (after projecting it onto US volatility). Fourth, we use the 66th and 75th percentile cutoffs for our baseline rotator—instead of the sample median—above which the regime indicator of high volatility is 1. Finally, we also use a regime indicator variable based on the standard deviation of UK stock returns using a two-quarter and eight-quarter rolling window, rather than a one-year rolling window. In all cases, the estimated demand is more inelastic during high-volatility regimes, and in most cases the difference in elasticities is statistically significant. The RV test favors the monopoly equilibrium for all specifications and almost all cost elasticities.

Table B.5: US public debt demand estimation: Alternative rotators

VARIABLES	(1) Baseline	(2) US Volatility	(3) Hong Kong Volatility	(4) Residualized UK Vol	(5) 66th bin	(6) 75th bin	(7) UK, 2 quarters	(8) UK, 8 quarters
Log(debt/gdp)	-0.13**	-0.13**	-0.29***	-0.18***	-0.18***	-0.21***	-0.19***	-0.14**
	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)
High Volatility Dummy	-0.14	-0.09	-0.30*	-0.00	-0.21	-0.15	-0.01	-0.14
	(0.10)	(0.09)	(0.17)	(0.10)	(0.13)	(0.16)	(0.10)	(0.12)
High Vol Dummy × Log(dept/gdp)	-0.23**	-0.26***	-0.24	-0.10	-0.25**	-0.21	-0.10	-0.21**
	(0.09)	(0.09)	(0.14)	(0.09)	(0.11)	(0.13)	(0.09)	(0.11)
Demand elasticity, high vol	1.73	1.58	1.34	2.28	1.46	1.48	2.14	1.78
Demand elasticity, low vol	4.66	4.75	2.43	3.55	3.49	2.94	3.25	4.56
Markup, high vol	0.58	0.63	0.75	0.44	0.68	0.68	0.47	0.56
Markup, low vol	0.21	0.21	0.41	0.28	0.29	0.34	0.31	0.22

Notes: The dependent variable is the weighted average of spreads between corporate and Treasury bond yields, both measured in percentage units. The columns correspond to different measures of the Volatility dummy indicator: (1) whether the UK volatility measure is above the sample median; (2) whether the US volatility measure is above the sample median; (3) whether the yearly rolling standard deviation of the annualized weekly log stock returns on the HangSeng index is above the sample median; (4) whether the residuals from a projection of the UK volatility on US volatility are above the sample median; (5) whether the UK volatility measure is above the sample 66th percentile; (6) whether the UK volatility measure is above the sample 75th percentile; (7) whether the two-quarter rolling standard deviation of the annualized weekly log stock returns on the MSCI United Kingdom Index, extended by projecting it on the two-quarter rolling standard deviation of the annualized monthly log stock returns on the UK share price index, is above the sample median; (8) whether the eight-quarter rolling standard deviation of the annualized weekly log stock returns on the MSCI United Kingdom Index, extended by projecting it on the eight-quarter rolling standard deviation of the annualized monthly log stock returns on the UK share price index, is above the sample median. The main independent variables of interest are the log of the ratio of the Treasury debt outstanding to US GDP and its interaction with the volatility dummy. The controls are the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield and Extended VIX (aside from column 2). The estimation method is instrumental variables (IV) for all columns. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

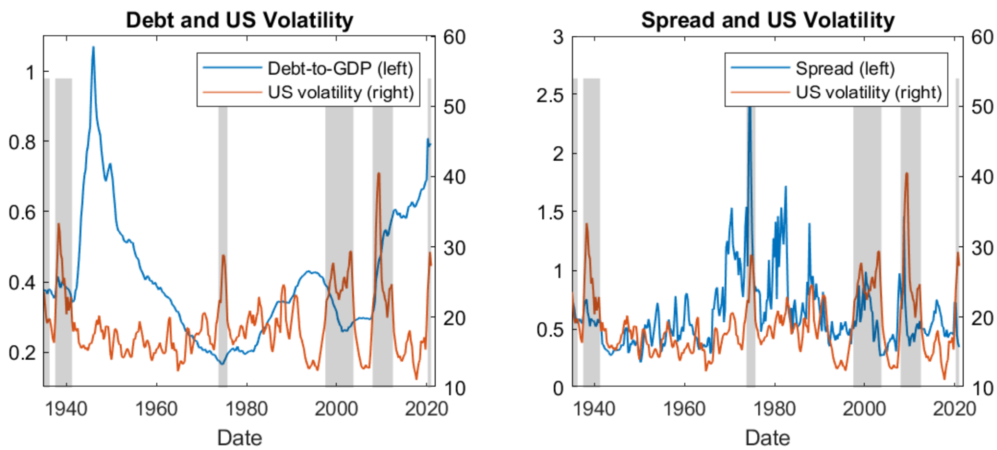
Table B.6: Government conduct test: Alternative rotators

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline								
	-3.99	-6.24	-7.08	-7.49	-7.73	-8.21	-8.37	-8.43
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Alternative volatility based rotators								
US Volatility	1.12	-0.4	-1.03	-1.34	-1.53	-1.9	-2.04	-2.09
	(0.26)	(0.69)	(0.3)	(0.18)	(0.13)	(0.06)	(0.04)	(0.04)
HongKong Volatility	-0.21	-2.95	-4.06	-4.58	-4.87	-5.42	-5.6	-5.66
	(0.83)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Residualized UK Vol	-4.86	-6.86	-7.62	-7.99	-8.2	-8.63	-8.79	-8.84
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
66th bin	-2.8	-5.63	-6.69	-7.2	-7.5	-8.08	-8.29	-8.36
	(0.01)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
75th bin	-3.36	-5.67	-6.46	-6.82	-7.02	-7.4	-7.53	-7.57
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
UK, 2 quarters	-4.74	-5.55	-5.78	-5.88	-5.93	-6.01	-6.03	-6.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
UK, 8 quarters	-4.71	-7.7	-8.74	-9.22	-9.49	-10.02	-10.2	-10.27
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
c. Alternative investor composition rotator								
	-12.45	-8.44	-5.12	-3.39	-2.41	-0.48	0.2	0.42
	(0.0)	(0.0)	(0.0)	(0.0)	(0.02)	(0.63)	(0.84)	(0.67)

Notes: This table shows the results of the RV statistical test comparing the fit of the monopoly and price-taking models for different values of the cost elasticity, λ, and different measures of volatility. Values lower than -1.96 reject the price-taking model in favor of the monopoly model. P-values are in parentheses.

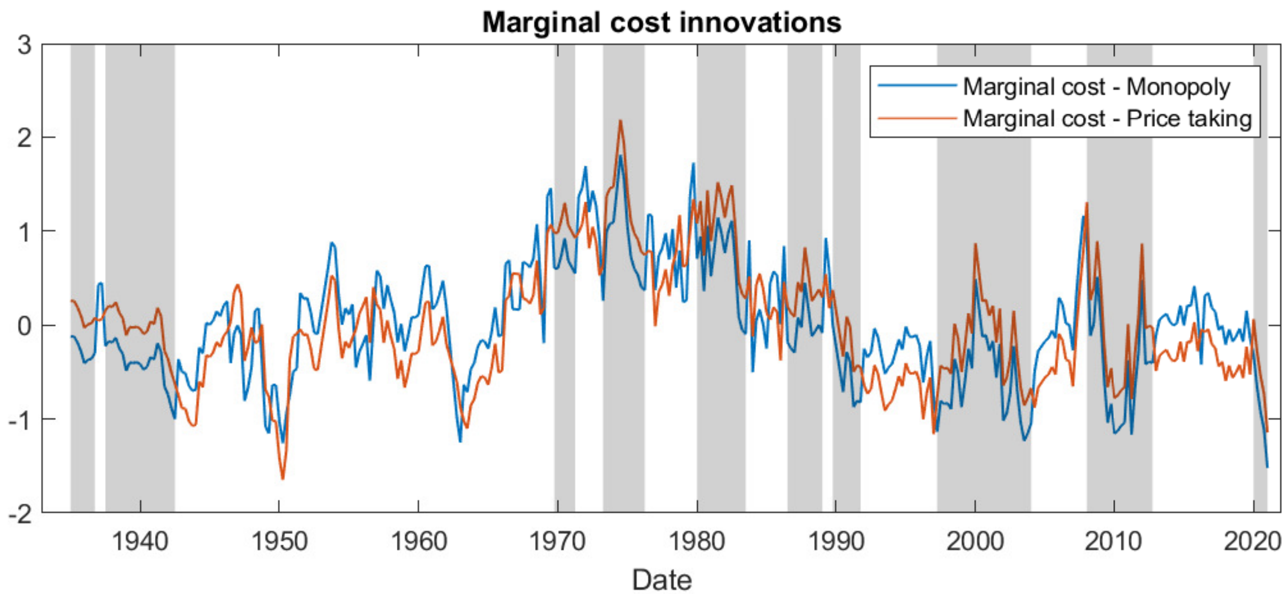
Figure B.2 shows the price and quantities of debt along with the measure of US volatility. Figure B.3shows the estimated innovations to marginal cost under both the price-taking and monopoly models using US volatility as the alternate rotator. The US and UK measures of volatility are only weakly correlated, and the respective periods of high volatility are different. This implies that the results of the conduct test favoring the monopoly model when we use US volatility is driven by the dynamics of prices and quantities of debt during different periods of high volatility, such as the 1930s.

Figure B.2: Prices and quantities of US public debt and US volatility



Notes: Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. Spread is the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. The shaded areas correspond to periods of high volatility where for at least one quarter the US volatility measure is above the sample 75th percentile. See Appendix B for a description of the construction of all the variables.

Figure B.3: Estimated marginal cost shocks: US volatility rotator



Notes: This figure shows the estimated marginal costs from the monopoly model and the price-taking model. The shaded areas correspond to periods of high volatility where for at least one quarter the US volatility measure is above the sample 75th percentile.

B.3.2 Rotator Based on Shifting Composition of Investors

Next, we conduct a complementary exercise that uses an alternative rotator that is based on the evolution of the composition of investors in the Treasury market. The motivation for this exercise is that foreign officials, which tend to be more inelastic investors, have increased their participation in the Treasury market in the past few decades. This suggests that the demand for US public debt may have become more inelastic. We formalize this by estimating investor-specific demand elasticities for foreign and domestic investors. In particular, we estimate

$$y_t = \alpha_i + \beta_i \ln b_{it} + \delta_i X_t + \varepsilon_{it,} \quad \text{for } i = \text{foreign, domestic}, \tag{19}$$

where y_t is the long-term convenience yield, $\ln b_{it}$ is the log of the ratio of investors' i holdings of public debt to GDP, and X_t is a vector of controls that includes the same controls as in the baseline demand estimation, and a time trend.[9] Table B.7 shows the estimation results, which imply a more inelastic demand for foreign investors than for domestic ones, in line with the results reported in Krishnamurthy and Vissing-Jorgensen (2007). Figure B.4 shows the weighted average demand elasticity across investors, where the weights are the yearly share of each investor's holdings in total public debt. The decreasing pattern of the demand elasticity reflects the increasing participation of foreign investors in the Treasury market.

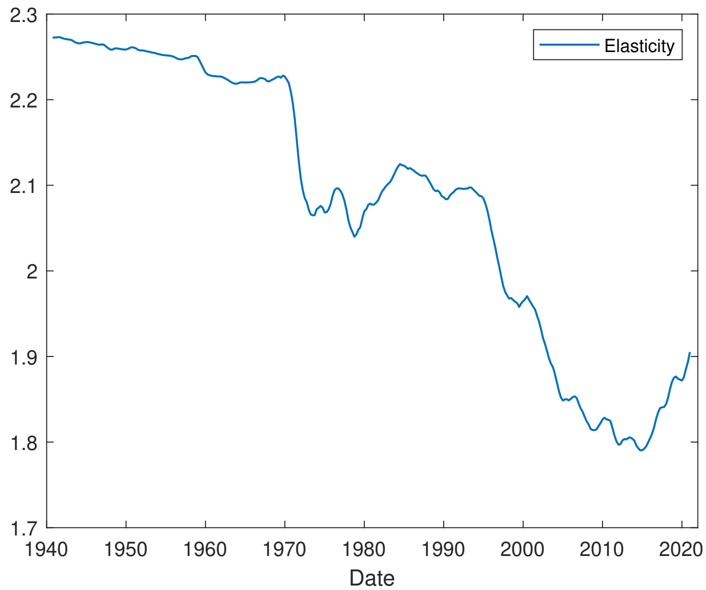
Table B.7: Demand elasticities for different types of investors

VARIABLES	(1) Foreign Investors	(2) Domestic Investors
Log(debt/gdp)	-0.50***	-0.34***
	(0.11)	(0.06)
Observations	325	325
Demand elasticity	1.56	2.28
Markup	0.64	0.44

Notes: The dependent variables are the spreads between corporate and Treasury bond yields, both measured in percentage units. In column 1, the main independent variable is the log of the ratio of Treasury debt held by foreign investors to US GDP. In column 2, the main independent variable is the log of the ratio of Treasury debt held by private domestic investors to US GDP. We include as controls the US volatility and the date. The estimation method is instrumental variables (IV), where the log change in US dependency ratio and military news shock are the instruments. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

[9] We use long-term yields because foreign investors are mostly active in long-term bonds, whereas domestic investors hold both short- and long-term bonds.

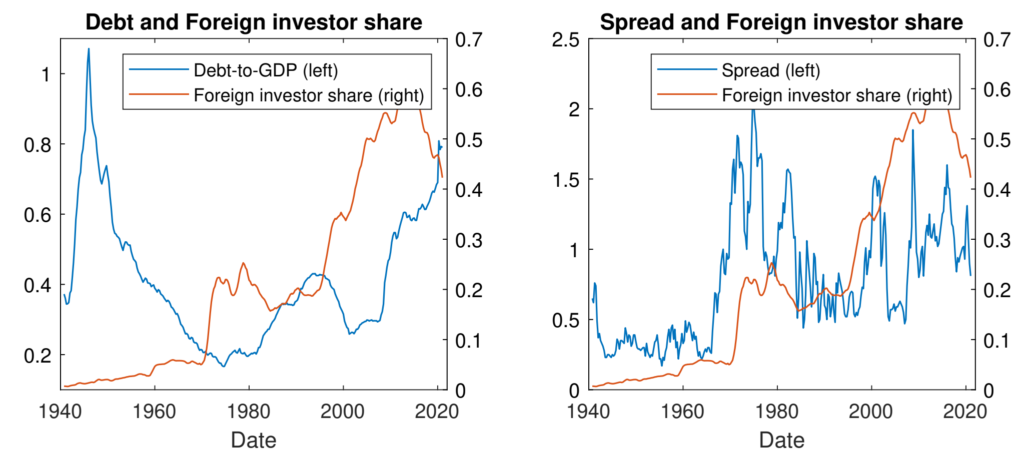
Figure B.4: Demand elasticity weighted by investor composition



Notes: This figure shows the average of domestic investors and foreign investors, weighted by the composition of investors over time.

We then pursue the conduct test using the share of foreign investors in total public debt as the demand rotator z_t. The results, shown in the last panel of Table B.6, reject the price-taking model in favor of the monopoly model for most values of the elasticity of the cost of supplying public debt, λ. In this case, the monopoly can better account for the observed increase in convenience yields that started in the 1970s through an increase in markups. This is because the increase in convenience yields roughly coincides with the increase in foreign-investor participation (see Figure B.5).

Figure B.5: Prices and quantities of US public debt and foreign-investor participation



Notes: Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. Spread is the difference between the yield of long-term corporate bonds and US Treasuries, both measured in percentage units. The share of foreign investors refers to the ratio of external public debt to total public debt.

B.3.3 Other Robustness Analyses

We also consider the robustness of the empirical results to alternative measures of convenience yields and public debt. Tables B.8 and B.9 show the demand estimation results with and without the demand rotator. Table B.10 shows the RV test results for different cost elasticities. The first set of robustness results involves using short- and long-term measures of convenience yields (see Appendix B for details on how we compute these variables). The RV test favors the monopoly equilibrium in both specifications. In addition, consistent with prior literature, we estimate a more inelastic demand for long-term debt. We next use the ratio of public debt to trend-GDP (instead of observed GDP) as the independent variable in the demand estimation. We do so to capture movements in the debt-to-GDP ratio that come from the numerator and not the denominator. Our results are invariant to using this measure. We also use external public debt as an independent variable in the demand estimation. In this case, the demand rotation is not well estimated, because the levels of external debt are small for a significant part of the sample and external debt exhibits a clear upward trend since then.

Table B.8: US public debt demand estimation: Alternative measures of spreads and debt

VARIABLES	(1) Baseline	(2) Short Mat.	(3) Long Mat.	(4) External Debt	(5) Debt to Trend GDP
Log(debt/gdp)	-0.13**	-0.09	-0.19**	-0.47***	-0.14**
	(0.06)	(0.08)	(0.09)	(0.11)	(0.06)
High Volatility Dummy	-0.14	-0.21	-0.03	-0.02	-0.14
	(0.10)	(0.15)	(0.16)	(0.23)	(0.10)
Vol Dummy$\times$Log(dept/gdp)	-0.23**	-0.26*	-0.18	0.04	-0.22**
	(0.09)	(0.14)	(0.15)	(0.06)	(0.09)
Demand elasticity, high vol	1.73	1.5	2.05	1.47	1.73
Demand elasticity, low vol	4.66	5.59	3.99	1.34	4.52
Markup, high vol	0.58	0.67	0.49	0.68	0.58
Markup, low vol	0.21	0.18	0.25	0.75	0.22

Notes: The dependent variables are the following: in columns 1, 4, and 5, the weighted average of spreads between corporate and Treasury bond yields, both measured in percentage units; in column 2, the yield spreads between bank bills and three-month Treasury bills; and in column 3, the yield spreads between long-maturity corporate bonds and Treasury bonds. In columns 1, 2, and 3, we use the log of the ratio of the Treasury debt outstanding to US GDP; in column 4, the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; and in column 5, the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering. Volatility is a dummy indicator for whether the UK volatility measure is above the sample median. The controls are the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield and the US volatility measure. The estimation method is instrumental variables (IV) for all columns. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table B.9: US public debt demand estimation without rotators: Alternative measures of spreads and debt

VARIABLES	(1) UK IV	(2) Short Mat.	(3) Long Mat.	(4) External Debt	(5) Debt to Trend GDP
Log(debt/gdp)	-0.22***	-0.19***	-0.27***	-0.44***	-0.34***
	(0.05)	(0.07)	(0.07)	(0.09)	(0.10)
Volatility	0.09***	0.05	0.16***	0.13***	0.43*
	(0.03)	(0.04)	(0.05)	(0.04)	(0.25)
Demand elasticity	2.84	2.82	2.87	1.43	1.84
Markup	0.35	0.35	0.35	0.7	0.54

Notes: The dependent variables are the following: in columns 1, 4, and 5, the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units; in column 2, the yield spreads between bank bills and three-month Treasury bills; and in column 3, the yield spreads between long-maturity corporate bonds and Treasury bonds. In columns 1, 2, and 3, we use the log of the ratio of the Treasury debt outstanding to US GDP; in column 4, the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; and in column 5, the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering. Volatility is a dummy indicator for whether the constructed UK volatility measure is above the sample median. The controls are the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield and the US volatility measure. The estimation method is instrumental variables (IV) for all columns. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table B.10: Government conduct test: Alternative measures of spreads and debt

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline								
	-3.99	-6.24	-7.08	-7.49	-7.73	-8.21	-8.37	-8.43
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Different Maturity								
Short	0.52	-2.17	-3.85	-4.91	-5.61	-7.24	-7.88	-8.1
	(0.6)	(0.03)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Long	-7.65	-8.95	-9.11	-9.08	-9.03	-8.82	-8.7	-8.65
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
c. Different dependent variable								
Debt-to-Trend GDP	-3.92	-6.27	-7.17	-7.6	-7.86	-8.37	-8.56	-8.62
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: This table shows the results of the RV statistical test comparing the fit of the monopoly and price-taking models for different values of the cost elasticity, λ, and different measures of spreads and debt. Values lower than -1.96 reject the price-taking model in favor of the monopoly model. P-values are in parentheses.

Finally, we redo our empirical exercises using different controls, estimation samples, and instruments for debt supply changes. Tables B.11 and B.12 show the demand estimation results with and without the demand rotator, and Table B.13 shows the RV test results. First, we include the volume of bank deposits as an additional control in the demand estimation, because deposits constitute a substitutable asset that offers similar liquidity properties as US Treasuries. We also estimate the baseline specification excluding the set of additional controls (slope of the yield curve and US volatility). In both specifications, we find similar results. We then redo our demand estimation exercise for three different samples: excluding periods in which the zero lower bound binds, starting after the Second World War (postwar), and a post-1985 sample that also excludes periods of binding zero lower bound. The main results are robust to using these different sample periods. Finally, we estimate the demand using alternative instruments for supply: we use the military news shock and the dependency ratio as separate instruments, and we also use a measure of government expenditure shocks developed by Blanchard and Perotti (2002). These shocks are constructed using the residuals of a regression of government spending on a set of controls, which include lagged values of taxes, output, and government spending (see Appendix B for further details). The main empirical results are robust to using these alternative instruments.[10]

[10]In the case of the Blanchard--Perotti shocks, the RV test cannot be computed because predicted marginal costs are negative for some part of the sample.

Table B.11: US public debt demand estimation: Additional robustness

VARIABLES	(1) Baseline	(2) Control for Deposits	(3) No controls	(4) No ZLB	(5) Postwar	(6) Military	(7) Dependency	(8) BP shock
Log(debt/gdp)	-0.13**	-0.21***	-0.13**	-0.19***	-0.12**	-0.30***	-0.05	-0.31***
	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.08)
High Volatility Dummy	-0.14	-0.14	-0.12	0.03	-0.24*	-0.06	-0.14	-0.57***
	(0.10)	(0.10)	(0.11)	(0.14)	(0.12)	(0.16)	(0.11)	(0.17)
High Vol × Log(dept/gdp)	-0.23**	-0.20**	-0.27**	-0.08	-0.29***	-0.11	-0.25**	-0.56***
	(0.09)	(0.09)	(0.11)	(0.12)	(0.11)	(0.15)	(0.11)	(0.16)
Demand elasticity, high vol	1.73	1.52	1.57	2.37	1.56	1.52	2.07	0.71
Demand elasticity, low vol	4.66	2.93	4.72	3.43	5.18	2.08	12.4	2.0
Markup, high vol	0.58	0.66	0.64	0.42	0.64	0.66	0.48	1.4
Markup, low vol	0.21	0.34	0.21	0.29	0.19	0.48	0.08	0.5

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above the sample median. The controls are the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield and the US volatility measure (aside from no controls). The estimation method is instrumental variables (IV) for all columns. In column 2, we include as control the log of the ratio of total bank deposits to US GDP. In column 4, we drop the periods in which the zero lower bound is binding. In column 5, we estimate the demand for public debt using the post-1945 (postwar) sample. In columns 6, 7, and 8, we use as IV variable only the Military news shock, the Log change in the dependency ratio, or the Blanchard–Peroti shocks, respectively. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table B.12: US public debt demand estimation without rotators: Additional robustness

VARIABLES	(1) UK IV	(2) Control for Deposits	(3) No controls	(4) No ZLB	(5) Postwar	(6) Military	(7) Dependency	(8) BP shock
Log(debt/gdp)	-0.22***	-0.28***	-0.23***	-0.21***	-0.21***	-0.32***	-0.18***	-0.14
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.12)
Volatility	0.09***	0.06*	0.15***	0.12***	0.07*	0.06*	0.11***	0.10**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Demand elasticity	2.84	2.2	2.68	3.01	2.99	1.95	3.54	4.42
Markup	0.35	0.46	0.37	0.33	0.33	0.51	0.28	0.23

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above the sample median. The controls are the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield and the US volatility measure (aside from no controls). The estimation method is instrumental variables (IV) for all columns. In column 2, we include as control the log of the ratio of total bank deposits to US GDP. In column 4, we drop the periods in which the zero lower bound is binding. In column 5, we estimate the demand for public debt using the post-1945 (postwar) sample. In columns 6, 7, and 8, we use as IV variable only the Military news shock, the Log change in dependency ratio, or the Blanchard–Peroti shocks, respectively. See Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table B.13: Government conduct test: Additional robustness

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline								
	-3.99	-6.24	-7.08	-7.49	-7.73	-8.21	-8.37	-8.43
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Different controls								
Controls for Deposits	-3.62	-5.94	-6.83	-7.28	-7.53	-8.06	-8.25	-8.31
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
No Controls	-3.12	-5.81	-6.82	-7.31	-7.58	-8.13	-8.32	-8.39
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
c. Other time samples								
No ZLB	-5.08	-6.49	-7.08	-7.39	-7.58	-7.98	-8.13	-8.18
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Postwar	-2.98	-5.69	-6.67	-7.13	-7.4	-7.92	-8.1	-8.16
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
d. Different demand instruments								
Military	-4.81	-7.11	-8.02	-8.48	-8.75	-9.31	-9.51	-9.58
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Dependency	-4.62	-6.7	-7.36	-7.66	-7.83	-8.15	-8.26	-8.29
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
e. Different testing instrument								
Extended UK vol. binned	0.81	-2.03	-3.15	-3.69	-4.0	-4.62	-4.84	-4.91
	(0.42)	(0.04)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: This table shows the results of the RV statistical test comparing the fit of the monopoly and price-taking models for different values of the cost elasticity, λ. Values lower than -1.96 reject the price-taking model in favor of the monopoly model. P-values are in parentheses.

C Additional Figures and Tables

Figure C.1: Demand rotations to identify US government conduct

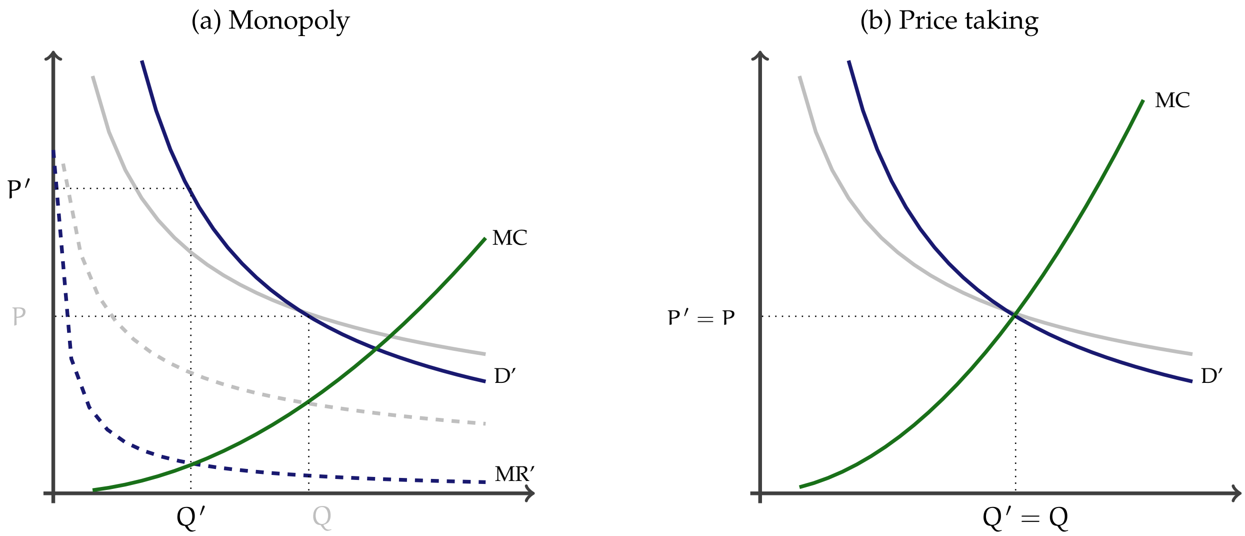
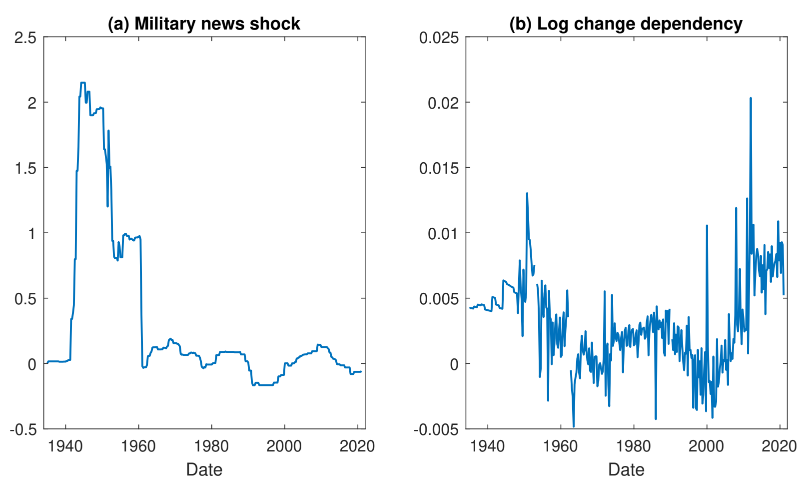


Figure C.2: Evolution of the fiscal supply instruments



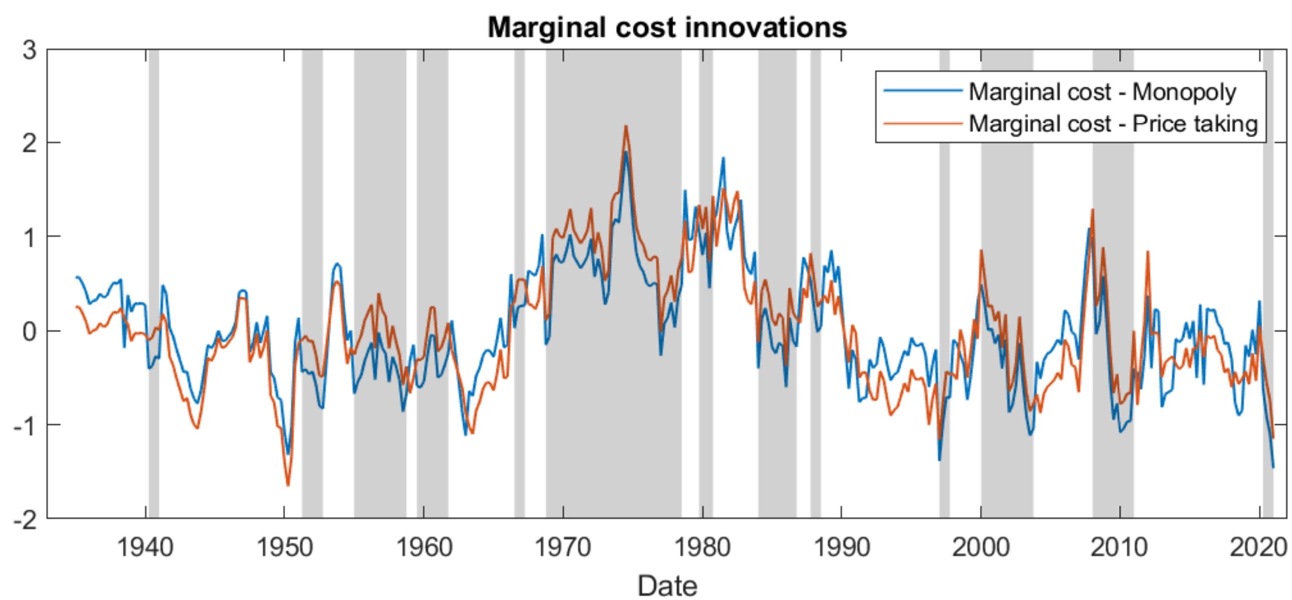
Notes: Military news shock is cumulative changes in military spending news scaled by GDP; we accumulate the military news shocks from t-5 to t-40. Dependency ratio is the US population aged 65 years or older divided by population aged 15 to 65 years. Appendix B details the construction of all the variables.

Table C.1: First-stage regressions

VARIABLES	Log(debt/GDP)	Vol Dummy × Log(debt/GDP)
Military news	0.31***	-0.00
	(0.04)	(0.03)
Dependency	63.39***	-1.26
	(7.27)	(5.86)
Vol Dummy×Military news	-0.05	0.26***
	(0.10)	(0.08)
Vol Dummy×Dependency	-4.20	61.46***
	(9.58)	(7.72)
High Volatility Dummy	-0.14***	-1.31***
	(0.05)	(0.04)
US volatility	-0.00	0.00
	(0.00)	(0.00)
Slope	0.05***	0.02*
	(0.01)	(0.01)
Constant	-1.18***	-0.06
	(0.06)	(0.05)
Observations	338	338
R-squared	0.53	0.86

Notes: The dependent variables are the log of the ratio of the Treasury debt outstanding to US GDP and an interaction with volatility. The independent variables are the various instruments we use. Military news is the cumulative news in changes in military spending scaled by GDP; we accumulate the military news shocks from t-5 to t-40. Dependency ratio is the US population aged 65 years or older divided by population aged 15 to 65 years. Slope is the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the three-month Treasury yield. US volatility is VIX from 1990 to 2020, and from 1935 to 1990, a historical series of VIX predicted by regressing VIX on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2020. Volatility is a dummy control for whether the constructed UK volatility measure is above the sample median. See the main text for further details, and Appendix B for a description of the construction of all the variables. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Figure C.3: Estimated marginal cost shocks (UK rotator)



Notes: This figures shows the estimated marginal costs from the monopoly model and the price-taking model. Shaded areas correspond to selected periods of high volatility, where at least one quarter has a UK volatility measure above the sample 75th percentile.

Figure C.4: Simultaneous demand rotations and shifts

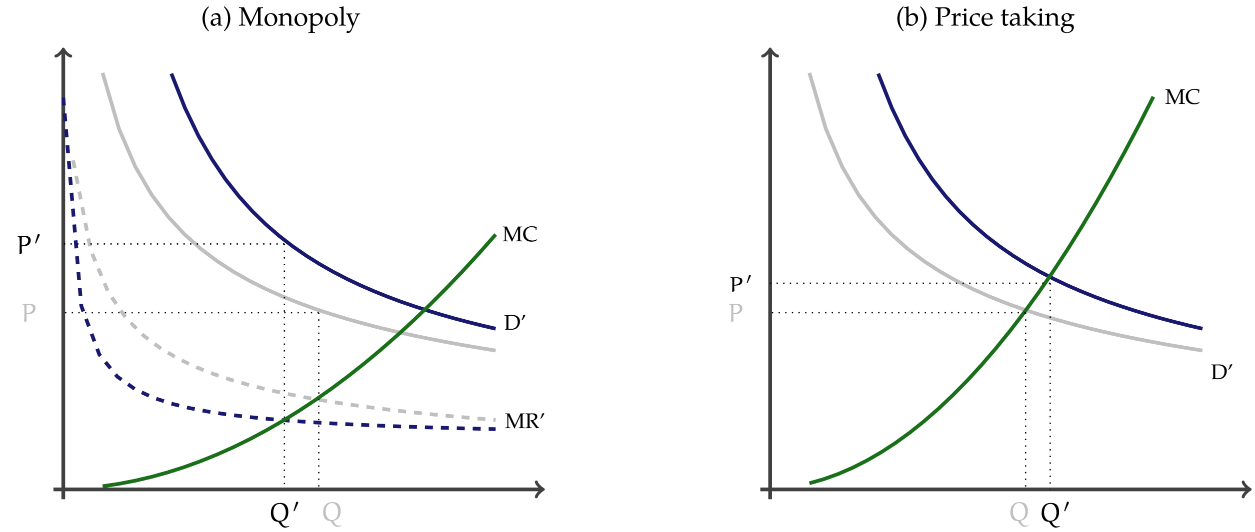


Table C.2: Debt-to-GDP and Volatility Comovement

	UK volatility	UK volatility, binned	US volatility	US volatility, binned
Debt to GDP	-0.24	-0.18	-0.25	-0.25
Debt to GDP (trend)	-0.24	-0.18	-0.25	-0.25
Debt to GDP (cycle)	-0.08	-0.05	-0.02	-0.06

Notes: We report correlations in the table. UK volatility is a 1935 to 2020 historical series of annualized rolling four-quarter standard deviation of the weekly log stock returns on the MSCI United Kingdom Index predicted by regressing the series on the annualized rolling four-quarter standard deviation of the monthly log stock returns on the UK share price index from 1972 to 2020. US volatility is the CBOE Volatility Index from 1990 to 2020 and from 1935 to 1990, a historical series of VIX predicted by regressing VIX on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2020. Debt to GDP is the ratio of outstanding Treasury debt to US GDP. We filter the series through an HP filter with a smoothing parameter of 1600 to also obtain the trend and cycle components.

Table C.3: Steady-state comparisons for different elasticities

	Total safe assets/GDP	Convenience yield	Interest on Public Debt
ME	0.39	0.68%	0.97%
		$\epsilon = 2.2, \lambda = 1$	
CE	0.59	0.57%	1.09%
		$\epsilon = 2.0, \lambda = 1$	
CE	0.62	0.55%	1.11%
		$\epsilon = 2.5, \lambda = 1$	
CE	0.56	0.59%	1.07%

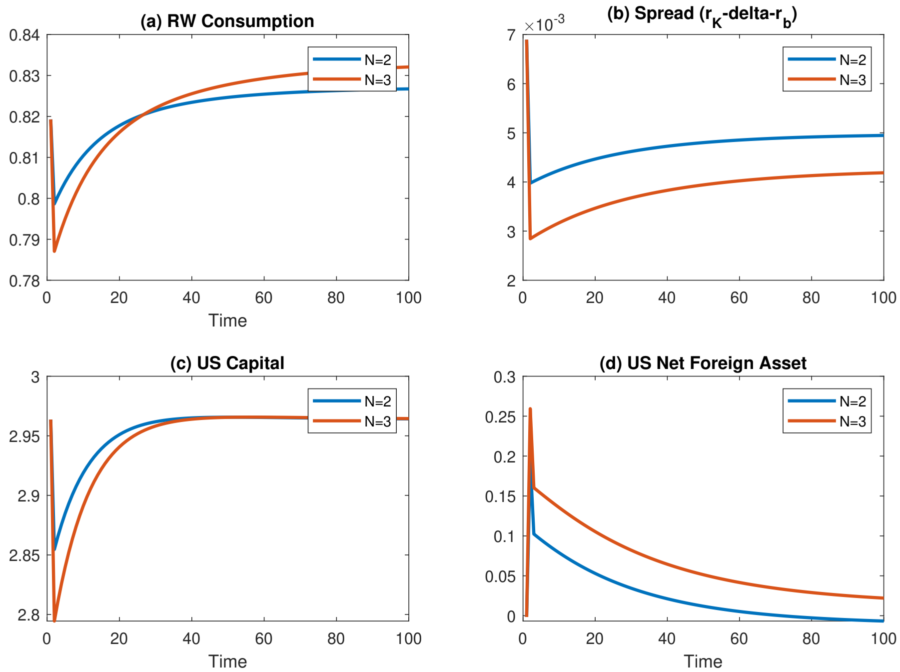
Notes: ME refers to the baseline monopoly equilibrium in which the US exercises market power. CE refers to counterfactual competitive equilibria in which the US acts as a price taker. We report these CE economies if we calibrated the monopoly equilbrium to different elasticities. Epsilon is the demand elasticity, and lambda is the cost function elasticity.

Table C.4: Welfare comparisons for different elasticities

	No special role	CE with special role
	$\epsilon = 2.2, \lambda = 1$	
US welfare	-0.21%	-0.08%
RoW welfare	-0.34%	$+0.10\%$
	$\epsilon = 2.0, \lambda = 1$	
US welfare	-0.22%	-0.09%
RoW welfare	-0.39%	$+0.12\%$
	$\epsilon = 2.5, \lambda = 1$	
US welfare	-0.19%	-0.06%
RoW welfare	-0.29%	$+0.08\%$

Notes: No special role is an economy in which the benefit and cost functions are both zero. CE with special role is a competitive equilibrium in which the US acts as a price taker. Welfare change is expressed in permanent consumption equivalence terms considering the whole transition period starting from the baseline monopoly equilibrium. Epsilon is the demand elasticity, and lambda is the cost function elasticity.

Figure C.5: Cournot transition



Notes: This figure shows the path of macroeconomic variables in response to increasing the number of safe-asset issuers to N, from the steady state of an economy with a single safe-asset issuer. RoW consumption is consumption in the rest of the world. Spread is the difference between the net returns on capital and the returns on safe assets.

D A Direct Measure of US Government Conduct

In this section, we present a complementary approach to assess whether a model of strategic behavior is an appropriate representation of the US issuance of debt. The approach involves directly inferring the value of the parameter ξ, which measures the degree of competition. Recall that $\xi = 1$ corresponds to the monopoly equilibrium, and $\xi = 0$, to the price-taking equilibrium. The supply of debt in both models is given by (9) in the main text. We can rewrite this equation as follows:

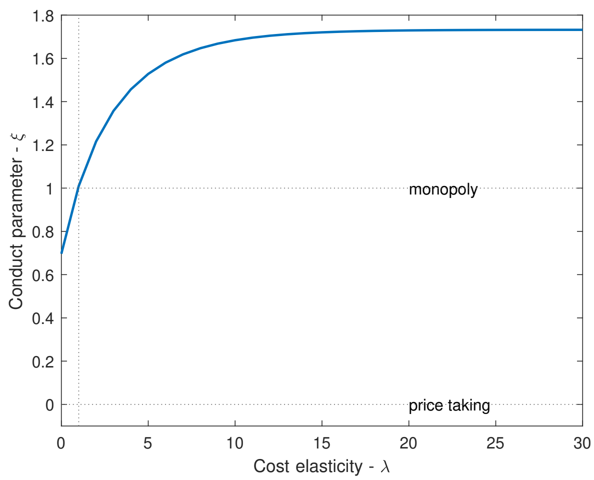
$$\xi = \frac{1}{\ln \mu_t} \left(\ln \mathcal{S}_t - \lambda \ln b_t - \ln \omega \right).$$

This equation gives us a direct way of measuring ξ. A value of ξ close to 0 would suggest price-taking behavior, whereas a value of ξ close to 1 would suggest a monopoly model. The variables $\mathcal{S}_t$ and b_t are observable in the data, and our demand estimation procedure yields μ_t. Consider the case in which we fix a value of λ. Our identifying assumption implies that ω should be unchanged across periods of high and low volatility. Thus, we can use the average measures of $\mathcal{S}_t$, b_t, and μ_t across high- and low-volatility regimes to write

$$\xi = \frac{1}{\ln \mu^i} \left(\ln \mathcal{S}^i - \lambda \ln b^i - \ln \omega \right), \quad i \in \{H, L\}.$$

This gives us two equations and two unknowns, which we can use to solve for ξ and ω. Figure D.1 plots the resulting values of ξ for different values of λ. The values of ξ are around 1, which suggests that the monopoly model is a good approximation for the behavior of the US. More generally, the results strongly suggest that the US exploits its market power when making debt-issuance decisions.

Figure D.1: Inferring US government conduct



Notes: This figure plots the measure of the conduct parameter backed out corresponding to various values of the cost elasticity. A conduct parameter of 1 indicates monopoly conduct, and 0, price-taking conduct.