US Public Debt and Safe Asset Market Power*

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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 we study its macroeconomic consequences. We develop a model of the global economy in which US public debt is a safe asset that generates a non-pecuniary value for its holders, analyze the equilibrium in which the US government exploits market power in safe assets, and contrast this case with one in which it 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 model in favor of the one in which the US exploits market power. 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 their issuances can have price impact, which implies 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 government 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. If the US exploits its market power, the equilibrium is associated with a scarce supply of US public 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 a markup. This model has different implications for how changes in demand elasticities for US public debt affect equilibrium outcomes relative to a model in which the US government acts as a price taker. We then measure these elasticities in the data and exploit variation in them during regimes of high and low foreign volatility, to empirically distinguish between the two models. We find that the data reject the price-taking behavior in favor of the model in which the US exploits its market power, because the latter can better account for increases in yields during these periods of high foreign 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 considerable 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, we assume that the 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. Because of 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 market power in its provision. As a result, the equilibrium convenience yield, which in the model corresponds to the spread between the return on US public 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 public debt. In contrast, if the US government is a price taker, this markup is zero. In addition, the presence of market power 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 market power model (i.e., the one in which the US government acts strategically and internalizes its price impact) 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 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 a model selection test developed by Rivers and Vuong (2002) to formally test between the price-taking and market power models. To do so, we first enrich the US Treasury demand structure estimated in prior literature to include a demand rotator. We use a regime indicator of high and low foreign volatility as our measure of a demand rotator and find that the demand for US Treasuries becomes more inelastic and shifts to the right during periods of high foreign volatility. Second, given the estimated demand, we use the model selection test and find that the data reject the price-taking model in favor of the market power model. This is because the market power model can better account for increases in the convenience yield during periods of high foreign volatility relative to the price-taking model by increases in markups, which are not present in the latter model. We also reach similar conclusions when we pursue a complementary exercise that tests between the price-taking and market power models 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 internalize the price impact of debt issuances and take into account that if they issue more debt, interest rates may rise. We highlight two examples that provide support for this phenomenon. One 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. A more recent example includes the series of large-scale asset purchases made by the Federal Reserve starting in 2008. As part of this program the Fed purchased long-term US-government-issued securities to reduce their available supply in the market and thereby affect their yields.

We then conduct a quantitative analysis of the market power model disciplined by the demand elasticity estimates as well as other moments related to the dynamics of the US public debt and its external balance sheet. One finding from the quantitative analysis is that shocks to the supply of public debt are more relevant than shocks to its demand, and they account for most of the dynamics of public debt prices and quantities. We also assess the macroeconomic implications of US safe asset market power and find that there is a significant underprovision of global safe assets, with safe-asset supply in the market power model being two thirds of that in the case when the US acts as a price taker. Additionally, the convenience yield in the market power model carries a markup of approximately one half. We also find that this market power brings considerable welfare benefits to the US while causing 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 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, 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. In the case of competition with a domestic fringe, 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, relative to the case of competition with a foreign fringe. One result we find across the different competition counterfactuals 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.

Related Literature

Our paper is related to various strands of the literature. First, it is connected to the literature in international macroeconomics that studies safe assets and their role in the global economy. Some notable contributions in this area include the works of Caballero, Farhi, and Gourinchas (2008); Bolton and Jeanne (2011); Azzimonti, De Francisco, and Quadrini (2014); Maggiori (2017); Gourinchas, Govillot, and Rey (2017); He, Krishnamurthy, and Milbradt (2019); Mendoza and Quadrini (2023).[1] A closely related paper is Farhi and Maggiori (2018), which develops a model of the international monetary system. In their model, the presence of market power generates a shortage in the global supply of safe assets. Building on their insights, we model an economy that possesses market power because of its ability to supply a safe asset that provides a fundamental non-pecuniary value. Our contribution to the literature is twofold: first, we provide empirical evidence supporting the notion that the US exercises its market power; second, we quantify the macroeconomic implications of this market power.

Other recent papers have explored the effects of increasing competition in global safe-asset markets. Clayton et al. (2022) develop a theoretical framework to examine how countries compete to establish themselves as safe-asset issuers by building reputations. Geromichalos, Herrenbrueck, and Lee (2022) investigate imperfect competition in a model where the liquidity premia of assets are endogenously determined. Our analysis comple-

[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.

ments this literature by studying the effects of increasing competition in safe assets within a quantitative model.

Second, a related literature focuses on the special role of US public debt and the demand for the US dollar. This literature builds on the work of Krishnamurthy and Vissing-Jorgensen (2012), who provide evidence of a downward sloping demand for US Treasuries and identify the presence of a convenience yield that reflects the additional safety and liquidity attributes of US Treasuries. Subsequent work has studied the term structure and sustainability of US public debt (e.g., Greenwood, Hanson, and Stein, 2015; Blanchard, 2019; Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2019; Mian, Straub, and Sufi, 2021; Brunnermeier, Merkel, and Sannikov, 2022).[2] There is also a body of literature that examines the implications for international asset markets and exchange rates (e.g., Du, Im, and Schreger, 2018; Krishnamurthy and Lustig, 2019; Jiang, Krishnamurthy, Lustig, and Sun, 2021b; Tabova and Warnock, 2021).[3] Motivated by the facts documented in this literature, 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 the 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 a significant underprovision of safe assets. We also quantify 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.

Third, our paper relates to the literature on optimal policy when there is a foreign demand for domestic assets. This literature builds on the extensive Ramsey literature in closed economies (see, for example, Chari and Kehoe, 1999, and the references therein). Schmitt-Grohé and Uribe (2010, 2012) show that the presence of a foreign demand for money leads to deviations from the Friedman rule. de Lannoy, Bhandari, Evans, Golosov, and Sargent (2022) study the implications for the optimal portofolio of public debt. Costinot, Lorenzoni, and Werning (2014) analyze optimal capital controls in the presence of a foreign demand for assets. Our paper provides empirical support for the notion that the government internalizes the effect of its policies on asset prices, which is a core assumption of this literature.

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

[3]Other related papers analyze public debt in the UK and Eurozone as a safe asset (Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2020c; Chen, Jiang, Lustig, Van Nieuwerburgh, and Xiaolan, 2022; Choi, Dang, Kirpalani, and Perez, 2023).

Finally, our empirical analysis draws upon the insights and methodologies developed in the industrial organization literature on firm conduct (e.g., Bresnahan, 1982; Berry and Haile, 2014; Backus, Conlon, and Sinkinson, 2021; Duarte, Magnolfi, Sølvsten, and Sullivan, 2021). In particular, we use a model selection test developed by Rivers and Vuong (2002) as in Backus et al. (2021) and Duarte et al. (2021). Our paper applies the tools developed in this literature to a macroeconomic setting.

The rest of the paper is organized as follows. Section 2 presents the model and compares the prices and allocations in the equilibrium in which the US exploits market power with one in which it acts as a price taker. 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 develop 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 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, we assume that the 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), we assume the US is the sole provider of this type of asset and hence enjoys market power in its provision. Henceforth, we refer to this model as the monopoly model.

2.1 Environment

The two countries are denoted by the US and RoW. The environment is deterministic[4], 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.[5]

[4]We introduce uncertainty when we quantify the model in Section 4.

[5]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

This extra benefit captures the collateral, liquidity benefits, or both that holding US debt provides. In Appendix A.1, we show that such a non-pecuniary value can arise when US debt serves 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

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

subject to

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

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

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

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

where K_t^* is generated using a CES technology,

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

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

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

formulation in which the function enters directly into preferences without wealth effects.

We next turn to the problem of the US. US households choose consumption and capital to maximize their lifetime utility. They also supply labor inelastically. We state their problem in Appendix A.1. We assume that the US government can issue debt to RoW households and transfer the proceedings from debt accumulation to US households. 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 A.1, we show that the problem for the US government is

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

subject to

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

where b_t is the debt issued by the US government, $\chi_t\left(b_t\right)$ is a cost of issuing debt, and, with some abuse of notation, $r_t\left(b_t\right)$ is the inverse demand function for US debt. There are two features of this problem worth noting. First, we assume that the US government internalizes the effect of issuing more debt on the interest rate on debt but takes other prices, including the returns on capital, as given. We make this assumption to isolate the effects of US market power on its cost of borrowing. Second, we assume that issuing debt generates an additional resource cost, $\chi_t\left(b_t\right)$, where χ is a positive, increasing, and convex function whenever $b_{t+1} > 0$, and zero otherwise. One interpretation of this cost function is that it corresponds to the distortionary costs of taxation to finance debt repayments, as in Gorton and Ordonez (2021). Another interpretation of this cost is that it captures the costs of expanding the balance sheet of the US government (see, for example, Hall and Reis, 2015 and Greenwood, Hanson, Stein et al., 2016). For example, if the US purchases private assets (capital) by issuing debt, it is subject to a costly interest rate risk.

The capital-goods producer in the US solves

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

where K_t is generated using a CES technology

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

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 $X_t = (x_t^*, x_t)$, where

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

and similarly for x_t.

We can now define an equilibrium for this environment.

Definition 1. A monopoly equilibrium is an allocation $\{X_t\}_{t\geqslant 0}$ and prices $\left\{R_t, R_t^*, r_{K,t}, r_{K,t}^*, w_t, w_t^*\right\}_{t\geqslant 0}$ 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: 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.[6]

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

[6] 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.

the fact that $b_{t-1} = b^*_{t-1}$, the problem for the US government can be written as

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

subject to

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

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.[7] Given the assumption that the US government takes as given the other prices in the economy, the first-order conditions from this problem imply

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

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

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

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,

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

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

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

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

[7]This result uses the assumption that debt is short-term. With long-term debt, the monopoly problem would no longer be static and the solution will depend on the ability of the issuer to commit.

for safe assets. The problem for the RoW is unchanged, while the problem for the US is

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

subject to

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

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

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

where the equilibrium level of debt is

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

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 A.1 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 distinguish strategic from competitive behavior. Movements in the demand curve that involve rotations will have different predictions for prices and quantities in the monopoly and the price-taking models because the changes in elasticity will imply changes in markups for the former model. Figure C.1 illustrates this point for a particular case in which the rotation happens around the original equilibrium point.[8] 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

$$\mathcal{S}_t = \alpha + \beta \ln b_t + \gamma \left(\ln b_t \times z_t\right) + \delta X_t + \varepsilon_t, \tag{8}$$

where $\mathcal{S}_t$ 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 $\beta + \gamma z_t$. When $\gamma = 0$, we obtain the same demand specification estimated in Krishnamurthy and Vissing-Jorgensen (2012). To obtain an estimate of the actual elasticity, we take the ratio of the semi-elasticity to the sample average of $\mathcal{S}_t$.[9]

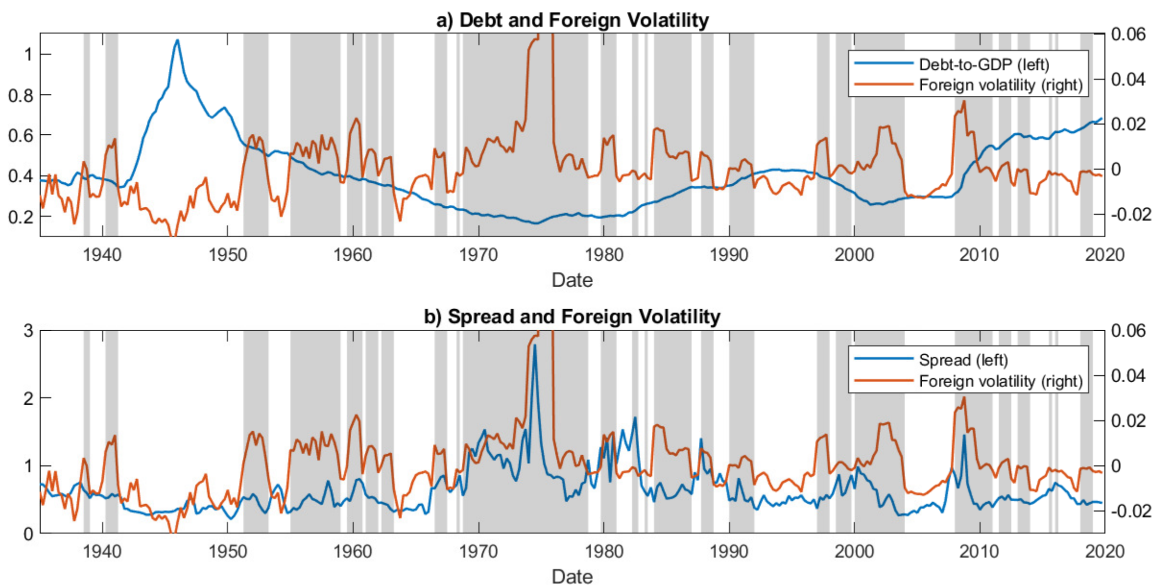
The data for the demand estimation are gathered at a quarterly level from 1935 to 2019. We compute measures of convenience yields for short- and long-term US public debt. The short-term convenience yield is computed as the difference in the yields to maturity of commercial paper and US Treasury Bills. The long-term convenience yield is computed

[8]As we discuss later, these differential predictions continue to hold if the rotation happens around any other point, i.e., a rotation around the original equilibrium point accompanied by a shift.

[9]The specification in (8) corresponds to a demand function that arises from a single-peaked benefit function $g_t(b_t) = (\beta + \gamma z_t)\, b_t \left(\log b_t - \xi_t\right)$, where $\xi_t = 1 - (\alpha + \delta X_t + \varepsilon_t)(\beta + \gamma z_t)^{-1}$. Note that one difference is that in the data we divide US public debt by GDP to remove its trend; we obtain similar empirical results if we use de-trended log real public debt. In addition, the elasticity estimates obtained from this specification can also be used to parameterize an increasing constant elasticity function of the form $f_t(b_t) = \exp(\nu_t)\, b^{\eta_t}/\eta_t$, where $\eta_t \approx (\beta + \gamma z_t)/\overline{\mathcal{S}}$ and $\overline{\mathcal{S}}$ is the average convenience yield across our sample. We obtain similar elasticity estimates if we estimate a log-log demand specification, which maps into a benefit function of the form $f_t(\cdot)$ (see Appendix B).

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. In the baseline specification, the vector of controls X_t includes the rotator z_t (described below), a measure of US volatility, and the slope of the yield curve. Our results are robust to considering alternative sets of controls.

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 the residualized foreign volatility measure is above the sample median. See Appendix B for a description of the construction of all the variables.

For the demand rotator, we use a slow-moving measure of foreign volatility residualized by US volatility and output growth. The motivation for doing so is that there is a flight to US Treasuries during periods of high foreign volatility that increases the demand for public debt relative to other safe assets and makes it more inelastic.[10] In

[10]A similar argument is made in the literature on intermediary based asset pricing (e.g., Gertler and Kiyotaki, 2010; He and Krishnamurthy, 2013; Gabaix and Maggiori, 2015; Morelli, Ottonello, and Perez, 2022). This literature argues that the aggregate demand for intermediated assets becomes more inelastic when the risk-bearing capacity of global intermediaries and specialists is impaired. Akinci, Kalemli-Özcan, and Queralto (2022) develop a model in which periods of high global volatility negatively affect the risk-bearing capacity of global intermediaries.

particular, $z_t = \mathbb{I}\left\{\tilde{z}_t \geqslant \bar{\tilde{z}}\right\}$ is a regime indicator variable that equals 1 when a residualized foreign volatility index, $\tilde{z}_t$, is higher than the sample median, and 0 otherwise. The foreign volatility index is the standard deviation of the weekly returns of the MSCI United Kingdom Index, computed over a yearly rolling window. We residualize this variable by projecting it on a measure of US stock market volatility and the growth rate of US GDP. In Appendix B we provide details about the construction of this variable. Figure 1 shows the evolution of the foreign volatility measure over time. We then 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.

The exclusion restriction that helps us identify if the US behaves strategically is that the demand rotator, which in our case is the residualized foreign volatility measure, is orthogonal to shocks to the marginal cost of issuing debt. In particular, we assume the following cost function, $\chi_t(b_t) = \exp(\omega_t)\frac{b_t^{1+\lambda}}{1+\lambda}$, which implies that the (log) marginal cost of issuing debt is given by

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

where ω_t is a mean-zero log marginal cost shifter.[11] In our specific application, shocks to ω_t can represent various factors that lead to spending shocks, such as wars, political turnover, or demographic trends. The exclusion restriction is that the random variables $\tilde{z}_t$ and ω_t are orthogonal, i.e., $\mathbb{E}[\tilde{z}_t\omega_t] = 0$. Thus, to identify if the US government behaves strategically or not, we need shocks that rotate the demand curve and are orthogonal to the shocks that affect the marginal cost of issuing debt.

Motivated by the exclusion restriction, our baseline volatility measure is based on the UK stock market and is residualized by US variables, to capture fluctuations in volatility that are likely unrelated to the US. By residualizing the UK volatility measure using US volatility and output growth, we address the concerns that periods of high foreign volatility may coincide with recessions or periods of high US volatility when the government implements expansionary fiscal policies. In Appendix B, we discuss the validity of the demand rotator and document its lack of correlation with various measures of fiscal supply shocks, such as government spending shocks and a recession indicator. We also consider alternative demand rotators and obtain similar results.

We use two 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).

[11] As we explain in Appendix B, the empirical analysis continues to hold if the log marginal cost shifter has a non-zero mean.

Second, we use 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, because 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 the robustness exercises described below, we also consider additional instruments. Using fiscal supply instruments for the quantities of debt allows us to estimate the elasticity of demand for US public debt, which in the context of our model corresponds to $f''(b)b/f'(b)$. The OLS estimation approach will also render consistent estimates of the demand elasticity if unobserved innovations to the supply of public debt are the main drivers of public debt dynamics.

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.

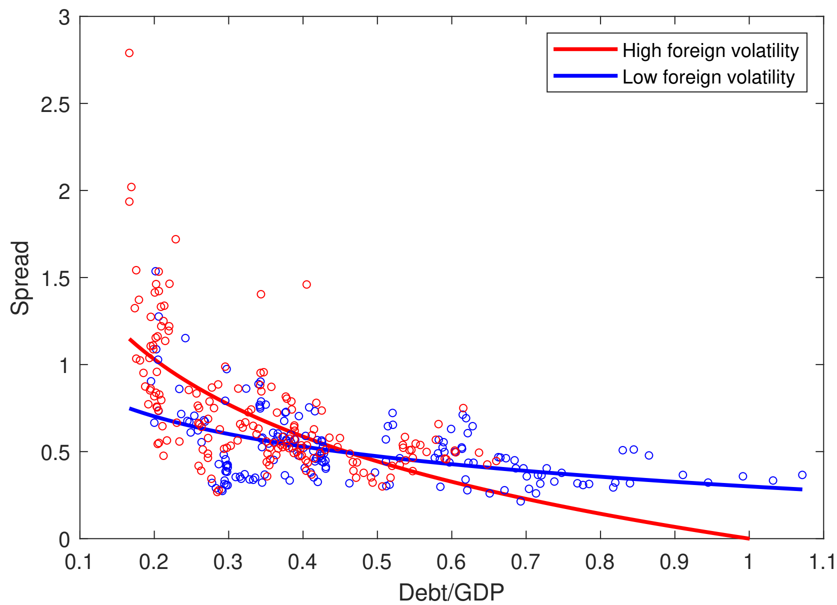
Table 1: Baseline demand estimation

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Log(debt/gdp)	-0.23***	-0.16***	-0.38***	-0.24***
	(0.04)	(0.05)	(0.03)	(0.04)
Foreign Volatility Dummy (FVD)	-0.31***	-0.12	0.05*	0.08***
	(0.07)	(0.09)	(0.03)	(0.03)
FVD × Log(debt/gdp)	-0.34***	-0.18**		
	(0.06)	(0.08)		
US VIX	0.02***	0.02***	0.02***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)
Yield curve slope	-0.06***	-0.07***	-0.06***	-0.07***
	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.11**	0.17***	-0.05	0.05
	(0.06)	(0.07)	(0.05)	(0.06)
Observations	339	339	339	339
R-squared	0.53		0.49	
Demand elasticity, high foreign vol	1.09	1.82	1.63	2.55
Demand elasticity, low foreign vol	2.68	3.78	1.63	2.55
Markup, high foreign vol	0.92	0.55	0.61	0.39
Markup, low foreign vol	0.37	0.26	0.61	0.39

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. Foreign Volatility Dummy (FVD) is an indicator for whether the residualized foreign 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 FVD. 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 doubling the debt-to-GDP ratio leads to a decrease in the convenience yield of 16 basis points in low-volatility periods and 40 basis points in high-volatility periods. Given the sample average for the convenience yield, the implied demand elasticities are $\varepsilon_D^L = 2.68$ and $\varepsilon_D^H = 1.09$ 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 3.78 and 1.82 during low- and high-volatility periods, respectively. In Appendix B, 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 1.63 and 2.55 in the OLS and IV specification, respectively, within the range of the estimates in prior literature (e.g., Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood et al., 2015; Koijen and Yogo, 2020; Jiang et al., 2021b; Mian et al., 2021; Krishnamurthy and Li, 2022). We will use an average of these point estimates 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) foreign volatility periods are periods with the residualized foreign 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 use a model selection test to distinguish between the price-taking and monopoly models. We build on the literature in industrial organization (Backus et al., 2021; Duarte et al., 2021) that uses the model selection test in Rivers and Vuong (2002) (RV) to test between different models of firm conduct. At a broad level, the test compares an empirical measure of goodness of fit in the two models.

To implement the test in our context, we use the supply equations from each model, (3) and (6). Given the assumed parametric cost function, these equations can be re-expressed as

$$\omega_t = \ln \mathcal{S}_t + \ln(1 - \xi\mu_t) - \lambda \ln b_t, \tag{9}$$

where ω_t is the marginal cost shifter, λ is the supply elasticity, and $\xi = 1$ under monopoly and $\xi = 0$ under the price-taking equilibrium. The goodness of fit measure is based on the exclusion restriction $\mathbb{E}[\tilde{z}_t \omega_t] = 0$. Under the true model, this moment condition should hold; hence, the test will favor the model in which this moment condition is closer to zero, in a statistical sense.

To understand how the test works, consider for illustration purposes the case of a constant marginal cost function, i.e., $\lambda = 0$. In this case, (9) implies that the moment condition can be written as $\mathbb{E}[\tilde{z}_t \ln \mathcal{S}_t] = 0$ for the price-taking model, and $\mathbb{E}[\tilde{z}_t (\ln \mathcal{S}_t + \ln(1 - \mu_t))] = 0$ for the monopoly model. Suppose that the true model is the price-taking model. In this case, spreads should not respond to demand rotations and the sample analog of the moment $\mathbb{E}[\tilde{z}_t \ln \mathcal{S}_t]$ will be closer to zero than $\mathbb{E}[\tilde{z}_t (\ln \mathcal{S}_t + \ln(1 - \mu_t))]$ so long as the covariance between the foreign volatility and the markup (inverse elasticity) is nonzero. As we show below, we estimate that the demand elasticity negatively covaries with foreign volatility. Therefore, in this case, the test will favor the price-taking model. Suppose instead that the true model is the monopoly model. In this case, spreads should increase during high $\tilde{z}_t$ periods because of the increase in markups (decrease in demand elasticity). Thus, the sample analog of the moment condition $\mathbb{E}[\tilde{z}_t (\ln \mathcal{S}_t + \ln(1 - \mu_t))]$ will be closer to zero than $\mathbb{E}[\tilde{z}_t \ln \mathcal{S}_t]$, where the latter term is positive. Thus, the test will favor the monopoly model over the price-taking one. If neither of the two models is the true model, the test favors the model in which this moment condition is closer to zero, in a statistical sense.

In the case of increasing marginal costs, $\lambda > 0$, the argument is similar except that spreads can change in both models if demand rotations are accompanied by demand shifts. Thus, in this case, the differential model prediction is related to the behavior of prices beyond what is purely explained by a demand shift, and the test compares $\mathbb{E}[\tilde{z}_t (\ln \mathcal{S}_t - \lambda \ln b_t)] = 0$ for the price-taking model, and $\mathbb{E}[\tilde{z}_t (\ln \mathcal{S}_t - \lambda \ln b_t + \ln(1 - \mu_t))] = 0$ for the monopoly model.

To compute the test, we obtain a time series of ω_{it} from (9) using observed data for $\mathcal{S}_t$ and b_t, and estimated data for μ_t, for the two models $i = 1, 2$, where model 1 is the monopoly model and model 2 is the price-taking one. We then define an empirical measure of distance from the moment condition for a model i as

$$Q_i \equiv \left(\sum_{t=1}^{T} \frac{1}{T} \left(\tilde{z}_t - \bar{\tilde{z}} \right) \left(\omega_{it} - \overline{\omega}_i \right) \right)^2,$$

where T is the total number of periods in our sample, and variables with the bar on top indicate sample means. 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 $(Q_1 - Q_2)$. RV shows that T^{RV} has a standard normal distribution. This implies that we can reject the null hypothesis of $T^{RV} = 0$ in favor of the monopoly model at the 5% significance level if T^{RV} is smaller than –1.96, and we can reject the null hypothesis in favor of the price-taking model if T^{RV} is larger than 1.96. In Appendix B, we provide an expression for σ_{RV} and a description of the implementation of the test for the general case in which the log marginal cost shifters have a nonzero mean and depend on observables.

Table 2 shows the test statistics using the demand elasticity estimates from Table 1 and different values of the elasticity of the cost function, λ.[12]

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								
	2.69	-2.91	-5.92	-6.99	-7.42	-7.93	-8.02	-8.03
	(0.01)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. IV								
	-4.06	-6.23	-7.2	-7.72	-8.03	-8.69	-8.94	-9.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: 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 consistently rejects the price-taking model in favor of the monopoly model across a wide range of values for λ. This rejection occurs because convenience yields exhibit an increase during periods of high volatility that cannot be explained solely by a shift in demand. Instead, they suggest a simultaneous rise in markups. Specifically, convenience yields experience significant spikes during high-volatility periods that are not accompanied by US recessions. Examples include the political turmoil in the UK during most of the 1970s, the global stock market crash in 1987, and the emerging market crises in the late 1990s (see Figure 1). These increases can be partially explained by the estimated rising markups in the monopoly model, whereas the

[12] In Table B.6 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.

price-taking model requires larger increases in marginal costs to account for the observed price dynamics. The latter introduces a correlation between innovations in marginal costs and the demand rotator, which weakens the likelihood of the moment condition holding.

In Appendix B 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 1, implying that the monopoly model is a good representation of the data.

The effects of simultaneous demand shifts and rotations. As the previous explanation suggests, the test can incorporate simultaneous rotations and shifts in the demand curve. High-volatility regimes are also associated with shifts in 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). The test compares increases in spreads across the two models after accounting for the changes due to shifts.

To see this, suppose that a change in $\tilde{z}_t$ implies a shift in demand in addition to a rotation. This would imply changes in both prices and quantities for both the monopoly and price-taking models. Consider the price-taking model first. If there is a demand shift and the US acts as a price taker, the supply equation (9) imposes a restriction on how prices and quantities should change:

$$\Delta \ln \mathcal{S}_t - \lambda \Delta \ln b_t = \Delta \omega_t. \tag{10}$$

In particular, if the demand curve shifts but there is no shift in the marginal cost function ($\Delta\omega_t = 0$), then this corresponds to a movement along the marginal cost curve. In this case, the left-hand side of the equation should be zero, and the observed elasticity of prices and quantities in response to this shock should be λ. In this case, any deviation of the left-hand side from zero under this model is attributed to a shift in the marginal cost function, which would introduce correlation between $\tilde{z}_t$ and ω_t and thus violate the identifying assumption. Now consider the monopoly model. If the demand curve shifts and rotates, the change in prices and quantities should satisfy

$$\Delta \ln \mathcal{S}_t - \lambda \Delta \ln b_t = -\Delta \ln (1 - \mu_t) + \Delta \omega_t. \tag{11}$$

Therefore, deviations in the left-hand side of this equation without changes in cost shifters can potentially be accounted for by changes in markups. In other words, in the monopoly model, in addition to the demand shift, changes in markups due to rotations in the demand curve serve as another reason for why prices and quantities should move. Similar to the previous case, the residual variation in prices and quantities that is not explained by markups is attributed to a shift in the marginal cost function. The test then favors the model that exhibits less comovement between the marginal cost shifters and the demand rotator.

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 rotations in demand would have any effect on quantities. However, as we see from Figure 1 and Appendix Table C.1, the level of debt is negatively correlated with the demand rotator of residualized foreign volatility. 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. This comovement could only be accounted for by a public debt rule that directly responds to the demand rotator, which would violate the exclusion restriction.

3.1 Robustness Analysis

In this section we assess the robustness of the main empirical results to the use of alternative demand rotators 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 the UK stock market volatility. We estimate the demand for public debt and the conduct test using a rotator of volatility regimes with a measure of UK stock market volatility residualized by detrended US GDP, and a non-residualized measure of UK volatility. We also consider alternate constructions of the regime indicator based on the UK volatility measure. In particular, we use regime indicators based on a standard deviation of the MSCI United Kingdom Index returns computed over six-month and two-year rolling windows (instead of the one-year rolling window used in the baseline), and 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). Appendix Table B.7 shows the demand estimates for these alternative rotators, which imply a more inelastic demand in periods of high volatility. Appendix Table B.8 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; Tabova and Warnock, 2021; Eren, Schrimpf, and Xia, 2023). 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 Appendix Table B.9). 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 model 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 Appendix Figures B.2 and B.3), 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. Appendix Tables B.11-B.19 report the demand estimates with and without the demand rotator, and the corresponding test statistics. We first include the volume of bank deposits as an additional control, to capture the presence of a substitutable safe asset that has similar liquidity properties.[13] Second, we include BAA-AAA corporate bond spreads and a measure of aggregate realized corporate default rates to control for any variation in spreads that may reflect default risk. Finally, we also conduct the empirical exercises excluding the set of controls. For alternative measures of the convenience yield, we use measures of short- and long-term convenience yields as dependent variables. For short-term convenience yields, we use commercial paper and certificates of deposit (CD) as comparable assets. The spread relative to CDs is informative because movements in this spread are unlikely to capture fluctuations in default risk, as these contain negligible default risk. For long-term convenience yields, we use long-maturity AAA corporate bonds as the comparable asset. For public debt, we also use the ratio of debt to trend-GDP and the detrended log of real debt—to avoid capturing movements driven by actual GDP—and external debt as a dependent variable. We also compute the conduct test using the detrended debt-to-GDP ratio to confirm that the results are not driven by movements in public debt due to secular trends that should not respond to demand rotations. Additionally, we consider a postwar sample and a

[13] A related literature studies the degree of substitutability between Treasuries and currency and bank deposits (see, for example, Nagel, 2016; Krishnamurthy and Li, 2022). Krishnamurthy and Li (2022) estimate that these assets are imperfectly substitutable and suggest that while bank deposits can offer greater liquidity, Treasuries may serve as superior collateral.

sample that excludes periods in which the zero lower bound binds. We also consider a subsample that starts in the 1970s, which is when the foreign holdings of public debt start to become sizable. 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 use 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 foreign 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.[14] Thus, the markup accounts for approximately 45% of the convenience yield. Given an average convenience yield of 62 basis points, the markup is significant and equals 28 basis points. In contrast, in the price-taking equilibrium, the markup is zero.

To further understand the economic implications of this market power, we extend, calibrate, and quantify our model. We introduce shocks to the shifters of US public debt demand and supply, as well as a common shock to the productivities of the two countries. We parameterize the benefit function as $f_t(b) = \exp(\nu_t)\, b^{\eta}/\eta$, and the cost function as $\chi_t(b) = \exp(\omega_t)\, b^{1+\lambda}/(1+\lambda)$. We assume that the benefit and cost shifters, ν_t and ω_t,

[14]This elasticity is the average of the OLS and IV demand estimates without the demand rotator (see Table 1).

as well as the log of productivities, $\log A_t$ and $\log A_t^*$, follow AR(1) processes:

$$x_{t+1} = (1-\rho_x)\,\bar{x} + \rho_x x_t + \sigma_x \varepsilon_t^x,$$

where $x \in \{\nu, \omega, \log A, \log A^*\}$, and $\varepsilon_t^A = \varepsilon_t^{A^*}$. In order to maintain the assumption that debt and capital have deterministic returns, we assume that the realization of the period $t+1$ shock happens in period t.

The model is calibrated at an annual frequency. Table 3 reports the parameter values. We set a subset of parameters to predetermined values and calibrate the remaining to match a set of moments related to the public debt and external balance sheet of the US. We assume a CRRA utility function $u(c) = c^{1-\gamma}/(1-\gamma)$. For the predetermined 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 $\alpha = 0.3$, a depreciation rate of $\delta = 0.1$, and a persistence of the productivity shocks of $\rho_A = \rho_{A^*} = 0.95$. We also set $\theta = 1$, which corresponds to a Cobb-Douglas aggregator for the capital composite. Finally, 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: Calibrated parameters

Panel A: Households			Panel B: Firms		
Param.	Description	Value	Param.	Description	Value
β	Discount rate	0.9886	α	Capital share	0.3
γ	Risk aversion	2	δ	Depreciation rate	0.1
η	Benefit elasticity	0.545	ι	US own capital share	0.91
$\bar{\nu}$	Benefit parameter	-5.47	ι^*	RoW own capital share	0.79
σ_ν	Benefit volatility	0.01	θ	Capital substitutability	1
ρ_ν	Benefit persistence	0.99	$\bar{A}$	US productivity	0.82
λ	Cost elasticity	1	$\bar{A}^*$	RoW productivity	0.93
$\bar{\omega}$	Cost parameter	-5.07	σ_A	Productivity volatility	0.02
σ_ω	Cost volatility	0.3	ρ_A	Productivity persistence	0.95
ρ_ω	Cost persistence	0.95			

Regarding the calibrated parameters, the domestic capital share in the capital composite and the average productivity levels are chosen to target moments associated with the external balance sheet of the US and the relative sizes of the two economies. In particular, the share parameter ι 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 ι^* is calibrated to match the average net foreign assets of the US in the data. We calibrate the average US productivity level $\bar{A}$ so that the US GDP is normalized to 1, and we calibrate the average productivity level 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.

The last set of parameters are calibrated to match simulated moments related to the dynamics of US public debt. We compute the model using a second-order perturbation solution and target stochastic steady states of the model moments. We calibrate the average shifters of the benefit and cost function, $\overline{\nu}$ and $\overline{\omega}$, to match an average stock of public debt of 41% of GDP and an average convenience yield of 62 bps. To calibrate the persistence of the benefit and cost parameters, ρ_ν and ρ_ω, we target the autocorrelations of the debt-to-GDP (b_t) and the spread $(\mathcal{S}_t)$. To calibrate the volatility of the processes through $\sigma_\nu, \sigma_\omega, \sigma_A$, we target the variance of debt-to-GDP (b), the spread $(\mathcal{S})$, and the correlation between debt and spread. Finally, we calibrate the discount factor β to match the average interest rate on public debt. We summarize these parameters in Table 3, and the moments in Table 4. One point worth noting is that the model requires shocks to the supply of public debt that are an order of magnitude more volatile than demand shocks, to match the moments related to public debt.

Table 4: Calibration moments

Panel A: Targeted moments			Panel B: Untargeted moments		
Moments	Data	Model	Moments	Data	Model
Mean (US real rate)	0.53%	0.53%	Var(CA)	0.03	0.02
Mean(US debt-GDP)	0.41	0.43	Var(deficit)	0.002	0.02
Mean(conv. yield)	0.62%	0.61%	Var(NFA)	0.035	0.013
Var(US debt-GDP)	0.03	0.01	Corr(debt-GDP,NFA)	−0.65	−0.98
Var(conv. yield)	0.086	0.072	Corr(CA,deficit)	−0.21	−0.98
Corr(debt-GDP,yield)	−0.56	−0.67			
Autocorr(US debt-GDP)	0.96	0.99			
Autocorr(conv. yield)	0.71	0.92			

Notes: Model moments are averages of stochastic simulations. Data moments are averages of our sample period 1935-2019. Appendix B contains detailed information on dataset construction.

Table 4 also reports a set of untargeted moments related to the dynamics of the US external balance sheet. The model replicates well the variance of the current account (CA) and the net foreign asset (NFA) position, the correlation of the NFA with public debt, and that of the CA and the government deficit.

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 than in the monopoly case. In Appendix Tables C.2 and C.4, we show how these results depend on alternative parameterizations of the demand and cost elasticities. In particular, the safe asset supply in the price-taking model is more than two times that in the monopoly model when we use the demand elasticity estimated during high-foreign-volatility regimes.

Table 5: Macroeconomic distortions due to market power

	Monopoly	Price-taking
Total safe assets-GDP	0.43	0.62
Convenience yield	0.61%	0.53%
Interest on public debt	0.53%	0.60%

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

We next use our model to quantify the welfare implications of US market power in safe assets. To do so, we study the transition from the monopoly steady state to the economy in which the US acts as a price taker. Table 6 documents the welfare loss for the US of losing its safe asset market power. The counterpart of this loss is a welfare gain for the RoW. To put this into context, our estimates of welfare benefit for the US of exerting market power are of similar magnitudes to the gains from seigniorage of external holdings of US currency.[15] Table 6 also shows the welfare losses of transitioning to an economy in which there is no special role for US assets (i.e., $f = 0$), which are sizable for both the US and the RoW. Appendix Tables C.3 and C.5 show 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).[16] Our measure focuses on the gains from the special role of US debt and abstracts from risk-premium considerations. Introducing such premia is an interesting extension that is beyond the scope of our analysis.

Finally, in Appendix A.1 we show that we obtain similar quantitative results if we

[15] A rough estimate of seigniorage benefits from external holdings of US currency is 0.1% of GDP, which corresponds to an interest rate saving of 3.5% over a base of 4% of GDP of foreign holdings of US currency. In the case of US public debt, the base is larger but the savings in interest rates are smaller.

[16] 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.

assume a single-peaked benefit function that features a satiation point for a finite level of debt at which the convenience yield is zero. Unlike our baseline parameterization, where we assume a constant elasticity, this benefit function implies a constant semi-elasticity demand function.

Table 6: Welfare implications of market power in safe assets

	Price-taking economy	No special role for US debt
US welfare	-0.08%	-0.22%
RoW welfare	$+0.10\%$	-0.33%

Notes: Price-taking economy is an equilibrium in which the US acts as a price taker. No special role for US debt is an economy in which the benefit and cost functions are both 0. Welfare changes are expressed in permanent consumption equivalence terms considering the whole transition period starting from the baseline monopoly equilibrium.

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

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

subject to

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

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*

$$\mathcal{S}_t^{CN} = \frac{1}{[1-\mu_t^{CN}]}\chi'\left(\frac{b_t^{CN}}{N}\right) \tag{12}$$

and

$$b_t^{CN} = f'^{-1}\left(\mathcal{S}_t^{CN}\right), \tag{13}$$

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

All proofs are in 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 to $N = 2, 3$. The calibration is identical to that in the previous section. Table 7 documents the change in convenience yields, interest rates, and welfare changes as a consequence of this transition. In Appendix Figure C.3, we plot the transition path for various macroeconomic variables. 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. This generates small non-Ricardian effects on the capital levels and rates of return during the transition. Finally, the US issuance of debt is not very different from that in the monopoly case. However, 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.

Table 7: The effects of increasing competition

	Monopoly	Cournot		Fringe	
		$N=2$	$N=3$	Foreign	Domestic
a. Steady-state variables					
Total safe assets	0.43	0.81	1.28	1.00	0.92
US public debt	0.43	0.41	0.43	0.45	0.36
Convenience yield	0.61%	0.47%	0.35%	0.40%	0.42%
Interest on public debt	0.53%	0.66%	0.83%	0.75%	0.74%
b. Welfare					
US welfare	–	−0.13%	−0.18%	−0.15%	−0.04%
RoW welfare	–	+0.15%	+0.24%	+0.18%	+0.16%

Notes: 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 of transitioning from the monopoly equilibrium to different economies.

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. Assuming that both capitals are perfectly substitutable, the 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

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

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

$$\mathcal{S}_t\left(b_t + b_t^f(b_t)\right) = \chi_F'\left(b_t^f(b_t)\right). \tag{14}$$

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

$$\mathcal{S}_t\left(b_t + b_t^f(b_t)\right) = f'\left(b_t + b_t^f(b_t)\right). \tag{15}$$

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*

$$\mathcal{S}_t^F = \frac{1}{[1 - \mu_t(b_t, b_t^f)]} \chi'(b_t), \tag{16}$$

$$b_t + b_t^f = f'^{-1}\left(\mathcal{S}_t^F\right), \tag{17}$$

and

$$b_t^f = \chi_F'^{-1}\left(\mathcal{S}_t^F\right), \tag{18}$$

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 problem for the US government is

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

subject to

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

and where, as before,

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

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

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

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 US households. Thus, the US maximizes the joint profits of the government and fringe, which implies that the outcomes are closer to those in the 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 the quantitative version of our model with imperfect substitution of capital. 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 internalizes its price impact 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. In our model, the US is able to exert market power because Treasuries are the only safe asset providing additional non-pecuniary benefits which arise from their money-like properties. We think it would be a worthwhile exercise to jointly model the supply of fiat money and government debt, and leave this for future work.

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 alleviates 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 Model Appendix

A.1 Further Details on the Optimization Problems

In this section we provide a microfoundation for the benefit function and derive the US government problem from a more primitive environment. We provide a microfoundation of $f(b)$ 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 RoW. As in the main text, 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

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

$$x_t \leqslant b_t$$

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

It is straightforward to see that the collateral constraint will always bind, and, hence, this problem is equivalent to the one in the main text.

Next, consider the US. We assume that the US is populated by households who choose capital and consumption to solve

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

subject to

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

taking as given prices and transfers from the government, T_t. The first-order condition of the household is

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

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 transfer the proceedings from net issuances to households. Issuing debt b_{t+1} in period t generates an additional resource cost $\chi_{t+1}(b_{t+1})$ in period $t+1$. As mentioned in the text, this cost can capture the distortions associated with taxing households to pay back debt or increasing the balance sheets of the central bank. This implies that the budget constraint of the government is

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

The government's objective is to maximize utility for households by choosing the level of debt issuance, taking all prices except for the cost of issuing debt as given. This implies that we can write the government problem as

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

subject to

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

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

where the first constraint is obtained by combining the households' and government's budget constraints, and the second constraint is the households' first-order constraint for the choice of capital. Finally, note that a problem in which the government directly chooses capital without the last constraint yields the same solution as the problem above. This implies that the problem of the government is identical to the problem described in Section 2.

A.2 A Single-peaked Benefit Function

One alternative microfoundation 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 case with a benefit function $g(b)$ that is concave and single-peaked. In particular, we assume that $g(b) = (\eta - 1) b (\log b - \nu)$, which implies a constant semi-elasticity of demand, $\eta - 1$. The rest of the environment is unchanged. We can use the empirical procedure described in Section 3, and estimate (8) imposing $\gamma = 0$ to estimate an average semi-elasticity of demand for this functional form. It is straightforward to see that the coefficient β estimated using (8) identifies η. We then recalibrate our model using the same targeted moments as in the baseline calibration, and compute the transition between the monopoly and price-taking models, where ν and ω follow the same AR process as in the baseline model.[17] As Tables A.1 and A.2 show, the results of the counterfactual exercises are very similar to those in the baseline model. The reason for this is that the implied marginal cost curve intersects both demand curves at points where the two demand functions behave similarly, i.e., away from the satiation point of g.

Table A.1: Counterfactual exercise with single-peaked benefit function

	Baseline benefit function		Alternative benefit function	
	Monopoly	Price-taking	Monopoly	Price-taking
Total safe assets-GDP	0.43	0.62	0.43	0.62
Convenience yield	0.61%	0.53%	0.61%	0.53%
Interest on public debt	0.53%	0.60%	0.53%	0.60%

Notes: The first two columns show the monopoly and price-taking equilibria calibrated to a power benefit function, f(b), as in the baseline; the last two columns show the monopoly and price-taking equilibria calibrated to a single-peaked benefit function, g(b).

Table A.2: Welfare exercise with single-peaked benefit function

	Baseline benefit function	Alternative benefit function
US welfare	-0.08%	-0.08%
RoW welfare	$+0.10\%$	$+0.10\%$

Notes: The baseline benefit function is calibrated with a power function, f(b) as in the baseline, and the alternative benefit function is calibrated with a single-peaked function, g(b). Welfare change is expressed in permanent consumption equivalence terms of transitioning to different economies.

The comparison between these two functional forms for the benefit function is related to Ireland (2009), who compares the welfare implications of deviating from the Friedman rule for two money demand functions, which correspond to the two functional forms

[17] To calibrate this model, we use the fact that the semi-elasticity of demand is $\eta - 1$. The regression coefficients in the last two columns of Table 1 provide an estimate of the semi-elasticity when convenience yields are measured in percentage points. We adjust the average coefficient to reflect the semi-elasticity when convenience yields are measured in decimal points and obtain a value of $\eta = 0.997 = 1 - 0.00305$. We then recalibrate $\bar{\nu} = 0.13$ and $\bar{\omega} = -4.92$ to match the average debt and convenience yields, and leave all other parameters as in the baseline calibration.

described above. In particular, one is a constant elasticity function (f in our baseline), and the other is a constant semi-elasticity function (g, as the one above). Ireland (2009) argues that the welfare differences between the two specifications are quite significant because the economy reaches monetary satiation under the Friedman rule. However, in our economy the welfare implications of the two functions are very similar because of the reason explained above.

A.3 Equilibrium characterization with imperfect capital substitutability

Consider the model in which the US capital 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

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

and the convenience yield is given by

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

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

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 than in the price-taking case.

A.4 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

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

Thus, in any symmetric equilibrium, we have

$$\mathcal{S}_t \left(b_t^{CN}\right) = f'\left(b_t^{CN}\right)$$

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

Proof of Lemma 4

From the proof of Lemma 3

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

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

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

which implies that

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

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

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

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

$$\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)\left[1 + b_t^{f'}(b_t)\right] b_t + \mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0. \tag{19}$$

Using the (14), 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

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

Next, using (15), 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

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

Substituting the above into (19) yields

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

and using the definition of markup in the text of the lemma yields the result. The equilibrium quantities can be obtained from (14) and (15). Q.E.D.

Proof of Lemma 6

The first-order condition for the US is

$$\mathcal{S}_t'\left(b_t + b_t^f(b_t)\right)\left[1 + b_t^{f'}(b_t)\right]\left(b_t + b_t^f\right) + \mathcal{S}_t\left(b_t + b_t^f(b_t)\right) - \chi'(b_t) = 0. \tag{20}$$

Using (14) and (15), 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 (20) 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 (14) and (15). Q.E.D.

B Empirical Analysis

B.1 Data Description

We use quarterly frequency data from 1935 to 2019. We first describe the construction of variables used in the baseline empirical analysis.

- *Debt-to-GDP*: Debt from 1942 to 2019 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 the 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 to 2000 and market yield on US Treasury securities at 20-year constant maturity for 2001 to 2019, 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 to 2019 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 to 1996. For 1935 to 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 to 2019 and six-month Treasury bills for 1959 to 1970, both from FRED. For 1935 to 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 2019, 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. We residualize this index by projecting it on US volatility (as defined below) and the growth rate of real GDP. Table B.2 reports the regression estimates used for the residualization.

- *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 2019 is from FRED, and the yield from 1935 to 1952 is from the NBER Macrohistory database.

- *US volatility*: We use VIX, the CBOE Volatility Index, from 1990 to 2019. 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 2019. The regression estimates are reported in Table B.1. We then take a four-quarter moving average of this series to obtain a measure of US volatility. 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. From 1947 onwards, the data were sourced from the Current Population Survey, Bureau of Labor Statistics. Prior to 1947, the data were sourced from the National Population Estimates by the US Census Bureau Population Division. To smooth out variations in quarters coming from BLS data revisions, we HP filter the dependency ratio from 1947 onwards and consider the resulting trend variable.

- *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 affects 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 $t_1 = 12$ and $t_2 = 24$. The IV results are robust to considering alternative numbers of lags and leads.

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

- *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 data from 1959 to 2019 are from FRED . Data prior to 1959 are from the FDIC historical bank dataset.

- UK public debt to (UK) GDP: Market value of public debt is aggregated from individual bonds with the dataset from Ellison and Scott (2020). UK GDP from 1948 onwards is from the Office for National Statistics. Prior to 1948, UK GDP is from *A Millenium of Macroeconomic Data (MMD)* published by the Bank of England.

- BAA-AAA spread: The percentage spread between Moody's Baa-rated long-maturity corporate bond yield and Moody's Aaa-rated long-maturity corporate bond yield. Moody's Baa and Aaa indexes are from FRED.

- Corporate default rate: The ratio of total defaulted corporate bond value to total par corporate bond value, excluding finance, real estate, nonprofits, and firms not domiciled in the US. The data are from Giesecke, Longstaff, Schaefer, and Strebulaev (2011), and run from 1935 to 2012.

- Certificate of deposits rate: Three-month certificate-of-deposit rate obtained from FRED. The data are from 1964 to 2019.

- US recession indicator: Indicator variable that equals 1 for quarters coinciding with a recession, as dated by the NBER Business Cycle Dating Commitee.

Table B.1: Volatility measure construction

VARIABLES	MSCI UK Volatility	VIX
UK Share Price Volatility	1.00***	
	(0.05)	
S&P500 Volatility		364.42***
		(18.85)
Const	-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 2019 and VIX, the CBOE Volatility Index from 1990 to 2019. The independent variables are the 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 is from FRED. The value-weighted S&P index is from CRSP. Standard errors are in parentheses; $*$, $**$, and $***$ represent statistical significance at the 10%, 5%, and 1% level, respectively.

Table B.2: Foreign volatility residual projection

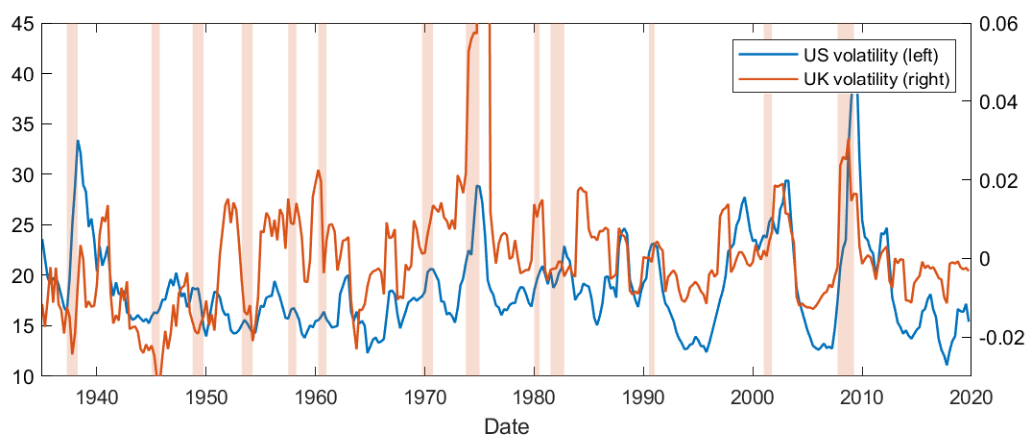
VARIABLES	UK Volatility
US Volatility	0.0001**
	(0.0000)
Real GDP growth	-0.0301**
	(0.0149)
Const	0.0228***
	(0.0018)
Observations	372

Notes: The dependent variable is a 1935 to 2019 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 2019. For the independent variables, US volatility is VIX from 1990 to 2019, and from 1935 to 1990, a historical series of VIX predicted by regressing it on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2019. We then take a four-quarter moving average of this series to obtain US volatility. The value-weighted S&P index is from CRSP. Real GDP is from FRED. 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. Figure B.1 plots the measures of UK and US volatilities. They exhibit a positive correlation that increases during the 1970s and after, when global capital markets became more integrated. The exclusion restriction for the demand rotator is that the random variables $\tilde{z}_t$ and ω_t are orthogonal, i.e., $\mathbb{E}[\tilde{z}_t \omega_t] = 0$, where ω_t is a marginal cost shifter. In our context, this requires that the residualized UK volatility measure and the regime indicator of high or low UK volatility are unrelated to fiscal supply shocks. Table B.3 shows that both measures have low correlation to various measures of fiscal supply shocks—government spending to GDP, government transfers to GDP, Blanchard–Perotti government spending shocks, and an indicator of US recessions. Most estimated correlations are not statistically different from zero. Additionally, the correlations become closer to zero once we residualize the UK volatility measure by US volatility and output growth.

Figure B.1: UK and US volatility



Notes: UK volatility is the standard deviation, computed over a yearly rolling window, of weekly returns of the MSCI United Kingdom Index, from 1972 to 2019; from 1935 to 2019, a projection of this series based on the yearly-rolling-window standard deviation of monthly returns of the UK share price index. We residualize this index by projecting it on US volatility (as defined below) and the growth rate of real GDP to obtain UK volatility. US volatility is VIX from 1990 to 2019; from 1935 to 1990, a historical series of VIX predicted by regressing it on the annualized standard deviation of the weekly log stock returns on the S&P 500 index from 1990 to 2019. We then take a four-quarter moving average of this series to obtain US volatility. Shaded areas correspond to NBER recessions. See Appendix B for a description of the construction of all the variables.

Table B.3: Demand rotator correlations

	Gov. spending/GDP	Gov. benefits transfer/GDP	Blanchard-Perotti shock	Recession indicator
UK volatility, non-residualized	0.16	0.06	0.01	0.14
	(2.76)	(1.02)	(0.18)	(2.6)
UK volatility, residualized	0.14	0.04	-0.01	0.1
	(2.4)	(0.68)	(-0.18)	(1.85)
UK volatility indicator	0.09	-0.02	-0.02	0.07
	(1.54)	(-0.34)	(-0.37)	(1.29)

Notes: UK volatility, non-residualized is a 1935 to 2019 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 2019. UK volatility, residualized is the preceding series residualized by a measure of US stock market volatility and US GDP growth rate. UK volatility indicator is an indicator function for whether UK volatility, residualized is above the sample median value. Government spending is US federal government spending. Government benefits transfer is US federal government social benefits to persons. Recession indicator is an indicator function for NBER recessions. Blanchard–Perotti is the cumulative exogenous government expenditure shocks from the Blanchard–Perotti regression; we accumulate the expenditure shocks from t-5 to t-40. T-statistics are in parentheses.

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.4 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.4: Fiscal supply instrument correlations

	UK volatility, residualized	VIX	GDP growth
Δ Log dependency ratio	-0.21	-0.18	0.02
	(-3.94)	(-1.99)	(0.37)
Military news shock	-0.21	0.28	-0.05
	(-3.94)	(3.17)	(-0.92)
Blanchard–Perotti shock	-0.01	0.04	-0.29
	(-0.18)	(0.43)	(-5.56)

Notes: UK volatility, non-residualized is a 1935 to 2019 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 2019. UK volatility, residualized is the preceeding series residualized by a measure of US stock market volatility and US GDP growth rate. VIX is the CBOE Volatility Index from 1990 to 2019. 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-12 to t-24. Blanchard–Perotti is the cumulative exogenous government expenditure shocks from the Blanchard–Perotti regression; we accumulate the expenditure shocks from t-5 to t-40. T-statistics are in parentheses.

Table B.5 shows the output of the first-stage regressions.

Table B.5: First-stage regressions

VARIABLES	Log(debt/GDP)	FVD × Log(debt/GDP)
Military news	0.31***	-0.00
	(0.04)	(0.03)
Δ Log Dependency	76.62***	-2.63
	(6.67)	(5.25)
FVD × Military news	-0.16*	0.13*
	(0.09)	(0.07)
FVD × Δ Log Dependency	30.93***	111.58***
	(9.34)	(7.35)
Foreign Volatility Dummy (FVD)	-0.23***	-1.44***
	(0.04)	(0.03)
US VIX	-0.01**	-0.00
	(0.00)	(0.00)
Yield curve slope	0.05***	0.03***
	(0.01)	(0.01)
Constant	-1.17***	0.01
	(0.05)	(0.04)
Observations	339	339
R-squared	0.69	0.92

Notes: The dependent variables are the log of the ratio of the Treasury debt outstanding to US GDP and an interaction with high foreign volatility dummy. 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-12 to t-24. 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 2019, 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 2019. Foreign volatility dummy is an indicator for whether the constructed residualized 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.

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 F-statistics for each of the rotator instruments we use are reported in Table B.6.

Table B.6: F-statistics

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline								
	30.64	55.63	80.91	93.03	98.68	105.31	105.92	105.91
b. Investor composition								
	191.1	132.52	104.6	93.3	87.66	78.34	75.68	74.87

Notes: 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 Test of Conduct Under More General Setting

In this section, we describe the conduct test under a general case where the log marginal cost function is a linear function of observable shifters, and the unobservable shifter may have a nonzero mean. This general case is implemented in our IV specification.

Assume the following cost function, $\chi_t(b_t) = \exp(\omega_t + \tau \boldsymbol{w}_t) \frac{b_t^{1+\lambda}}{1+\lambda}$, which implies that the log marginal cost of issuing debt is given by

$$\ln mc_t = \tau \boldsymbol{w}_t + \lambda \ln b_t + \omega_t,$$

where $\boldsymbol{w}_t$ is a vector of observable shifters that also includes a constant.[18] The inclusion of the constant allows us to assume, without loss of generality, that $\mathbb{E}\omega_t = 0$. Combining the supply equations (3) and (6) with the assumed cost function gives an expression for $\omega_t + \tau \boldsymbol{w}_t$ based on the observables $\mathcal{S}_t, b_t, \mu_t$, and an assumed value for the cost elasticity λ:

$$\omega_t + \tau \boldsymbol{w}_t = \ln \mathcal{S}_t + \ln(1 - \xi\mu_t) - \lambda \ln b_t. \tag{21}$$

Recall that the test relies on the moment condition $\mathbb{E}[\tilde{z}_t \omega_t] = 0$. We further assume that ω_t satisfies the orthogonality condition $\mathbb{E}[\boldsymbol{w}_t \omega_t] = 0$. We can then obtain an estimate of ω_t by residualizing the right hand side of (21) by the vector of observables $\boldsymbol{w}_t$. In particular, for any variable x, define the residualized variable $\hat{x} = x - \boldsymbol{w}\mathbb{E}[\boldsymbol{w}'\boldsymbol{w}]^{-1}\mathbb{E}[\boldsymbol{w}'x]$.

[18]In the OLS estimation, the vector of observable shifters includes only the constant, i.e., $\boldsymbol{w}_t = \mathbf{1}$. In the IV estimation, $\boldsymbol{w}_t = [\mathbf{1}\ \tilde{\mathbf{w}}_t]$, where $\tilde{\mathbf{w}}_t$ includes the two supply instruments, i.e., the military news shocks variable and the change in the dependency ratio.

Thus, we can express the moment condition for the test as

$$\mathsf{E}\left[\hat{\tilde{z}}_t(\ln \mathcal{S}_t + \ln \widehat{(1-\xi\mu_t)} - \lambda \ln b_t)\right] = 0.$$

Note that we also residualize the rotator variable $\tilde{z}_t$. We form the empirical measure of distance from the moment condition for a model i as follows, where model 1 is the monopoly model and model 2 is the price-taking one:

$$\tilde{Q}_i = \tilde{g}_i^2, \quad \text{where}$$
$$\tilde{g}_i = \sum_{t=1}^{T} \frac{1}{T}\hat{\tilde{z}}_t(\ln \mathcal{S}_t + \ln \widehat{(1-\xi_i\mu_t)} - \lambda \ln b_t).$$

Here T is the total number of periods in our sample, $\xi_1 = 1$ and $\xi_2 = 0$. The RV test statistic is given by

$$T^{RV} = \frac{\sqrt{n}\left(\tilde{Q}_1 - \tilde{Q}_2\right)}{\tilde{\sigma}_{RV}},$$

where $\tilde{\sigma}^2_{RV}$ is an estimator of the asymptotic variance of the scaled difference in the measure of fit $(Q_1 - Q_2)$. We follow Duarte et al. (2021) and let $\tilde{\sigma}^2_{RV}$ be a delta-method variance estimator that takes the form

$$\tilde{\sigma}^2_{RV} = 4\left[\ \tilde{g}_1^2\tilde{V}_{11}^{RV} + \tilde{g}_2^2\tilde{V}_{22}^{RV} - 2\tilde{g}_1\tilde{g}_2\tilde{V}_{12}^{RV}\ \right],$$
$$\tilde{V}_{lk}^{RV} = T^{-1}\sum_{t=1}^{T}\tilde{\psi}_{lt}\tilde{\psi}_{kt},$$
$$\tilde{\psi}_{it} = \left(\hat{\tilde{z}}_t(\ln y_t - \ln \widehat{(1-\xi_i\mu_t)} - \lambda \ln b_t) - \tilde{g}_i\right) - \frac{1}{2}\left(\frac{\hat{\tilde{z}}_t^2}{T^{-1}\sum_{t=1}^{T}\hat{\tilde{z}}_t^2} - 1\right)\tilde{g}_i.$$

The test statistic T^{RV} is standard normal under the null of $Q_1 = Q_2$. A negative and large absolute value T^{RV} implies that the test rejects the null in favor of model 1 (i.e., monopoly model has a better fit), whereas a positive and large T^{RV} implies that the test rejects the null in favor of model 2 (i.e., price-taking model has a better fit).

B.4 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.4.1 Alternative Rotators Based on Volatility

To begin, we consider the effects of using alternative demand rotators based on measures of foreign volatility. Table B.7 shows the demand estimation results of using the instrumental variables approach, and Table B.8 shows the RV test results. First, we consider residualizing the UK volatility measure by the US volatility index and detrended GDP. We also consider the non-residualized UK volatility measure as well. Second, 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 an eight-quarter rolling window and a two-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.7: US public debt demand estimation: Alternative rotators

VARIABLES	(1) Baseline	(2) UK Vol Residualized with detrended GDP	(3) Non-Residualized UK Vol	(4) 66th perc. cutoff	(5) 75th perc. cutoff	(6) 8 quarters std dev	(7) 2 quarters std dev
Log(debt/gdp)	-0.16***	-0.15***	-0.15***	-0.19***	-0.21***	-0.14***	-0.19***
	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)
Foreign Volatility Dummy (FVD)	-0.12	-0.06	-0.12	-0.27**	-0.22*	-0.19*	-0.07
	(0.09)	(0.07)	(0.09)	(0.11)	(0.12)	(0.10)	(0.09)
FVD × Log(debt/gdp)	-0.18**	-0.12*	-0.20**	-0.29***	-0.27***	-0.26***	-0.14
	(0.08)	(0.07)	(0.08)	(0.10)	(0.10)	(0.09)	(0.08)
Observations	339	322	339	339	339	339	339
Demand elasticity, high foreign vol	1.82	2.14	1.79	1.29	1.3	1.55	1.94
Demand elasticity, low foreign vol	3.78	3.83	4.13	3.26	2.97	4.43	3.35
Markup, high foreign vol	0.55	0.47	0.56	0.78	0.77	0.65	0.52
Markup, low foreign vol	0.26	0.26	0.24	0.31	0.34	0.23	0.3

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 foreign volatility dummy indicator: (1) Volatility is above the sample median, where volatility is UK volatility residualized by a measure of US volatility and GDP growth rate; (2) Volatility is above the sample median, where volatility is UK volatility residualized by a measure of US volatility and HP filtered GDP fluctuations; (3) Volatility is above the sample median, where volatility is raw UK volatility; (4) and (5) Volatility is above the sample 66th and 75th percentile, respectively, where volatility is UK volatility residualized by a measure of US volatility and GDP growth rate; (6) Volatility is above the sample median, where volatility is UK volatility residualized by a measure of US volatility and GDP growth rate, with UK volatility as 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; (7) Volatility is above the sample median, where volatility is UK volatility residualized by a measure of US volatility and GDP growth rate, with UK volatility as 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. 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 foreign 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. 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.8: 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								
	-4.06	-6.23	-7.2	-7.72	-8.03	-8.69	-8.94	-9.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Alternative volatility-based rotators								
UK Vol Residualized with detrended GDP	-5.63	-8.01	-8.68	-8.94	-9.06	-9.24	-9.27	-9.28
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Non-Residualized UK Vol	-4.13	-6.25	-7.22	-7.73	-8.05	-8.72	-8.97	-9.05
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
66th perc. cutoff	0.27	-3.51	-5.41	-6.44	-7.06	-8.36	-8.83	-8.99
	(0.79)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
75th perc. cutoff	-0.55	-4.12	-5.68	-6.47	-6.93	-7.88	-8.22	-8.34
	(0.58)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
8 quarters std dev	-2.74	-6.75	-8.44	-9.27	-9.75	-10.7	-11.02	-11.13
	(0.01)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
2 quarters std dev	-4.35	-5.88	-6.36	-6.56	-6.66	-6.82	-6.85	-6.86
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
c. Investor composition rotator								
	-12.45	-9.0	-5.74	-4.02	-3.02	-1.07	-0.38	-0.16
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.29)	(0.7)	(0.88)

Notes: 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.

B.4.2 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

$$y_t = \alpha_i + \beta_i \ln b_{it} + \delta_i X_t + \varepsilon_{it,} \quad \text{for } i = \text{foreign, domestic,} \tag{22}$$

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.[19] Table B.9 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.2 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

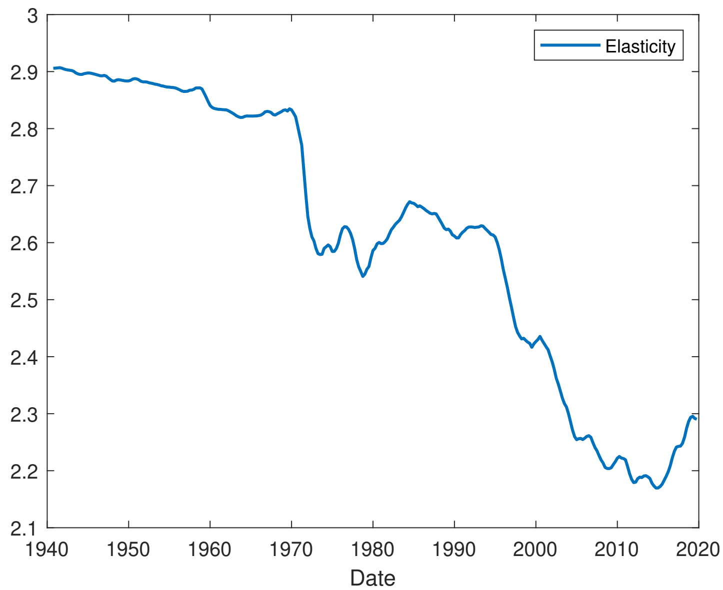
Table B.9: Demand elasticities for different types of investors

VARIABLES	Foreign Investors	Domestic Investors
Log(debt/gdp)	-0.44***	-0.28***
	(0.09)	(0.06)
Observations	319	319
Demand elasticity	1.84	2.92
Markup	0.54	0.34

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.

[19]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.

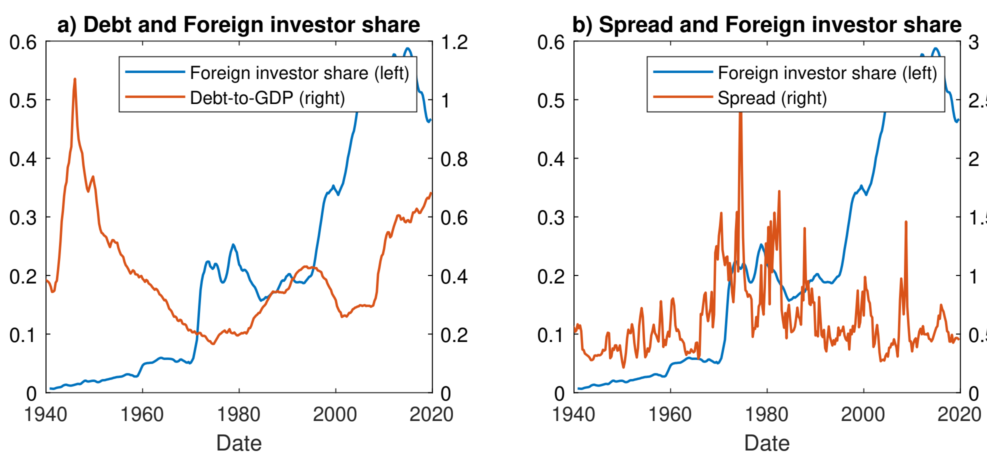
Figure B.2: Demand elasticity weighted by investor composition



Notes: 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.8, 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.3).

Figure B.3: 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.4.3 Other Robustness Analyses

Finally, we analyze the robustness of our results to alternative demand specifications. We start by estimating a log-log specification for demand, instead of the semi-log specification in the baseline analysis. As Table B.10 shows, the estimates of demand elasticities are very similar.

Table B.10: Demand estimation with log spread

VARIABLES	(1) OLS	(2) IV	(3) OLS	(4) IV
Log(debt/gdp)	-0.40***	-0.29***	-0.53***	-0.38***
	(0.06)	(0.07)	(0.04)	(0.06)
Foreign Volatility Dummy (FVD)	-0.23**	-0.07	0.08**	0.12***
	(0.09)	(0.12)	(0.03)	(0.04)
FVD × Log(debt/gdp)	-0.30***	-0.18		
	(0.08)	(0.11)		
US VIX	0.02***	0.02***	0.02***	0.03***
	(0.00)	(0.00)	(0.00)	(0.00)
Yield curve slope	-0.06***	-0.07***	-0.06***	-0.07***
	(0.02)	(0.02)	(0.02)	(0.02)
Constant	-1.33***	-1.23***	-1.50***	-1.39***
	(0.08)	(0.09)	(0.07)	(0.08)
Observations	339	339	339	339
R-squared	0.52		0.50	
Demand elasticity, high foreign vol	1.44	2.12	1.88	2.65
Demand elasticity, low foreign vol	2.5	3.45	1.88	2.65
Markup, high foreign vol	0.7	0.47	0.53	0.38
Markup, low foreign vol	0.4	0.29	0.53	0.38

Notes: The dependent variables are the log of the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. Foreign Volatility Dummy (FVD) is an indicator for whether the residualized foreign 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 FVD. 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.

We then consider the robustness of the empirical results to alternative measures of convenience yields and public debt. Tables B.11 and B.12 show the demand estimation results with and without the demand rotator, respectively. Table B.13 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. For short-term convenience yields, we use commercial paper and certificates of deposit (CD) as comparable assets. The spread relative to CDs is informative because movements in this spread are unlikely to capture fluctuations in default risk, as these contain negligible default risk. For long-term convenience yields, we use long-maturity AAA corporate bonds as the comparable asset. The RV test favors the monopoly equilibrium in all specifications. 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. For similar reasons, we use the detrended log of real public debt as an independent variable. Our results are invariant to using these measures. 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. Finally, we also compute the RV test using the detrended debt-to-GDP ratio as a measure of the quantities of debt and find similar results to those in the baseline.

Table B.11: US public debt demand estimation: Alternative measures of spreads and debt

VARIABLES	(1) Baseline	(2) Short Mat. (CP)	(3) Short Mat. (CD)	(4) Long Mat.	(5) External Debt	(6) Debt to Trend GDP	(7) Detrended Log of Real Debt
Log(debt/gdp)	-0.16***	-0.15*	-0.36***	-0.19**	-0.47***	-0.18***	-0.22***
	(0.05)	(0.08)	(0.13)	(0.08)	(0.11)	(0.05)	(0.06)
Foreign Volatility Dummy (FVD)	-0.12	-0.08	-0.22	-0.17	0.27	-0.12	0.06**
	(0.09)	(0.13)	(0.25)	(0.14)	(0.22)	(0.09)	(0.03)
FVD × Log(debt/gdp)	-0.18**	-0.10	-0.14	-0.30**	0.05	-0.18**	-0.24**
	(0.08)	(0.12)	(0.20)	(0.13)	(0.07)	(0.08)	(0.09)
Observations	339	339	221	339	319	339	339
Demand elasticity, high foreign vol	1.82	2.15	1.29	1.57	1.49	1.75	1.37
Demand elasticity, low foreign vol	3.78	3.61	1.79	3.98	1.34	3.47	2.86
Markup, high foreign vol	0.55	0.47	0.77	0.64	0.67	0.57	0.73
Markup, low foreign vol	0.26	0.28	0.56	0.25	0.75	0.29	0.35

Notes: The dependent variables are the following: in columns 1, 5, and 6, the weighted average of spreads between corporate and Treasury bond yields, both measured in percentage units; in column 2, the yield spreads between three-month commercial paper and three-month Treasury bills; in column 3, the yield spreads between three-month certificate of deposit and three-month Treasury bills; and in column 4, the yield spreads between long-maturity corporate bonds and Treasury bonds. In columns 1, 2, 3, and 4, we use the log of the ratio of the Treasury debt outstanding to US GDP; in column 5, the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; in column 6, the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering; and in column 7, the linearly time detrended log of real Treasury debt. High foreign volatility dummy is an indicator for whether the residualized 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.12: US public debt demand estimation without rotators: Alternative measures of spreads and debt

VARIABLES	(1) Baseline	(2) Short Mat. (CP)	(3) Short Mat. (CD)	(4) Long Mat.	(5) External Debt	(6) Debt to Trend GDP	(7) Detrended Log of Real Debt
Log(debt/gdp)	-0.24***	-0.19***	-0.42***	-0.31***	-0.42***	-0.25***	-0.30***
	(0.04)	(0.06)	(0.11)	(0.07)	(0.09)	(0.04)	(0.05)
Foreign Volatility Dummy (FVD)	0.06**	0.02	-0.05	0.13***	0.11***	0.06**	0.07**
	(0.03)	(0.04)	(0.07)	(0.04)	(0.04)	(0.03)	(0.03)
Observations	339	339	221	339	319	339	339
Demand elasticity	2.6	2.78	1.55	2.44	1.5	2.5	2.05
Markup	0.38	0.36	0.65	0.41	0.67	0.4	0.49

Notes: The dependent variables are the following: in columns 1, 5, and 6, the weighted average of spreads between corporate and Treasury bond yields, both measured in percentage units; in column 2, the yield spreads between three-month commercial paper and three-month Treasury bills; in column 3, the yield spreads between three-month certificate of deposit and three-month Treasury bills; and in column 4, the yield spreads between long-maturity corporate bonds and Treasury bonds. In columns 1, 2, 3, and 4, we use the log of the ratio of the Treasury debt outstanding to US GDP; in column 5, the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; in column 6, the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering; and in column 7, the linearly time detrended log of real Treasury debt. High foreign volatility dummy is an indicator for whether the residualized 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.13: 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								
	-4.06	-6.23	-7.2	-7.72	-8.03	-8.69	-8.94	-9.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Different Maturity								
Short (Commercial Paper)	-0.89	-2.87	-4.21	-5.14	-5.8	-7.55	-8.33	-8.61
	(0.37)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Short (Certificate of Deposit)	-1.49	-3.31	-4.52	-5.31	-5.84	-7.01	-7.41	-7.54
	(0.13)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Long	-3.79	-7.03	-8.48	-9.06	-9.3	-9.45	-9.37	-9.33
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
c. Different dependent variable								
Debt-to-Trend GDP	-3.94	-6.24	-7.27	-7.81	-8.14	-8.84	-9.1	-9.19
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Detrended Log of Real Debt	-1.51	-4.28	-5.61	-6.33	-6.76	-7.66	-7.99	-8.1
	(0.13)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Detrended Debt-to-GDP	-4.06	-3.99	-3.9	-3.81	-3.72	-3.3	-2.94	-2.77
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.01)

Notes: 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.

Next, we compute the empirical exercises using different controls. Tables B.14 and B.15 show the demand estimation results with and without the demand rotator, respectively, and Table B.16 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 to US Treasuries. Second, we include the BAA-AAA corporate bond spread and the realized aggregate corporate default rate as additional controls, to capture potential fluctuations in the convenience yield driven by default risk. Finally, we estimate the baseline specification excluding the set of additional controls (slope of the yield curve and US volatility). In all these specifications, we find similar results.

Table B.14: US public debt demand estimation: Different controls

VARIABLES	(1) Baseline	(2) Control for Deposits	(3) Control for BAA/AAA spread + Corp default	(4) No controls
Log(debt/gdp)	-0.16***	-0.26***	-0.25***	-0.16***
	(0.05)	(0.05)	(0.06)	(0.06)
Foreign Volatility Dummy (FVD)	-0.12	-0.16*	-0.18*	-0.17*
	(0.09)	(0.08)	(0.09)	(0.10)
FVD $\times$ Log(debt/gdp)	-0.18**	-0.17**	-0.21**	-0.29***
	(0.08)	(0.08)	(0.09)	(0.09)
Observations	339	339	311	339
Demand elasticity, high foreign vol	1.82	1.43	1.37	1.37
Demand elasticity, low foreign vol	3.78	2.38	2.53	3.79
Markup, high foreign vol	0.55	0.7	0.73	0.73
Markup, low foreign vol	0.26	0.42	0.4	0.26

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. High foreign volatility dummy is an indicator for whether the residualized 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 in column 4). 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 3, we include as control the BAA-AAA corporate bond spread and the realized aggregate corporate default rate. 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.15: US public debt demand estimation without rotators: Different controls

VARIABLES	(1) Baseline	(2) Control for Deposits	(3) Control for BAA/AAA spread + Corp. Default	(4) No controls
Log(debt/gdp)	-0.24***	-0.34***	-0.33***	-0.29***
	(0.04)	(0.04)	(0.05)	(0.05)
Foreign Volatility Dummy (FVD)	0.06**	0.01	0.05*	0.12***
	(0.03)	(0.03)	(0.03)	(0.03)
Observations	339	339	311	339
Demand elasticity	2.6	1.82	1.93	2.19
Markup	0.38	0.55	0.52	0.46

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. High foreign volatility dummy is an indicator for whether the residualized 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 in column 4). 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 3, we include as control the BAA-AAA corporate bond spread and the realized aggregate corporate default rate. 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.16: Government conduct test: Different controls

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$	$\lambda = 3$	$\lambda = 4$	$\lambda = 10$	$\lambda = 20$	$\lambda = 30$
a. Baseline								
	-4.06	-6.23	-7.2	-7.72	-8.03	-8.69	-8.94	-9.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Different controls								
Control for Deposits	-3.24	-5.84	-6.99	-7.58	-7.93	-8.67	-8.93	-9.02
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Control for BAA/AAA spread + Corp. Default	-1.87	-4.89	-6.25	-6.95	-7.36	-8.18	-8.46	-8.55
	(0.06)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
No Controls	-1.13	-4.58	-6.24	-7.1	-7.6	-8.57	-8.9	-9.0
	(0.26)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: 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.

Finally, we compute the empirical exercises using different estimation samples and instruments for debt supply changes. Tables B.17 and B.18 show the demand estimation results with and without the demand rotator, respectively, and Table B.19 shows the RV test results. We then redo the demand estimation exercise for four different samples: excluding periods in which the zero lower bound binds; starting after the Second World War (postwar); pre-2008, to exclude the Global Financial Crisis; and starting in 1972, after which external debt issued by the US increased significantly. The main results are robust to using these different sample periods. Additionally, we estimate the demand using alternative instruments for supply: first, we use the military news shock and the dependency ratio as separate instruments, and then 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.[20]

[20] 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.17: US public debt demand estimation: Additional robustness

VARIABLES	(1) Baseline	(2) No ZLB	(3) Post War	(4) Pre GFC	(5) High External Debt	(6) Military	(7) Dependency	(8) BP shock
Log(debt/gdp)	-0.16***	-0.19***	-0.16***	-0.26***	-0.29***	-0.31***	-0.14**	-0.33***
	(0.05)	(0.06)	(0.06)	(0.06)	(0.08)	(0.06)	(0.06)	(0.08)
Foreign Volatility Dummy (FVD)	-0.12	-0.11	-0.15	-0.02	-0.38***	-0.05	-0.12	-0.59***
	(0.09)	(0.11)	(0.10)	(0.13)	(0.13)	(0.16)	(0.09)	(0.19)
FVD $\times$ Log(debt/gdp)	-0.18**	-0.17*	-0.18*	-0.09	-0.28**	-0.09	-0.19**	-0.56***
	(0.08)	(0.10)	(0.09)	(0.11)	(0.11)	(0.14)	(0.09)	(0.18)
Observations	339	310	299	291	192	339	339	339
Demand elasticity, high foreign vol	1.82	1.73	1.84	1.83	1.21	1.58	1.89	0.7
Demand elasticity, low foreign vol	3.78	3.26	3.89	2.45	2.38	2.01	4.5	1.9
Markup, high foreign vol	0.55	0.58	0.54	0.55	0.83	0.63	0.53	1.42
Markup, low foreign vol	0.26	0.31	0.26	0.41	0.42	0.5	0.22	0.53

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. High foreign volatility dummy is an indicator for whether the residualized 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. In column 2, we drop the periods in which the zero lower bound is binding. In columns 3, 4 and 5, we estimate the demand for public debt using, respectively, the post-1945 (postwar) sample, pre-2008 (before the Global Financial Crisis) sample, and post-1972 sample (when external debt is sufficiently high). 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.18: US public debt demand estimation without rotators: Additional robustness

VARIABLES	(1) Baseline	(2) No ZLB	(3) Post War	(4) Pre GFC	(5) High External Debt	(6) Military	(7) Dependency	(8) BP shock
Log(debt/gdp)	-0.24***	-0.25***	-0.23***	-0.28***	-0.43***	-0.33***	-0.23***	-0.17
	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.12)
Foreign Volatility Dummy (FVD)	0.06**	0.08**	0.04	0.07**	-0.06	0.04	0.07**	0.08*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)
Observations	339	310	299	291	192	339	339	339
Demand elasticity	2.6	2.54	2.79	2.26	1.62	1.91	2.72	3.62
Markup	0.38	0.39	0.36	0.44	0.62	0.52	0.37	0.28

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds, both measured in percentage units. High foreign volatility dummy is an indicator for whether the residualized 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. In column 2, we drop the periods in which the zero lower bound is binding. In columns 3, 4 and 5, we estimate the demand for public debt using, respectively, the post-1945 (postwar) sample, pre-2008 (before the Global Financial Crisis) sample, and post-1972 sample (when external debt is sufficiently high). 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.19: 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								
	-4.06	-6.23	-7.2	-7.72	-8.03	-8.69	-8.94	-9.03
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
b. Other time samples								
No ZLB	-4.0	-6.19	-7.15	-7.66	-7.96	-8.61	-8.86	-8.94
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Postwar	-4.02	-6.15	-7.09	-7.59	-7.9	-8.55	-8.8	-8.88
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Pre-GFC	-4.88	-6.66	-7.41	-7.8	-8.04	-8.56	-8.75	-8.82
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
High External Debt	1.79	1.09	0.46	-0.08	-0.51	-1.76	-2.33	-2.52
	(0.07)	(0.27)	(0.65)	(0.94)	(0.61)	(0.08)	(0.02)	(0.01)
c. Different supply instruments								
Military news	-4.93	-7.1	-7.95	-8.37	-8.62	-9.13	-9.32	-9.38
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Δ Dependency ratio	-4.32	-6.48	-7.31	-7.7	-7.93	-8.39	-8.55	-8.6
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
d. Different testing instrument								
UK vol indicator	0.18	-2.15	-3.18	-3.7	-4.0	-4.59	-4.8	-4.87
	(0.86)	(0.03)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

Notes: 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.

B.5 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:

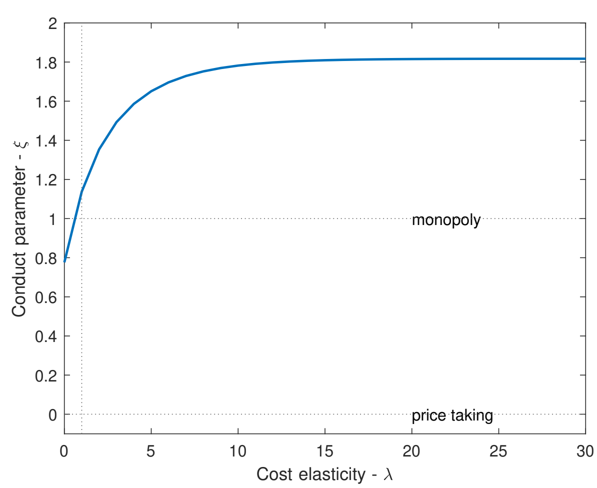
$$\xi = \frac{\mathcal{S}_t - \exp(\omega)\, b^{\lambda}}{\mathcal{S}_t \mu_t}.$$

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 the distribution of 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

$$\xi = \frac{\mathcal{S}_i - \overline{\exp(\omega)} b^{\lambda}}{\mathcal{S}_i \mu_i}, \quad i \in \{H, L\},$$

where $\overline{\exp(\omega)}$ is the mean of $\exp(\omega)$. This gives us two equations and two unknowns, which we can use to solve for ξ and $\overline{\exp(\omega)}$. Figure B.4 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 B.4: Inferring US government conduct



Notes: 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.

C Additional Figures and Tables

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

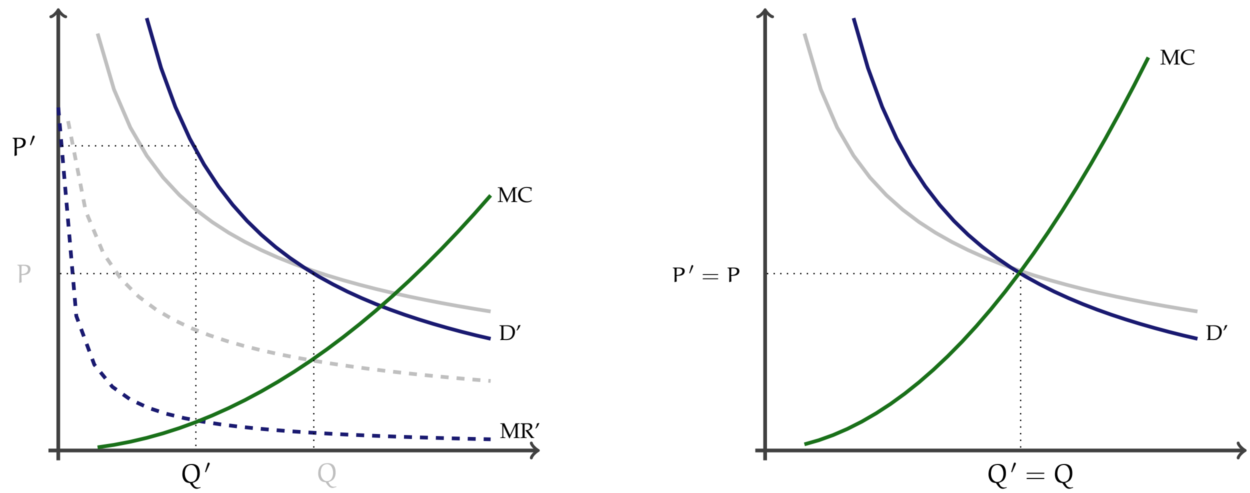
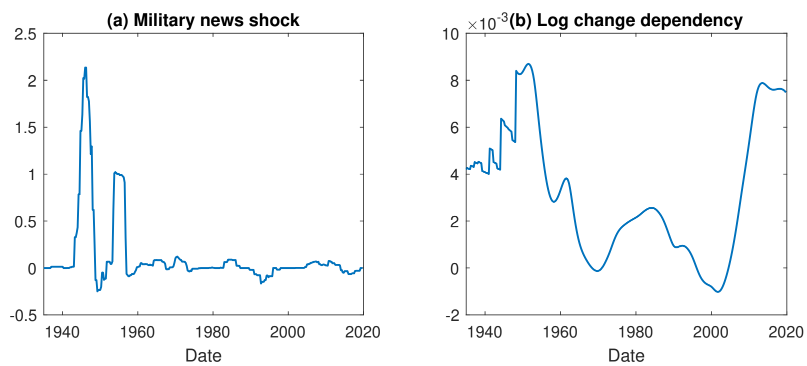


Figure C.2: Evolution of the fiscal supply instruments



Notes: Military news shock is cumulative changes in military spending news scaled by GDP; we accumulate the military news shocks from t-12 to t-24. 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: Debt-to-GDP and Volatility Comovement

	UK volatility	UK vol indicator
Debt to GDP	-0.38	-0.35

Notes: We report correlations in the table. UK volatility is a 1935 to 2019 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 2019 residualized by a measure of US volatility and GDP growth rate. Debt to GDP is the ratio of outstanding Treasury debt to US GDP.

Table C.2: Steady-state comparisons for different demand elasticities

	Total safe assets/GDP	Convenience yield	Interest on Public Debt
Monopoly	0.43	0.61%	0.53%
	$\epsilon_D = 2.2, \lambda = 1$		
Price-taking	0.62	0.53%	0.60%
	$\epsilon_D = 1.5, \lambda = 1$		
Price-taking	0.82	0.38%	0.75%
	$\epsilon_D = 3.2, \lambda = 1$		
Price-taking	0.54	0.56%	0.56%

Notes: Monopoly refers to the baseline monopoly equilibrium in which the US exercises market power. Price-taking refers to the counterfactual equilibrium in which the US acts as a price taker. Epsilon D is the demand elasticity, and lambda is the cost function elasticity.

Table C.3: Welfare comparisons for different demand elasticities

	Price-taking economy	No special role for US debt
	$\epsilon_D = 2.2, \lambda = 1$	
US welfare	-0.08%	-0.22%
RoW welfare	$+0.10\%$	-0.33%
	$\epsilon_D = 1.5, \lambda = 1$	
US welfare	-0.14%	-0.26%
RoW welfare	$+0.20\%$	-0.73%
	$\epsilon_D = 3.2, \lambda = 1$	
US welfare	-0.04%	-0.17%
RoW welfare	$+0.05\%$	-0.20%

Notes: Price-taking economy is an equilibrium in which the US acts as a price taker. No special role for US debt is an economy in which the benefit and cost functions are both 0. Welfare change is expressed in permanent consumption equivalence terms considering the whole transition period starting from the baseline monopoly equilibrium. Epsilon D is the demand elasticity, and lambda is the cost function elasticity.

Table C.4: Steady-state comparisons for different cost elasticities

	Total safe assets/GDP	Convenience yield	Interest on public debt
Monopoly	0.43	0.61%	0.53%
	$\epsilon_D = 2.2, \lambda = 1$		
Price-taking	0.62	0.53%	0.60%
	$\epsilon_D = 2.2, \lambda = 0$		
Price-taking	1.42	0.32%	0.82%
	$\epsilon_D = 2.2, \lambda = 2$		
Price-taking	0.51	0.56%	0.58%

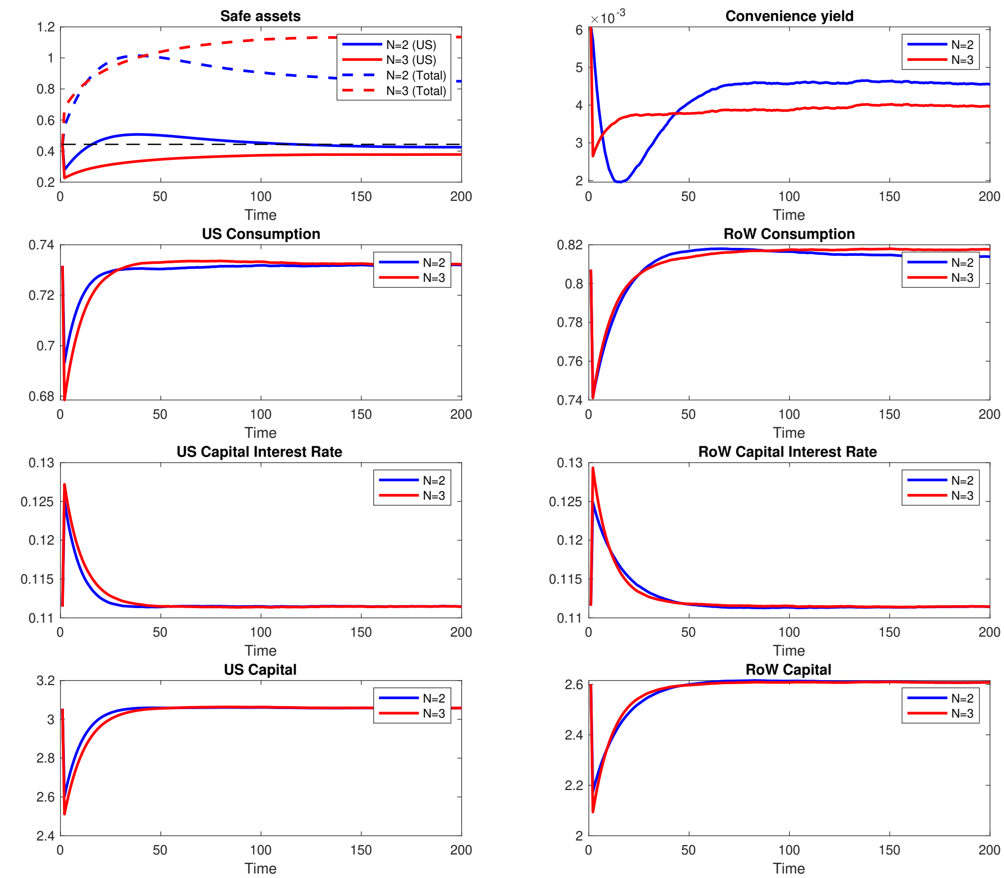
Notes: Monopoly refers to the baseline monopoly equilibrium in which the US exercises market power. Price-taking refers to the counterfactual equilibrium in which the US acts as a price taker. Epsilon D is the demand elasticity, and lambda is the cost function elasticity.

Table C.5: Welfare comparisons for different cost elasticities

	Price-taking economy	No special role for US debt
	$\epsilon_D = 2.2, \lambda = 1$	
US welfare	-0.08%	-0.22%
RoW welfare	$+0.10\%$	-0.33%
	$\epsilon_D = 2.2, \lambda = 0$	
US welfare	-0.18%	-0.31%
RoW welfare	$+0.21\%$	-0.26%
	$\epsilon_D = 2.2, \lambda = 2$	
US welfare	-0.05%	-0.09%
RoW welfare	$+0.06\%$	-0.42%

Notes: Price-taking economy is an equilibrium in which the US acts as a price taker. No special role for US debt is an economy in which the benefit and cost functions are both 0. Welfare change is expressed in permanent consumption equivalence terms considering the whole transition period starting from the baseline monopoly equilibrium. Epsilon D is the demand elasticity, and lambda is the cost function elasticity.

Figure C.3: Cournot transition



Notes: 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.