The Macroeconomic Implications of US Market Power in Safe Assets*

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Abstract

The US government is the dominant supplier of global safe assets and faces a downward sloping demand for its debt. In this paper, we ask if the US exercises its market power when issuing debt and study its macroeconomic consequences. We develop a model of the global economy in which US public debt generates a non-pecuniary value for its holders and analyze the equilibrium in which the US government is the monopoly provider of this safe asset and contrast this with the case in which it acts 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 rejects price-taking behavior in favor of the monopoly one. We then quantify the distortions due to market power and find that it generates a significant under-provision of safe assets, a sizable markup in the convenience yield, and large welfare benefits for the US in detriment of the rest of the world. We also study the implications of increasing competition in safe assets from other sovereigns and private institutions.

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1 Introduction

The last few decades have seen an increasingly large demand for safe assets fueled by the rapid growth of high-saving emerging economies. These safe assets are produced by a small number of advanced economies that have the institutional capability to do so. One consequence of the relatively small number of safe asset issuers is that they have the ability to exert market power. As argued by Farhi and Maggiori (2018), this 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 their safety, liquidity, and collateral properties.

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

We consider a dynamic model of international borrowing and lending with two countries, the US and the rest of the world. In our model, agents can trade two types of safe assets, public debt issued by the US and capital. We enrich this setting with two key features. First, following the recent theoretical literature on the convenience yield, US public debt provides a non-pecuniary benefit to its holders. This benefit can capture a variety of mechanisms studied in the literature, including the expansion in output associated with the ability to use such assets as collateral or the ease in which they can be traded in secondary markets. Due to this non-pecuniary benefit, in equilibrium, the US issues
Motivated by the theoretical predictions, we ask whether the data supports the model with market power, i.e., the one in which the US government acts strategically, over a price-taking benchmark. As is well understood from the industrial organization literature, price and quantity data are insufficient to distinguish between price taking and strategic behavior when marginal costs are unobservable. We use the insight of Bresnahan (1982) to argue that rotations in the demand curve for US treasuries, i.e., changes in demand elasticities can help us test whether price taking or strategic behavior by the US provides a better representation of the data. We follow the firm conduct literature and use the test developed by Rivers and Vuong (2002) to formally test between the price taking and monopoly model. To do so, we enrich the demand structure estimated in prior literature to include a demand rotator. We use a regime indicator of high and low global volatility as our measure of a demand rotator and find that the data rejects price-taking behavior in favor of monopoly model. This is because the monopoly model can better account for increases in the convenience yield during high volatility periods by increases in markups. We also find that the demand curve is relatively inelastic, with average elasticities in line with those in the literature.

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

Our next exercise tries to understand the effects of increasing safe asset competition on the global economy. This is motivated by the recent efforts to create alternative safe assets, both by other governments and the private financial sector. Examples of the former are the
initiatives to create a supra-national 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 et al., 2022). In the latter, this has been achieved through increased securitization (Gorton et al., 2010; Sunderam, 2015). We use our model to assess the macroeconomic impacts of transitioning to an economy in which there is increased competition for safe assets that are substitutable with US government debt. We consider competition from two sources, other sovereigns and the financial sector. We model the former by considering an extension of our model in which \( N \) symmetric countries Cournot compete for the provision of safe assets. Our baseline monopolist model corresponds to case in which \( N = 1 \), and we consider the effects of transitioning to an economy with larger \( N \). An economy with \( N = 2 \) features a global steady-state supply of such assets that is approximately two times larger than the baseline economy with monopoly provision, which implies that the steady state issuance of US debt is roughly unchanged. However, borrowing costs increase and there are significant redistributive effects in terms of welfare. As \( N \) further increases, the aggregate supply of safe assets and the borrowing costs for the US increase further.

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

**Related literature**

Our paper is related to a literature in international finance that studies safe assets and the global economy. Maggiori (2017), Gourinchas et al. (2017), and He et al. (2019) develop macroeconomic theories of the determination of safe assets.\footnote{See Holmstrom and Tirole (1997); Krishnamurthy and Vissing-Jorgensen (2015); Lenel (2017); J Caballero and Farhi (2018); Jiang et al. (2020b); Gorton and Ordonez (2021) for contributions in the closed-economy literature.} A closely related paper is Farhi and Maggiori (2018), which develops a model of the international monetary system. In their model, the shortage in the global supply of safe assets arises due to the presence of market power. Building on their insights, our model features an economy that enjoys market power due to its ability to supply a safe asset which provides a fundamental
non-pecuniary value. We contribute to this literature by providing empirical support for the idea that the US exercises its market power and quantifying the macroeconomic implications of it.

A related literature studies the special role of US public debt and the dollar demand. This literature builds on the work of Krishnamurthy and Vissing-Jorgensen (2012), which documents a downward sloping demand for US Treasuries and the presence of a convenience yield that reflects the additional safety and liquidity attributes of US Treasuries. Subsequent work has studied the implications for the term structure and sustainability of US public debt (Greenwood et al., 2015; Blanchard, 2019; Jiang et al., 2019; Mian et al., 2021), and international safe assets and exchange rates (Du et al., 2018; Krishnamurthy and Lustig, 2019; Koijen and Yogo, 2020; Jiang et al., 2020c; Jiang et al., 2021b). Motivated by these facts, a set of papers develop macroeconomic models to study the global implications of the special role of US debt (e.g., Engel and Wu, 2018; Jiang et al., 2020a, 2021a; Valchev, 2020; Kekre and Lenel, 2021). Our theory shares this idea that US debt generates special benefits to its holders. We contribute to this literature by modeling the behavior of the US government when its debt generates non-pecuniary benefits to holders. Our analysis suggests that these benefits endows the US with market power in safe assets, which accounts for a sizable component of the convenience yield and gives rise to significant under-provision of safe assets. In this sense, our paper quantifies the welfare benefit of the “exorbitant privilege” (Gourinchas and Rey, 2007b,a) that the US enjoys due to its ability to issue large amounts of safe debt at low interest rates.

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

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

A related literature has studied the substitutability of US Treasuries with other near-money assets (see, e.g., Nagel 2016; Krishnamurthy and Li 2022).
2 Model

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

The two countries are denoted by US and RoW. The environment is deterministic, and time is discrete, infinite, and denoted by $t = 0, 1, 2, \ldots$. 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 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 $f_{t+1}(b_{t+1}^*)$ units of the consumption good in period $t+1$, where $f$ is an increasing and concave function. In Appendix B, we show that such a non-pecuniary value can arise due to the ability of US debt to serve as collateral to finance investment projects. An alternative microfoundation that has been studied in monetary theory is one in which these benefits arise due to the favorable liquidity properties of US debt, i.e., the usefulness of US public debt in facilitating transactions (see, for example, Lagos et al., 2017 and references therein).\footnote{In Venkateswaran and Wright, 2014, assets differ in their liquidity due to differences in their ability to serve as collateral.}

The problem for the representative RoW household is

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

subject to

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

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

as well as standard non-negativity constraints. Here $c_t^*$ and $k_{t+1}^*$ denote consumption and capital choices in period $t$, $r_{K,t}^*$ 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 this composite capital good to final goods producers in 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,

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

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

The problem for the final goods producer is

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

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

\[
\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t\geq0}} \sum_{t=0}^{\infty} \beta^t u(c_t)
\]

subject to

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

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

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

where \( K_t \) is generated using a CES technology

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

while the final goods producer solves

\[
\max_{k_t, L_t} A_t K_t^{\alpha} L_t^{1-\alpha} - R_t K_t - w_t L_t.
\]

An allocation is this economy is given by \( x_t = (x_t^*, x_t) \) where

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

and similarly for \( x_t \).

We can now define an equilibrium for this environment.

**Definition 1.** A monopoly equilibrium is an allocation \( \{x_t\}_{t \geq 0} \) and prices \( \{R_t, R_t^*, r_{K,t}, r_{K,t}^*, w_t, w_t^*\} \) 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:

   \[
   b_t = b_t^* ,
   \]

   \[
   k_t = k_{US,t} + k_{US,t}^*,
   \]

   \[
   k_t^* = k_{RW,t} + k_{RW,t}^*,
   \]

   \[
   L_t^* = L_t = 1.
   \]

**2.1 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 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, $S_t \equiv (r_{K,t} - \delta) - r^\text{US}_t$. This model-based definition is consistent with the definition of the convenience yield used in the literature and in the empirical analysis, which is defined to be the spread between US safe corporate debt and US public debt. This is because, in the model, we can interpret the return on capital as the return on safe corporate debt.\(^4\)

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 RoW). Given this change of variable and using the fact that $b_{t-1} = b^*_t$, the problem for the US government can be written as

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

subject to,

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

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 $\chi$. The first order conditions from this imply

$$
S_t (b^*_t) = \chi' (b^*_t) - S'_t (b^*_t) b^*_t.
$$

(1)

An implication of US and RoW capital being perfect substitutes is that $r^*_t = r_{K,t}$ for all $t$. Using this result, one can rewrite the RoW problem using a similar change of variable. The first order conditions from RoW’s problem implies that

$$
S_t (b^*_t) = f'_t (b^*_t).
$$

(2)

Thus, due to 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 spread and debt level in the monopoly equilibrium are

$$
S^\text{ME}_t = \frac{1}{[1 - \mu_t]} \chi' (b^\text{ME}_t)
$$

(3)

\(^4\)Formally, our model is equivalent to one in which firms own the capital stock and borrow from households in order to make investments. In this model the return on firm debt is identical to the return on capital in our model.
and
\[ b_t^{ME} = f^{-1} \left( S_t^{ME} \right). \]  (4)

Since the US is a monopolist, the convenience yield features a *markup* \( \mu_t \) where:
\[ \mu_t \equiv \frac{S_t' \left( b_t^* \right) - \chi_t' \left( b_t^* \right)}{S_t \left( b_t^* \right)} \]
\[ = -\frac{f'' \left( b_t^* \right)}{f' \left( b_t^* \right)} b_t^* \]  (5)

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

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

\[ \max \{c_t, a_{t+1}, b_t\} \sum_{t=0}^{\infty} \beta^t u(c_t) \]

subject to,
\[ c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t + S_t b_t - \chi(b_t) \]

where the US takes the convenience yield as given. It is straightforward to see that the convenience yield in the competitive equilibrium is given by
\[ S_t^{CE} = \chi' \left( b_t^{CE} \right) \]  (6)

where the equilibrium level of debt is
\[ b_t^{CE} = f^{-1} \left( S_t^{CE} \right). \]  (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 if the US behaves strategically. The degree of underprovision then depends crucially on the markup \( \mu_t \). The markup is completely pinned down by the elasticity of demand, \( \mu_t = \varepsilon_{D,t}^{-1} \) where
\[ \varepsilon_{D,t} \equiv \frac{d b_t^*}{d S_t} \frac{S_t}{b_t^*} = -\frac{f' \left( b_t^* \right)}{f'' \left( b_t^* \right) b_t^*}. \]
We summarize the above arguments in the lemma below.

**Lemma 2.** In the model in which US and RW 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 RoW and US capital are no longer perfect substitutes. We show in the appendix that the above analysis continues to hold in the steady state of this model.

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

### 3 Empirical Analysis

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

$$y_t = \alpha + \beta \ln b_t + \gamma (\ln b_t \times z_t) + \delta X_t + \varepsilon_t, \quad (8)$$

where $y_t$ is a measure of the convenience yield, $\ln b_t$ is 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 $\beta + \gamma z_t$. To obtain an estimate of the actual elasticity we take the ratio of semi-elasticity to the average value of $y_t$ in our sample.\(^5\) When $\gamma = 0$ we obtain the same demand specification estimated in the literature. We also assume the following cost function, $\chi_t(b_t) = \omega_t \frac{b_t^\lambda}{1 + \lambda}$, which implies

\(^5\)As an alternative, one could directly measure the demand elasticity by using log of the convenience yield as the dependent variable. We prefer our empirical specification since the observed convenience yield is negative during short windows of time.
that the (log) marginal cost of issuing debt is given by

\[ \ln mc_t = \omega_t + \lambda \ln b_t, \]

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

The data for the demand estimation is gathered at a quarterly level from 1935-2020. 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 short-maturity AAA corporate bonds and US Treasury Bills. The long-term convenience yield is computed as the difference in the yields of long-maturity AAA corporate bonds and US Treasury bonds. Our baseline measure of the convenience yield consists of a weighted average of the short- and long-term convenience yields, with the weights given by the average share of short- and long-term US public debt over the sample period. Our baseline measure of public debt is privately held gross federal debt. In robustness analysis, we also conduct our empirical analysis using short- and long-term convenience yields separately, and externally held public debt. We provide details on the data sources and the construction of these and other variables in Appendix B. Panels (a) and (b) of Figure 1 depict the time series of the convenience yield and the public debt-to-GDP ratio.

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

Notes: Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. Spread is the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. High (low) volatility are periods where the constructed UK volatility measure is above (below) the sample median. The shaded areas correspond to periods of high volatility where for at least one quarter the UK volatility measure is above the sample 75th percentile.

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

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

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

Table 1: Baseline demand estimation

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

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above sample median. The main independent variables of interest is the log of the ratio of the Treasury debt outstanding to US GDP, and its interaction with the volatility dummy Slope is the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield. Extended VIX is a 1935 to 2020 historical predicted series of VIX by regressing VIX on annualized standard deviation of weekly log stock returns on the S&P 500 index from 1990 to 2020. The estimation method is OLS for columns 1 and 3, and IV for columns 3 and 4. 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.

The OLS estimates of β and γ are both negative and statistically significant. The point
estimates imply that a 10% increase in the supply of government debt leads to a decrease in the convenience yield of 20 bps in low-volatility periods and 59 bps in high-volatility periods. Given that the sample average for the convenience yield is 64 bps, the implied demand elasticities are $\varepsilon_L = (0.2/0.64)^{-1} = 3.18$ and $\varepsilon_H = (0.59/0.64)^{-1} = 1.07$ during low and high volatility periods, respectively (see the last rows of Table 1). In other words, the demand curve is more inelastic in periods of high volatility. This can be visually seen in Figure 2 that shows the convenience yields and debt levels for high and low volatility episodes. Column (2) reports the IV estimates that uses both instruments simultaneously. In this specification the point estimates for $\beta$ and $\gamma$ are also negative and significant, and imply demand elasticities of 4.66 and 1.73 during low and high volatility periods. The fact that the OLS estimate is similar to the IV estimates suggests that most of the variation in the debt-to-GDP ratio can be attributed to supply shocks. In Appendix C, we report the output of the first-stage regressions, which estimate the log of public debt on each of the instruments and the set of controls used in the main regressions. The last two columns of Table 1 reports the estimates of the demand specification when we drop the demand rotator. The average estimated elasticities are 1.59 and 2.84 in the OLS and IV specifications, respectively, which are within the range of the estimates in prior literature (see, e.g., Krishnamurthy and Vissing-Jorgensen (2012); Greenwood et al. (2015); Jiang et al. (2021b); Mian et al. (2021); Krishnamurthy and Li (2022)). We will use an average of these point estimates (2.2) in the quantitative analysis of our model.

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

Notes: Spread is the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. Debt/GDP is the ratio of the Treasury debt outstanding to US GDP. High (low) volatility are periods where the constructed UK volatility measure is above (below) the sample median.
We now test the validity of the competitive and monopoly models by comparing their relative fit of the data. Formally, we use a model selection test to distinguish between these two models. We build on the literature in industrial organization that uses the model selection test in Rivers and Vuong (2002) (RV) to test between different models of firm conduct (Backus et al., 2021; Duarte et al., 2021). Under our structural model and the assumed parametric cost function, we can use equations (3) and (6) to express the log of innovations to the marginal costs as

$$\ln \omega_t = \ln S_t - \xi \ln \mu_t - \lambda \ln b_t,$$

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

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

where $T$ is the total number of periods in our sample, and $\omega_t$ is obtained from (9) using observed data for $S_t$ and $b_t$, and estimated data for $\mu_t$. Given this measure, the RV test statistic is

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

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

We implement this test in our framework, where $Q_1$ is the lack of fit for the price-taking model and $Q_2$ the equivalent for the monopoly model, for different values of $\lambda$, the elasticity of the marginal cost function. In Table 2, we display the test statistics for our baseline model and different values of the elasticity of the cost function, $\lambda$. 
Table 2: Conduct tests for different cost elasticities

<table>
<thead>
<tr>
<th>Cost elasticity</th>
<th>$\lambda = 0$</th>
<th>$\lambda = 1$</th>
<th>$\lambda = 2$</th>
<th>$\lambda = 3$</th>
<th>$\lambda = 4$</th>
<th>$\lambda = 10$</th>
<th>$\lambda = 20$</th>
<th>$\lambda = 30$</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{a. OLS}</td>
<td>3.47</td>
<td>-1.11</td>
<td>-4.72</td>
<td>-6.45</td>
<td>-7.25</td>
<td>-8.23</td>
<td>-8.4</td>
<td>-8.44</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.27)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
</tbody>
</table>

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

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

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

The effects of simultaneous demand shifts and rotations. One potential source of concern is that high volatility regimes are also associated with shifts in the demand in addition to rotations. Indeed, our demand estimation results suggest that this is the case, since the estimated partial derivative of the convenience yield with respect to the volatility measure is positive (see Table 1). Recall that our methodology to differentiate between the two models relied on rotations in the demand curve changing prices and quantities if the US acts strategically, but not when it acts as a price taker. If rotations are also accompanied by shifts in demand then prices and quantities can change even in the price taking model. Under the price-taking model, both prices and quantities should increase in high volatility periods in response to the demand shifting outwards (see Figure C.5). However, as Figure
shows, high volatility periods are associated with high prices and low debt levels. For instance, debt-to-GDP ratios were particularly low during high volatility periods like the 1970s oil crisis and the early 2000s dotcom crisis. These observed dynamics of debt prices and quantities makes it even more challenging for the price taking model to explain the data in the presence of demand shifts. This is also reflected in the results of the RV test, which uses information on both prices and quantities, and favors the monopoly model for any elasticity of the cost function, $\lambda$. It is worth noting, however, that the opposing movement in prices and quantities is not necessary to reject price taking behavior in the presence of demand shifts. As suggested by equation (9), even if prices and quantities increase in high volatility periods, the test could favor the monopoly model if the increase in prices is more than that predicted by a movement along the marginal cost curve.

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

Robustness analysis. The empirical results are robust to other choices for the demand rotator (see Appendix B for details about these exercises). First, we estimate the demand for public debt and the conduct test using a rotator of volatility regimes using a volatility measure based on the VIX. Second, we consider a rotator based on the volatility of the Hong Kong stock market index. Finally, we consider alternate constructions of the baseline UK based volatility measure. In particular, we use a regime indicator based on a standard deviation of the UK MSCI returns computed over a 6-months and 2-years rolling windows (instead of the one-year rolling window used in the baseline), and also consider a regime indicator in which high volatility periods correspond to those in which the standard deviation of the MSCI UK is greater than its 66th and 75th percentiles (instead of the sample median). Table B.4 shows the demand estimates, which imply a more inelastic demand in periods of high volatility in all these different specifications. Table B.5 shows the test statistics, which reject price taking in favor of monopoly behavior.

The empirical results are also robust to how we measure the convenience yield and public debt, to the time sample used in the estimation, as well as to using alternative instruments for the supply of public debt. Tables B.6, B.7, B.9, and B.10 report the demand estimates with and without the demand rotator, while Tables B.8 and B.11 report the
corresponding test statistics. For the convenience yield, we use the short and long-
term convenience yields as dependent variables. For public debt, we also consider using
the ratio of debt to trend-GDP—to avoid capturing movements driven by actual GDP—as
well as external debt as a dependent variable. For the time sample, we consider a post-
war sample as well as a sample that excludes periods in which the zero lower bound
binds. As an alternative instrument, we use a measure of government expenditure shocks
developed by Blanchard and Perotti (2002). This measure consists of the component of
current government spending that is not explained by a set of controls, which include
lagged values of taxes, output and government spending (see Appendix B for further
details). We also consider using the military news and dependency ratio instruments
separately. We also pursue the empirical exercises excluding the set of controls. The
demand estimates are fairly stable across these specifications and imply more inelastic
demand in periods of high volatility. Moreover, 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 quite inelastic. As we will see in the next section, this implies
sizable distortions due to market power.

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
($\mu$). Note that this analysis only requires the estimate of the elasticity of demand and is
independent of the remaining parameters of the model. Recall that the markup is just the
inverse of the elasticity of demand, which in our sample is 2.2. Thus the markup accounts
for approximately 45% of the convenience yield. Given an average convenience yield of
68 basis points, the markup is significant and equals 30 basis points. This is in contrast to
the price taking equilibrium in which the markup is zero.

To further understand the economic implications due to this market power, we calibrate
our model. The model is calibrated at an annual frequency. The 4 externally calibrated
parameters are described in Table 3. We assume a utility function of the form $u(c) =$
\( c^{1-\gamma}/(1-\gamma) \), a benefit function of the form \( f(b) = \nu b^{\eta}/\eta \), and a cost function of the form \( \chi(b) = \omega b^{1+\lambda}/(1+\lambda) \). The cost function is the same as the one used in the previous section. For parameters on preferences and technologies, we use standard values in the business-cycle literature: a coefficient of relative risk aversion of \( \gamma = 2 \), a capital share of \( \alpha = 0.3 \), and a depreciation rate of \( \delta = 0.1 \). We follow Barro (1979) and Jiang et al. (2022) and assume that \( \lambda = 1 \) in our baseline calibration but also consider robustness to different values.

Table 3: Externally calibrated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma )</td>
<td>2</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0.3</td>
</tr>
<tr>
<td>( \delta )</td>
<td>0.1</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>1</td>
</tr>
</tbody>
</table>

The 8 internally calibrated parameters are described in Table 4 and are chosen to match 8 moments in steady state. The discount factor \( \beta \) and the parameters associated with the benefits and cost of issuing debt, \( \nu \) and \( \omega \), are calibrated to match the average convenience yield, the interest rate on US debt and its debt position. In particular, \( \beta \) is determined using the average convenience yield, the US interest rate, and the steady state model equation \( \beta^{-1} = r^K - \delta \) which implies that

\[
\beta^{-1} = S + r^{US}
\]

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

\[
S = \nu b^{\eta-1}
\]

and

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

Using the average convenience yield, the average debt-to-GDP ratio of 0.39, and our empirical estimate of \( \eta \), we can obtain \( \nu \) from the first equation. Next, we obtain \( \omega \) from the second equation. The remaining parameters, which are related to the capital share and productivity levels target moments associated with the external balance sheet of the US, and the relative sizes of the two economies. In particular, the share parameter \( \sigma \) 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 $\sigma^*$ is calibrated to match the average NFA of the US in the data. We calibrate US TFP so that US GDP is normalized to 1 and the TFP of RoW, so that the steady state model ratio of US GDP to RoW GDP is equal to that in the data. Here the GDP of RoW corresponds to the GDP of EU and China during the sample period.

Table 4: Internally calibrated parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.98</td>
<td>Discount rate</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.0045</td>
<td>Benefit parameter</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.0096</td>
<td>Cost parameter</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.92</td>
<td>US own capital share</td>
</tr>
<tr>
<td>$\sigma^*$</td>
<td>0.79</td>
<td>RW own capital share</td>
</tr>
<tr>
<td>$A$</td>
<td>0.82</td>
<td>US productivity</td>
</tr>
<tr>
<td>$A^*$</td>
<td>0.94</td>
<td>RW productivity</td>
</tr>
</tbody>
</table>

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

Table 5: Macroeconomic distortions due to market power

<table>
<thead>
<tr>
<th></th>
<th>ME</th>
<th>CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total safe assets/GDP</td>
<td>0.39</td>
<td>0.59</td>
</tr>
<tr>
<td>Convenience yield</td>
<td>0.68%</td>
<td>0.57%</td>
</tr>
<tr>
<td>Interest on public debt</td>
<td>0.97%</td>
<td>1.09%</td>
</tr>
</tbody>
</table>

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

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

Table 6: Welfare implications of market power in safe assets

<table>
<thead>
<tr>
<th></th>
<th>No special role</th>
<th>CE with special role</th>
</tr>
</thead>
<tbody>
<tr>
<td>US welfare</td>
<td>−0.21%</td>
<td>−0.08%</td>
</tr>
<tr>
<td>RW welfare</td>
<td>−0.34%</td>
<td>+0.10%</td>
</tr>
</tbody>
</table>

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

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

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 size of the RoW and the total suppliers of the safe asset constant and equal to that 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

\[
\max_{\{c_t, k_{t+1}, b_{t+1}\}_{t,t' \geq 0}} \sum_{t=0}^{\infty} \beta^t u(c_t)
\]

subject to

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

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

Here, the markup as well as the level of safe asset provision depends 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

\[
S_{CN}^t = \frac{1}{[1 - \mu_t^{CN}]} \chi' \left( \frac{b_t^{CN}}{N} \right)
\]

and

\[
b_t^{CN} = f^{-1} \left( S_{CN}^t \right).
\]

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

All proofs are included in the Appendix. 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 \( b_{CN}^N/N \). 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 increase, the additional effect on competition is smaller and the latter effect dominates.

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

In Figure 3 we plot the transition path for the quantity of safe assets and US consumption. Table 7 documents the change in convenience yields, interest rates and welfare changes as a consequence of this transition. In Appendix C (Figure C.6), we plot the transition path for other variables, including RoW consumption. We observe a significant increase in the equilibrium quantity of safe assets and decrease in spreads. Note that equilibrium quantity of safe assets is larger than the case in which the US acts as a price taker due to the assumption of increasing marginal costs. As more countries contribute to the provision of safe assets the marginal cost for each country decreases which results in a larger aggregate quantity.

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

Figure 3: Transition path due to increased competition

![Figure 3: Transition path due to increased competition](image)

Notes: US indicates safe asset produced by US only, while total includes safe assets produced by all Cournot competitors in the economy.
Table 7: The effects of increasing competition

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

Notes: Panel A shows steady state values of key macroeconomic variables for various equilibria. Panel B shows welfare change expressed in permanent consumption equivalence terms. The first two rows indicate the welfare change if the economy instantaneously jumped to the new competitive steady state. The last two rows consider the transition period.

4.1.2 Competition from financial intermediaries

Unlike sovereigns we model financial intermediaries as a competitive fringe. These intermediaries are owned by households. Using a similar argument to the one 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

$$c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t + S_t(b_t) b_t - \chi_F(b_t).$$

where $\chi_F$ is cost of issuing safe assets for the intermediary. An important assumption is whether these intermediaries/households correspond to ones from a third country or the US. In the former case, the US government will be in direct competition with these intermediaries while in the latter, the US government would like to consolidate market power. First consider the case in which the households reside in a third country. The
Ramsey problem for the US government is

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

subject to

$$c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t + S_t (b_t + b_f^f(b_t)) b_t - \chi (b_t)$$

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

$$S_t (b_t + b_f^f(b_t)) = \chi' (b_f^f(b_t)). \quad (12)$$

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

$$S_t (b_t + b_f^f(b_t)) = f' (b_t + b_f^f(b_t)). \quad (13)$$

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

$$S_t^f = \frac{1}{[1 - \mu_t(b_t, b_f^f)]} \chi' (b_t), \quad (14)$$

$$b_t + b_f^f = f^{-1} (S_t^f), \quad (15)$$

and

$$b_f^f = \chi_f^{-1} (S_t^f) \quad (16)$$

where the markup

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

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

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

$$\max_{\{c_t, a_{t+1}, b_t, b_f\}_{t=0}^{\infty}} \beta^t u(c_t)$$
subject to
\[
c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t \\
+ S_t (b_t + b_t^f (b_t)) b_t - \chi (b_t) + S_t (b_t + b_t^f (b_t)) b_t^f - \chi_f (b_t^f)
\]
and where as before
\[
S_t (b_t + b_t^f (b_t)) = f' (b_t + b_t^f (b_t)).
\]

Lemma 6. When there is competition from a domestic fringe, the equilibrium spread and quantities of safe assets \((b_t, b_t^f)\) are given by equations in Lemma 5 except that
\[
\mu_t (b_t, b_t^f) = \left( \left( 1 - \frac{f'' (b_t + b_t^f (b_t))}{\chi''_f (b_t^f (b_t))} \right) \varepsilon_{D,t} \right)^{-1}.
\]

When compared with the case when foreign intermediaries we can see that the markup is larger and the equilibrium quantity of debt is smaller. The reason for less competition in the case of the domestic fringe relative to the foreign fringe is that the US government directly cares about the profits of the fringe since they are owned by households. Thus, the US maximizes the joint profits of the government and fringe which implies that the outcomes are closer to monopoly case relative when the fringe is owned by foreign households.

We now consider the transition from our initial monopoly steady state to the steady state with the fringe in our quantitative model. Table 7 highlights they 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 to the US in the domestic fringe case is significantly lower relative to the other cases owing to the fact that the benefits from the fringe are also internalized by the US.

5 Conclusion

In this paper, we find empirical support for the idea that the US government behaves strategically and exploits its market power when issuing debt, as emphasized by Farhi and Maggiori (2018). We quantify the distortions due to this power and find that they are sizable, and give rise to a significant under-provision of global safe assets. This provides one interpretation of the “shortage” of safe assets highlighted by academics and policy-makers.

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

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A Theoretical Appendix

Consider the model in which US and RoW capital are imperfect substitutes in the aggregate capital technology. We show that the results in Section 2.1 continue to hold in the steady state of this model.

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

\[ f'(b_{ME}) = \chi'(b_{ME}) - f''(b_{ME}) b_{ME} \]

and the convenience yield is given by

\[ S_{ME} = \chi'(b_{ME}) - f''(b_{ME}) b_{ME}. \]

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

\[ f'(b_{CE}) = \chi'(b_{CE}) \]

and the convenience yield is given by

\[ S_{CE} = \chi'(b_{CE}). \]

Therefore, \( b_{ME} < b_{CE} \) and \( S_{ME} > S_{CE} \).

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

A.1 Microfoundation for the benefit and cost functions

We now derive the benefit and cost functions from a more primitive environment. Alternative microfoundations 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).

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

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

subject to

\[ c_t + k_{t+1} = w_t l_t + (1 - \delta + r_{K_t}) k_t - T_t \]
where $T_t$ is the total tax burden on private agents. The capital and final goods producers are identical to those described in the main text. We assume that the US government can issue debt and uses taxes to pay back its debt. We assume that taxation is distortionary and results in a resource cost $\chi(\cdot)$. We also assume that existing debt and interest payments must be paid back before new debt can be issued. These assumptions imply that

$$T_t = (1 + r_t^{US}) b_t + \chi ((1 + r_t^{US}) b_t) - b_{t+1}$$

The equations characterizing the equilibrium given these taxes are

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

and

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

Thus we can write the Ramsey problem as

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

subject to

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

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

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

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

subject to

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

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

Next, consider RW. As before assume RW 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 which need to be collateralized by safe assets. Thus, the amount that households can borrow in period $t$ is given by

$$x_t \leq b_t.$$  

The problem for the household in RW is

$$\max \left\{ c_t, l_t, k_t+1, b_t+1 \right\} \beta^t u(c^*_t)$$

subject to

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

$$x_t \leq b_t$$  

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

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

A.2 Proofs from Section 4.1

Proof of Lemma 3

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

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

subject to

$$c_t + a_{t+1} = w_t l_t + (1 - \delta + r_{K,t}) a_t + S_t (b_t + B_t) b_t - \chi(b_t).$$

The first order condition for the US is

$$S_t (b_t + B_t) = \chi'(b_t) - S'_t (b_t + B_t) b_t.$$  

Thus, in any symmetric equilibrium we have

$$S_t (b_t^{CN}) = f'(b_t^{CN})$$.
and
\[ S_t \left( b_t^{CN} \right) = \chi' \left( \frac{b_t^{CN}}{N} \right) - f''(b_t^{CN}) \frac{b_t^{CN}}{N}. \]

Therefore,
\[ S_t \left( b_t^{CN} \right) = \frac{1}{1 - \mu_t^{CN}} \chi \left( \frac{b_t^{CN}}{N} \right) \]
where \( \mu_t^{CN} = (N\varepsilon_{D,t})^{-1} \). Q.E.D.

**Proof of Lemma 4**

From the proof of Lemma 3
\[ \chi'(\frac{b}{N}) - \frac{1}{N} f''(b) b = f'(b) \]

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

Suppose that \( f = \eta f b^n/\eta \). Then,
\[ z'(N) = z \frac{(2 - \eta) \frac{1}{N} - 1}{\left[ - \frac{c''(z)}{f''(Nz)} + N + \eta - 1 \right]} . \]

Note that for \( N \geq 1 \) the denominator is positive. Thus the sign depends on \( 2 - \eta - N \). Thus as \( N \) increases from 1 to 2 US safe asset provision increases while as \( N \) increases beyond 2, US safe asset provision is decreasing in \( N \). Q.E.D.

**Proof of Lemma 5**

**Proof.** The first order condition for the US is
\[ S_t' \left( b_t + f_t' \left( b_t \right) \right) \left[ 1 + f_t'' \left( b_t \right) \right] b_t + S_t \left( b_t + f_t' \left( b_t \right) \right) - \chi' \left( b_t \right) = 0 \] (17)
Using the (12) we have

\[ S_t' (b_t + b_t^f (b_t)) \left[ 1 + b_t^{f'} (b_t) \right] = \chi_t'' (b_t^f (b_t)) \ b_t' (b_t) \]

and so

\[ b_t^{f'} (b_t) = \frac{S_t' (b_t + b_t^f (b_t))}{\chi_t'' (b_t^f (b_t)) - S_t' (b_t + b_t^f (b_t))}. \]

Next, using (13) we have \( S_t' (b_t + b_t^f (b_t)) = f'' (b_t + b_t^f (b_t)) \) and so inserting this into the previous equation yields

\[ b_t^{f'} (b_t) = \frac{f'' (b_t + b_t^f (b_t))}{\chi_t'' (b_t^f (b_t)) - f'' (b_t + b_t^f (b_t))}. \]

Substituting the above into (17) yields

\[
\left[ 1 - \varepsilon^{-1} \frac{\chi_t'' (b_t^f (b_t))}{\chi_t'' (b_t^f (b_t)) - f'' (b_t + b_t^f (b_t))} \right] \frac{b_t}{b_t + b_t^f (b_t)} S_t (b_t + b_t^f (b_t)) - \chi' (b_t) = 0
\]

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

**Proof of Lemma 6**

The first order condition for the US is

\[ S_t' (b_t + b_t^f (b_t)) \left[ 1 + b_t^{f'} (b_t) \right] (b_t + b_t^f) + S_t (b_t + b_t^f (b_t)) - \chi' (b_t) = 0 \quad (18) \]

Using (12) and (13) we have

\[ b_t^{f'} (b_t) = \frac{f'' (b_t + b_t^f (b_t))}{\chi_t'' (b_t^f (b_t)) - f'' (b_t + b_t^f (b_t))}. \]

Substituting the above into (18) yields

\[
\left[ 1 - \varepsilon_{D,t}^{-1} \frac{\chi_t'' (b_t^f (b_t))}{\chi_t'' (b_t^f (b_t)) - f'' (b_t + b_t^f (b_t))} \right] S_t (b_t + b_t^f (b_t)) - \chi' (b_t) = 0
\]

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

B.1 Data description

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

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


- **CP-Bills**: The percentage yield spread between high-grade commercial paper and Treasury bills. For commercial paper rates, we use “3-month AA nonfinancial commercial paper rate” for 1997-2020, and “average of offering rates on 3-month commercial paper placed by several leading dealers for firms whose bond rating is AA or equivalent” for 1971-1996. For 1935-1970, we use prime commercial paper, 4-6 month maturity, from Banking and Monetary Statistics. The Treasury bill rates are 3-month Treasury bills for 1971-2020 and 6-month Treasury bills for 1959-1970 from FRED. For 1935-1958, we use 3-6 month Treasury bills from NBER Macro History database.

- **Maturity-weighted convenience yield**: Our baseline measure of 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 3 years, and long term to be those with maturities longer than 3 years. We obtain US Treasury auction data from the US Treasury from 1980 to 2020 to construct a time series of the maturity composition of outstanding US Treasuries. Specifically, we add newly issued Treasuries, drop matured Treasuries, and keep track of maturities of still outstanding debt. Given the stability of the maturity share within this timeframe, we take the average of the weights to get a short term weight of 0.6 and long term weight of 0.4.
• **Demand rotator based on UK volatility.** The demand rotator is an indicator variable that equals one if the UK volatility index is greater than its sample median, and zero otherwise. The UK volatility index is the standard deviation, computed over a yearly rolling window, of weekly returns of the MSCI UK stock market index. Since this index is only available starting in 1972, we use a projection based on the yearly-rolling-window standard deviation of monthly returns of the UK share price index for the earlier part of the sample. The MCSI UK index was obtained from Bloomberg and the monthly share price index from FRED. Table B.1 reports the regression estimates used for the projection. The R-squared of the regression is 0.68.

• **Slope:** The slope of the Treasury yield curve is the different between the 10-year Treasury yield and the 3-month Treasury yield. The yield on 10-year interest rates from 1953-2020 is from FRED, while the yields from 1935-1952 is from the NBER Macro History Database.

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

• **Dependency ratio:** Total population in the US aged 65+ divided by population between ages 15-65. Data from Current Population Survey, Bureau of Labor Statistics.

• **Military news shocks:** We directly use the series constructed by Valerie Ramey ([Ramey (2011), Ramey and Zubairy (2018)]) of news in changes in military spending. We scale this by nominal GDP and create a cumulative series. Since news about military expenditures are often announced ahead of the time in which expenditures actually take place, 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

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

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

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

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

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

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

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

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

\[
g_t = \beta_0 + \sum_{s=1}^{4} \beta_s X_{t-s} + \varepsilon_{t}^{BP}
\]

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

- **External public debt**: Foreign holdings of US Treasuries expressed as a share of annual GDP. The data is from the US Treasury’s “Treasury International Capital (TIC)” database. The data is available starting in 1939.
Table B.1: Volatility measure construction

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>MSCI UK Volatility</th>
<th>VIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK Share Price Volatility</td>
<td>1.00***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td></td>
</tr>
<tr>
<td>S&amp;P500 Volatility</td>
<td>364.42***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(18.86)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-0.01***</td>
<td>8.34***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.66)</td>
</tr>
<tr>
<td>Observations</td>
<td>177</td>
<td>124</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.68</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are annualized rolling 4 quarter standard deviation of weekly log stock returns on the MSCI UK index from 1972 to 2020; and VIX, CBOE Volatility Index from 1990 to 2020. Independent variables are annualized rolling 4 quarter standard deviation of monthly log stock returns on the UK share price index; and annualized standard deviation of weekly log stock returns on the S&P 500 index. Market cap weighted UK share price index was obtained from FRED. Value-weighted S&P index was obtained from CRSP. Standard errors are in parentheses. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

B.2 Validity of the demand rotator and supply instruments

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

Table B.2: Demand rotator correlations

<table>
<thead>
<tr>
<th></th>
<th>Gov. spending growth</th>
<th>Corporate tax rate</th>
<th>Highest ind. tax rate</th>
<th>Blanchard-Perotti shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended UK vol</td>
<td>0.06</td>
<td>0.21</td>
<td>0.20</td>
<td>0.03</td>
</tr>
<tr>
<td>Extended UK vol, binned</td>
<td>0.07</td>
<td>0.20</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Extended VIX</td>
<td>0.13</td>
<td>-0.16</td>
<td>-0.19</td>
<td>-0.16</td>
</tr>
<tr>
<td>Extended VIX, binned</td>
<td>0.10</td>
<td>-0.10</td>
<td>-0.17</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th></th>
<th>Extended UK vol</th>
<th>VIX</th>
<th>GDP growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependency</td>
<td>-0.12</td>
<td>-0.08</td>
<td>-0.01</td>
</tr>
<tr>
<td>Military news</td>
<td>-0.21</td>
<td>-0.24</td>
<td>-0.04</td>
</tr>
<tr>
<td>Blanchard-Perotti</td>
<td>0.03</td>
<td>-0.06</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

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

B.3 Additional Empirical Results

In this section we conduct a set of additional exercises that illustrate the robustness of our main empirical results. 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 quite inelastic, with point estimates for the elasticity that are in the range of those estimated in prior literature.

To begin, we consider the effects of using alternative demand rotators. Table B.4 shows the demand estimation results using the instrumental variables approach, and Table B.5 shows the RV test results. The first alternate rotator is a regime indicator that equals one when a US volatility index is greater than the sample median, and zero otherwise. The US volatility index is computed as the yearly moving average of the extended VIX (see Appendix B for details on how we compute the extended VIX). Second, we consider a regime indicator based on the yearly standard deviation of the Hong Kong stock market index (HangSeng index) weekly returns. This variable is only available starting in 1970, so the estimation sample for this exercise is shorter than the baseline. Third, we consider using the 66th and 75th percentile cutoffs for our baseline rotator—instead of the sample median—above which the regime indicator of high volatility is one. Finally, we also consider using a regime indicator variable based on the standard deviation of UK stock returns using a 2-year 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 differences in elasticities is statistically significant. The RV test favors the monopoly equilibrium for all specifications, and almost all cost elasticities. Figure C.4 shows the estimated innovations.
to marginal cost under both the price-taking and monopoly model for the first alternate rotator (extended VIX) and we see much the same patterns as in the baseline.

Table B.4: US public debt demand estimation: Alternative rotators

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Baseline</th>
<th>(2) Extended VIX, MA</th>
<th>(3) Hangseng 66th bin</th>
<th>(4) 75th bin 66th quarters</th>
<th>(5) 75th bin 75th quarters</th>
<th>(6) UK, 2 quarters</th>
<th>(7) UK, 8 quarters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(debt/gdp)</td>
<td>-0.13**</td>
<td>-0.13**</td>
<td>-0.29***</td>
<td>-0.18***</td>
<td>-0.21***</td>
<td>-0.19***</td>
<td>-0.14**</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>High Volatility Dummy</td>
<td>-0.14</td>
<td>-0.09</td>
<td>-0.30*</td>
<td>-0.21</td>
<td>-0.15</td>
<td>-0.01</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.09)</td>
<td>(0.17)</td>
<td>(0.13)</td>
<td>(0.16)</td>
<td>(0.10)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>High Vol Dummy × Log(debt/gdp)</td>
<td>-0.23**</td>
<td>-0.26***</td>
<td>-0.24</td>
<td>-0.25**</td>
<td>-0.21</td>
<td>-0.10</td>
<td>-0.21**</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.09)</td>
<td>(0.14)</td>
<td>(0.11)</td>
<td>(0.13)</td>
<td>(0.09)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Demand elasticity, high vol</td>
<td>1.73</td>
<td>1.58</td>
<td>1.34</td>
<td>1.46</td>
<td>1.48</td>
<td>2.14</td>
<td>1.78</td>
</tr>
<tr>
<td>Demand elasticity, low vol</td>
<td>4.66</td>
<td>4.75</td>
<td>2.43</td>
<td>3.49</td>
<td>2.94</td>
<td>3.25</td>
<td>4.56</td>
</tr>
<tr>
<td>Markup, high vol</td>
<td>0.58</td>
<td>0.63</td>
<td>0.75</td>
<td>0.68</td>
<td>0.68</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>Markup, low vol</td>
<td>0.21</td>
<td>0.21</td>
<td>0.41</td>
<td>0.29</td>
<td>0.34</td>
<td>0.31</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. The columns correspond to different measures of the Volatility dummy indicator: (1) Whether the constructed UK volatility measure is above sample median; (2) Whether the yearly moving average of Extended VIX is above sample median; (3) Whether the yearly rolling standard deviation of annualized weekly log stock returns on the Hangseng index is above sample median; (4) Whether the constructed UK volatility measure is above sample 66th percentile; (5) Whether the constructed UK volatility measure is above sample 75th percentile; (6) Whether the 2 quarter rolling standard deviation of annualized weekly log stock returns on the MSCI UK index, extended by projected on the 2 quarter rolling standard deviation of annualized monthly log stock returns on the UK share price index, is above sample median; (7) Whether the 8 quarter rolling standard deviation of annualized weekly log stock returns on the MSCI UK index, extended by projected on the 8 quarter rolling standard deviation of annualized monthly log stock returns on the UK share price index, is above sample median. The main independent variables of interest is the log of the ratio of the Treasury debt outstanding to US GDP, and its interaction with the volatility dummy. Controls include the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield and Extended VIX (aside from column 2). The estimation method is 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.5: Government conduct test: Alternative rotators

<table>
<thead>
<tr>
<th>Cost elasticity</th>
<th>$\lambda = 0$</th>
<th>$\lambda = 1$</th>
<th>$\lambda = 2$</th>
<th>$\lambda = 3$</th>
<th>$\lambda = 4$</th>
<th>$\lambda = 10$</th>
<th>$\lambda = 20$</th>
<th>$\lambda = 30$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>b. Alternative rotators</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended VIX, MA</td>
<td>1.12</td>
<td>-0.4</td>
<td>-1.03</td>
<td>-1.34</td>
<td>-1.53</td>
<td>-1.9</td>
<td>-2.04</td>
<td>-2.09</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.69)</td>
<td>(0.3)</td>
<td>(0.18)</td>
<td>(0.13)</td>
<td>(0.06)</td>
<td>(0.04)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Hangseng</td>
<td>-0.21</td>
<td>-2.95</td>
<td>-4.06</td>
<td>-4.58</td>
<td>-4.87</td>
<td>-5.42</td>
<td>-5.6</td>
<td>-5.66</td>
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<tr>
<td></td>
<td>(0.83)</td>
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<td>(0.0)</td>
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<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>66th bin</td>
<td>-2.8</td>
<td>-5.63</td>
<td>-6.69</td>
<td>-7.2</td>
<td>-7.5</td>
<td>-8.08</td>
<td>-8.29</td>
<td>-8.36</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>75th bin</td>
<td>-3.36</td>
<td>-5.67</td>
<td>-6.46</td>
<td>-6.82</td>
<td>-7.02</td>
<td>-7.4</td>
<td>-7.53</td>
<td>-7.57</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>UK, 2 quarters</td>
<td>-4.74</td>
<td>-5.55</td>
<td>-5.78</td>
<td>-5.88</td>
<td>-5.93</td>
<td>-6.01</td>
<td>-6.03</td>
<td>-6.03</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>UK, 8 quarters</td>
<td>-4.71</td>
<td>-7.7</td>
<td>-8.74</td>
<td>-9.22</td>
<td>-9.49</td>
<td>-10.02</td>
<td>-10.2</td>
<td>-10.27</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
</tbody>
</table>

Notes: This table shows the results of the RV statistical test comparing the fit of the monopoly and price-taking models for different values of the cost elasticity, $\lambda$, 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.

We also consider the robustness of the empirical results to alternative measures of convenience yields and public debt. Tables B.6 and B.7 show the demand estimation results with and without the demand rotator. Table B.8 shows the RV test results for different cost elasticities. The first set of robustness results involves using measures of short- and long-term measures of convenience yields (see Appendix B for details on how we compute these variables). The RV test favors the monopoly equilibrium in both specifications. In addition, consistent with prior literature, we estimate a more inelastic demand for long-term debt. We next consider using the the ratio of public debt to trend-GDP (instead of observed GDP) as the independent variable in the demand estimation. The motivation for using such a variable is to capture movements in the debt-to-GDP ratio that come from the numerator and not the denominator. Our results are invariant to using this measure. We also consider using external public debt as an independent variable in the demand estimation. In this case, the demand is not well estimated due to the fact that the levels of external debt were small for a significant part of the sample and that external
debt exhibits a clear upward trend since then.

Table B.6: US public debt demand estimation: Alternative measures of spreads and debt

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Baseline</th>
<th>(2) Short Mat.</th>
<th>(3) Long Mat.</th>
<th>(4) External Debt</th>
<th>(5) Trend GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(debt/gdp)</td>
<td>-0.13**</td>
<td>-0.09</td>
<td>-0.19**</td>
<td>-0.75***</td>
<td>-0.14**</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.08)</td>
<td>(0.09)</td>
<td>(0.19)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>High Volatility Dummy</td>
<td>-0.14</td>
<td>-0.21</td>
<td>-0.03</td>
<td>0.50*</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.15)</td>
<td>(0.16)</td>
<td>(0.28)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Vol Dummy×Log(dept/gdp)</td>
<td>-0.23**</td>
<td>-0.26*</td>
<td>-0.18</td>
<td>0.10</td>
<td>-0.22**</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.14)</td>
<td>(0.15)</td>
<td>(0.08)</td>
<td>(0.09)</td>
</tr>
<tr>
<td>Demand elasticity, high vol</td>
<td>1.73</td>
<td>1.5</td>
<td>2.05</td>
<td>0.96</td>
<td>1.73</td>
</tr>
<tr>
<td>Demand elasticity, low vol</td>
<td>4.66</td>
<td>5.59</td>
<td>3.99</td>
<td>0.84</td>
<td>4.52</td>
</tr>
<tr>
<td>Markup, high vol</td>
<td>0.58</td>
<td>0.67</td>
<td>0.49</td>
<td>1.04</td>
<td>0.58</td>
</tr>
<tr>
<td>Markup, low vol</td>
<td>0.21</td>
<td>0.18</td>
<td>0.25</td>
<td>1.19</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are (1, 4, 5) the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units; (2) the yield spreads between bank bills and 3-month T-bills; (3) the yield spreads between long maturity corporate bonds and Treasury bonds. (1, 2, 3) use the log of the ratio of the Treasury debt outstanding to US GDP; (4) uses the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; (5) use the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering. Volatility is a dummy indicator for whether the constructed UK volatility measure is above sample median. Controls include the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield and Extended VIX. The estimation method is 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.7: US public debt demand estimation without rotators: Alternative measures of spreads and debt

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) UK IV Short Mat.</th>
<th>(2) Short Mat.</th>
<th>(3) Long Mat.</th>
<th>(4) External Debt</th>
<th>(5) Trend GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(debt/gdp)</td>
<td>-0.22***</td>
<td>-0.19***</td>
<td>-0.27***</td>
<td>-0.60***</td>
<td>-0.34***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.07)</td>
<td>(0.07)</td>
<td>(0.13)</td>
<td>(0.10)</td>
</tr>
<tr>
<td>Volatility</td>
<td>0.09***</td>
<td>0.05</td>
<td>0.16***</td>
<td>0.18***</td>
<td>0.43*</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(0.05)</td>
<td>(0.04)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>2.84</td>
<td>2.82</td>
<td>2.87</td>
<td>1.05</td>
<td>1.84</td>
</tr>
<tr>
<td>Markup</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.96</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are (1, 4, 5) the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units; (2) the yield spreads between bank bills and 3-month T-bills; (3) the yield spreads between long maturity corporate bonds and Treasury bonds. (1, 2, 3) use the log of the ratio of the Treasury debt outstanding to US GDP; (4) uses the log of the ratio of the Treasury debt held by foreigners outstanding to US GDP; (5) use the log of the ratio of the Treasury debt outstanding to US trend GDP obtained from HP filtering. Volatility is a dummy indicator for whether the constructed UK volatility measure is above sample median. Controls include the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield and Extended VIX. The estimation method is 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 measures of spreads and debt

<table>
<thead>
<tr>
<th>Cost elasticity</th>
<th>λ = 0</th>
<th>λ = 1</th>
<th>λ = 2</th>
<th>λ = 3</th>
<th>λ = 4</th>
<th>λ = 10</th>
<th>λ = 20</th>
<th>λ = 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>b. Different Maturity</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short</td>
<td>0.52</td>
<td>-2.17</td>
<td>-3.85</td>
<td>-4.91</td>
<td>-5.61</td>
<td>-7.24</td>
<td>-7.88</td>
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</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(0.03)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Long</td>
<td>-7.65</td>
<td>-8.95</td>
<td>-9.11</td>
<td>-9.08</td>
<td>-9.03</td>
<td>-8.82</td>
<td>-8.7</td>
<td>-8.65</td>
</tr>
<tr>
<td></td>
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<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>c. Different dependent variable</td>
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<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
</tbody>
</table>

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

Finally, we redo our empirical exercises excluding the set of controls, using alternative estimation samples, and using alternative instruments for debt supply changes. Tables
B.9 and B.10 show the demand estimation results with and without the demand rotator, and Table B.11 shows the RV test results. For the case when we exclude the set of additional controls, (slope of the yield curve and US volatility) in the demand estimations, and find similar results. We then redo our demand estimation exercise for three different samples: excluding periods in which the zero lower bound binds, starting after the Second World War, and a post-1985 sample that also excludes periods of binding zero lower bound. The main results are robust to using these different sample periods. Finally, we estimate the demand using alternative instruments for supply: we use the military news shock and the dependency ratio as separate instruments, and we also use a measure of government expenditure shocks developed by Blanchard and Perotti (2002). This 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.\(^6\)

\(^6\)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.9: US public debt demand estimation: Additional robustness

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) Baseline</th>
<th>(2) No controls</th>
<th>(3) No ZLB</th>
<th>(4) Post War</th>
<th>(5) Military</th>
<th>(6) Dependency shock</th>
<th>(7) BP shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(debt/gdp)</td>
<td>-0.13**</td>
<td>-0.13**</td>
<td>-0.19***</td>
<td>-0.12**</td>
<td>-0.30***</td>
<td>-0.05</td>
<td>-0.31***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.07)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>High Volatility Dummy</td>
<td>-0.14</td>
<td>-0.12</td>
<td>0.03</td>
<td>-0.24*</td>
<td>-0.06</td>
<td>-0.14</td>
<td>-0.57***</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.11)</td>
<td>(0.14)</td>
<td>(0.12)</td>
<td>(0.16)</td>
<td>(0.11)</td>
<td>(0.17)</td>
</tr>
<tr>
<td>High Vol × Log(debt/gdp)</td>
<td>-0.23**</td>
<td>-0.27**</td>
<td>-0.08</td>
<td>-0.29***</td>
<td>-0.11</td>
<td>-0.25**</td>
<td>-0.56***</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.11)</td>
<td>(0.12)</td>
<td>(0.11)</td>
<td>(0.15)</td>
<td>(0.11)</td>
<td>(0.16)</td>
</tr>
</tbody>
</table>

Demand elasticity, high vol

- 1.73
- 1.57
- 2.37
- 1.56
- 1.52
- 2.07
- 0.71

Demand elasticity, low vol

- 4.66
- 4.72
- 3.43
- 5.18
- 2.08
- 12.4
- 2.0

Markup, high vol

- 0.58
- 0.64
- 0.42
- 0.64
- 0.66
- 0.48
- 1.4

Markup, low vol

- 0.21
- 0.21
- 0.29
- 0.19
- 0.48
- 0.08
- 0.5

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above sample median. Controls include the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield and Extended VIX (aside from no controls). The estimation method is IV for all columns. In (3), we drop periods in which the zero lower bound is binding. In (4), we estimate using the sample post 1945. In (5, 6, 7), we only use as IV variable the Military news shock, the Log change in dependency ratio, or the Blanchard-Perot 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.10: US public debt demand estimation without rotators: Additional robustness

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) UK IV No controls</th>
<th>(2) No ZLB No ZLB</th>
<th>(3) Post War No ZLB</th>
<th>(4) Military Dependency BP shock</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log(debt/gdp)</td>
<td>-0.22***</td>
<td>-0.23***</td>
<td>-0.21***</td>
<td>-0.21***</td>
<td>-0.32***</td>
<td>-0.18***</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Volatility</td>
<td>0.09***</td>
<td>0.15***</td>
<td>0.12***</td>
<td>0.07*</td>
<td>0.06*</td>
<td>0.11***</td>
<td>0.10**</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>2.84</td>
<td>2.68</td>
<td>3.01</td>
<td>2.99</td>
<td>1.95</td>
<td>3.54</td>
<td>4.42</td>
</tr>
<tr>
<td>Markup</td>
<td>0.35</td>
<td>0.37</td>
<td>0.33</td>
<td>0.33</td>
<td>0.51</td>
<td>0.28</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are the weighted average of yield spreads between corporate and Treasury bonds both measured in percentage units. Volatility is a dummy indicator for whether the constructed UK volatility measure is above sample median. Controls include the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield and Extended VIX (aside from no controls). The estimation method is IV for all columns. In (3), we drop periods in which the zero lower bound is binding. In (4), we estimate using the sample post 1945. In (5, 6, 7), we only use as IV variable the Military news shock, the Log change in dependency ratio, or the Blanchard-Perot 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.11: Government conduct test: Additional robustness

<table>
<thead>
<tr>
<th>Cost elasticity</th>
<th>$\lambda = 0$</th>
<th>$\lambda = 1$</th>
<th>$\lambda = 2$</th>
<th>$\lambda = 3$</th>
<th>$\lambda = 4$</th>
<th>$\lambda = 10$</th>
<th>$\lambda = 20$</th>
<th>$\lambda = 30$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a. Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>b. No controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>c. Other time samples</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No ZLB</td>
<td>-5.08</td>
<td>-6.49</td>
<td>-7.08</td>
<td>-7.39</td>
<td>-7.58</td>
<td>-7.98</td>
<td>-8.13</td>
<td>-8.18</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td>Post War</td>
<td>-2.98</td>
<td>-5.69</td>
<td>-6.67</td>
<td>-7.13</td>
<td>-7.4</td>
<td>-7.92</td>
<td>-8.1</td>
<td>-8.16</td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>d. Different demand instruments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
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<td>(0.0)</td>
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<td>(0.0)</td>
<td>(0.0)</td>
</tr>
<tr>
<td><strong>e. Different testing instrument</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extended UK vol. binned</td>
<td>0.81</td>
<td>-2.03</td>
<td>-3.15</td>
<td>-3.69</td>
<td>-4.0</td>
<td>-4.62</td>
<td>-4.84</td>
<td>-4.91</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(0.04)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
<td>(0.0)</td>
</tr>
</tbody>
</table>

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

Figure C.1: Demand rotations to identify government conduct

(a) Monopoly

(b) Price taking

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 from t-5 to t-40. Dependency ratio is the US population aged 65+ divided by population ages 15-65. Appendix B details the construction of all the variables.
Table C.1: First stage regressions

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Log(debt/gdp)</th>
<th>Vol Dummy × Log(debt/gdp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military news</td>
<td>0.31***</td>
<td>-0.00</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Dependency</td>
<td>63.39***</td>
<td>-1.26</td>
</tr>
<tr>
<td></td>
<td>(7.27)</td>
<td>(5.86)</td>
</tr>
<tr>
<td>Vol Dummy × Military news</td>
<td>-0.05</td>
<td>0.26***</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Vol Dummy × Dependency</td>
<td>-4.20</td>
<td>61.46***</td>
</tr>
<tr>
<td></td>
<td>(9.58)</td>
<td>(7.72)</td>
</tr>
<tr>
<td>High Volatility Dummy</td>
<td>-0.14***</td>
<td>-1.31***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Extended VIX</td>
<td>-0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Slope</td>
<td>0.05***</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.18***</td>
<td>-0.06</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Observations</td>
<td>338</td>
<td>338</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.53</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Notes: The dependent variables are the log of the ratio of the Treasury debt outstanding to US GDP, and an interaction with volatility. The independent variables are the various instruments we use. Military news is the cumulative news in changes in military spending scaled by GDP; we accumulate from t-5 to t-40. Dependency ratio is the US population aged 65+ divided by population ages 15-65. Slope is the slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield. Extended VIX is VIX from 1990 to 2020, and from 1935 to 1990, this is a historical predicted series of VIX by regressing VIX on annualized standard deviation of weekly log stock returns on the S&P 500 index from 1990 to 2020. Volatility is a dummy control for whether the constructed UK volatility measure is above sample median. See the main text for further details, and Appendix B for a description of the construction of all the variables. Standard errors are in parentheses. *, **, and *** represent statistical significance at the 10%, 5%, and 1% level, respectively.
Figure C.3: Estimated marginal cost shocks (UK rotator)

Notes: This figure shows the estimated marginal costs from the monopoly model and the price-taking model. Shaded areas correspond to selected periods of high volatility, where at least 1 quarter has an UK volatility measure above the sample 75th Percentile.
Figure C.4: Estimated marginal cost shocks (VIX rotator)

Notes: This figures shows the estimated marginal costs from the monopoly model and the price taking model. Shaded areas correspond to selected periods of high volatility, where at least 1 quarter has the extended VIX measure above the sample 75th percentile.
Figure C.5: Simultaneous demand rotations and shifts

(a) Monopoly

(b) Price taking

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

<table>
<thead>
<tr>
<th></th>
<th>Extended UK vol</th>
<th>Extended UK vol, binned</th>
<th>Extended VIX</th>
<th>Extended VIX, binned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debt to GDP</td>
<td>-0.24</td>
<td>-0.18</td>
<td>-0.25</td>
<td>-0.25</td>
</tr>
<tr>
<td>Debt to GDP (trend)</td>
<td>-0.24</td>
<td>-0.18</td>
<td>-0.25</td>
<td>-0.25</td>
</tr>
<tr>
<td>Debt to GDP (cycle)</td>
<td>-0.08</td>
<td>-0.05</td>
<td>-0.02</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

Notes: We report correlations in the table. Extended UK vol is a 1935 to 2020 historical predicted series of annualized rolling 4 quarter standard deviation of weekly log stock returns on the MSCI UK index by regressing the series on annualized rolling 4 quarter standard deviation of monthly log stock returns on the UK share price index from 1972 to 2020. Extended VIX is the CBOE Volatility Index from 1990 to 2020, from 1935 to 1990 this is a historical predicted series of VIX by regressing VIX on annualized standard deviation of weekly log stock returns on the S&P 500 index from 1990 to 2020. Debt to GDP is the ratio of outstanding Treasury debt to US GDP. We filter the series through an HP filter with smoothing parameter of 1600 to also obtain the trend and cycle components.
Table C.3: Steady state comparisons for different elasticities

<table>
<thead>
<tr>
<th></th>
<th>Total safe assets/GDP</th>
<th>Convenience yield</th>
<th>Interest on Public Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME</td>
<td>0.39</td>
<td>0.68%</td>
<td>0.97%</td>
</tr>
<tr>
<td></td>
<td>( \epsilon = 2.2, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>0.59</td>
<td>0.57%</td>
<td>1.09%</td>
</tr>
<tr>
<td></td>
<td>( \epsilon = 2.0, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>0.62</td>
<td>0.55%</td>
<td>1.11%</td>
</tr>
<tr>
<td></td>
<td>( \epsilon = 2.5, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>0.56</td>
<td>0.59%</td>
<td>1.07%</td>
</tr>
</tbody>
</table>

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

Table C.4: Welfare comparisons for different elasticities

<table>
<thead>
<tr>
<th></th>
<th>No special role</th>
<th>CE with special role</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \epsilon = 2.2, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US welfare</td>
<td>-0.21%</td>
<td>-0.08%</td>
</tr>
<tr>
<td>RW welfare</td>
<td>-0.34%</td>
<td>+0.10%</td>
</tr>
<tr>
<td>( \epsilon = 2.0, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US welfare</td>
<td>-0.22%</td>
<td>-0.09%</td>
</tr>
<tr>
<td>RW welfare</td>
<td>-0.39%</td>
<td>+0.12%</td>
</tr>
<tr>
<td>( \epsilon = 2.5, \lambda = 1 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US welfare</td>
<td>-0.19%</td>
<td>-0.06%</td>
</tr>
<tr>
<td>RW welfare</td>
<td>-0.29%</td>
<td>+0.08%</td>
</tr>
</tbody>
</table>

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

In this section, we present a complementary approach to assess whether a model of strategic behavior is an appropriate representation of the US issuance of debt. The approach involves directly inferring the value of the parameter $\xi$, 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 equation (9) in the main text. Notice that we can rewrite this equation as follows

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

This equation gives us a direct way of measuring $\xi$. A value of $\xi$ close to zero would suggest price taking behavior while a value of $\xi$ close to 1 would suggest a monopoly model. The variables $S_t$ and $b_t$ are observable in the data and our demand estimation procedure gives us $\mu_t$. Consider the case in which we fix a value of $\lambda$. Our identifying assumption implies that $\omega$ should be unchanged across periods of high and low volatility. Thus, we can use average measures of $S_t$, $b_t$, and $\mu_t$ across high/low volatility regimes to
write
\[ \xi = \frac{1}{\ln \mu_i} (\ln S^i - \lambda \ln b^i - \ln \omega), \quad i \in \{H, L\}. \]

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

**Figure D.1: Inferring US government conduct**

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