The Convenience Yield and the Demand for U.S. Treasury Securities[1]

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Abstract

This paper investigates the heterogeneity in investors' preferences for non-pecuniary attributes of U.S. Treasury securities. My goal is to determine which groups of investors draw benefits from holding Treasuries and the reasons why they are willing to pay a premium over safe and liquid corporate bonds. I first present a conceptual framework to interpret the implications of heterogeneity in valuations of convenience on yields and price elasticities. Then, using sector-level bond holdings from the Financial Accounts, I recover structural demand curves and rank investors by their valuations of convenience services. Estimates reveal that the convenience of long term Treasuries is valuable for U.S. private depository institutions, and security brokers and dealers, whereas it is less attractive to households, pension funds and insurance companies. The ordering suggests that a safety attribute is secondary to liquidity even at longer maturities. Models of convenience yields should (i) accommodate heterogeneity in the elasticity of substitution between Treasuries and corporate bonds and (ii) incorporate liquidity motives at both long and short maturities.

Keywords: Convenience Yield; Non-pecuniary Benefits; Demand System; U.S. Government Debt; Supply of Safe Assets; Liquidity and Safety Attributes; Preferred Habitat Hypothesis.

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1 Introduction

U.S. Treasury securities are among the safest and most liquid assets in the world (He, Krishnamurthy, & Milbradt, 2019). Investors accept lower returns on their investment portfolios to hold U.S. debt over corporate or foreign sovereign debt. The yield differential is commonly referred to as the convenience yield, and it reflects non-pecuniary benefits that market participants attribute to Treasuries (Choi, Kirpalani, & Perez, 2022; Du, Im, & Schreger, 2018; Jiang, Krishnamurthy, & Lustig, 2020, 2021; Krishnamurthy & Vissing-Jorgensen, 2012). The existence of a convenience yield is consistent with evidence that the U.S. government debt is too expensive and that the U.S. dollar has a higher valuation than predicted by frictionless asset pricing models (Gourinchas & Rey, 2007; Ivashina, Scharfstein, & Stein, 2015)). Krishnamurthy and Vissing-Jorgensen (2012) argue that the special demand for U.S. Treasuries is due to safety and liquidity attributes. A natural question is why do these yield spreads exist in the first place and who draws benefits from the convenience services of Treasury securities.

In this paper, I investigate the heterogeneity in investors' preferences for non-pecuniary attributes of U.S. Treasury securities. My goal is to establish which groups of investors draw benefits from holding Treasuries and the reason why they are willing to pay a premium over similarly safe and liquid corporate bonds. The ultimate purpose is to shed light on the sources of the demand shocks that induce variations in yield spreads in order to establish the underlying nature of convenience yields. I tackle this question by looking at the relation between Treasury holdings and yield spreads to assess whose demand shocks for convenience are more likely to comove with yields spreads. I consider securities that differ in terms of non-pecuniary attributes but that are otherwise similar. My approach builds on the premise that sectors are subject to a variety of institutional features and have different investment horizons. For example, insurance companies are required to maintain minimum levels of capital on a risk-adjusted basis (Becker & Ivashina, 2015). Similarly, depository institutions and security dealers may value repurchase agreements with the Federal Reserve for liquidity purposes. However, non-pecuniary attributes are likely to be less attractive for sectors that are exempt from regulatory constraints or that do not perform repo transactions.

To formalize how heterogeneous valuations of non-pecuniary benefits affect the yield and the demand elasticity of Treasury securities, I propose a stylized conceptual framework building on Krishnamurthy and Vissing-Jorgensen (2012). I model convenience services by assuming that agents derive utility from the real holdings of Treasury securities, such that convenience benefits are not separable from the standard utility of consumption. This modification is analogous to a money-in-the-utility setup where cash holdings act as a mean of transaction or as a store of value. (Kekre & Lenel, 2021; Krishnamurthy & Vissing-Jorgensen, 2012; Sidrauski, 1967). Other than Treasury holdings, the convenience is a function of income and a preference shock that characterizes the shape of the utility function. The stylized model features heterogeneity in the perception of non-pecuniary benefits by assuming that the shape of the utility function and the exposure to convenience shocks vary across sectors.

Under the assumption that corporate bonds do not produce convenience services, I derive demand curves for Treasury securities. I demonstrate heuristically that differences in the shape of the utility function generate cross-sectional variation in price elasticities. Subsequently, I establish that structural demand curves include the Treasury yield and the convenience shock, but not the equilibrium price of non-pecuniary benefits, i.e. the convenience yield. I emphasize the distinction between convenience yields and preference shocks through a demand system that is linear in both Treasury yields and the convenience shock in the spirit of Koijen and Yogo (2019, 2020) and Gabaix and Koijen (2022).

Convenience shocks are assumed to be endogenous processes that move around preferences but that are uncorrelated with latent demand and other systematic factors. Krishnamurthy and Vissing-Jorgensen (2012) introduce preference shocks that determine how much utility is derived from convenience assets. In contrast, Kekre and Lenel (2021) model safety shocks as an exogenous driving force. While the safety shock process exogenously determines the convenience yield, it is correlated with disaster risk. Mota (2021) specifies convenience shocks as a demand shifter that reflects shocks to the demand of safety services. Unfortunately, convenience shocks are unobservable and extremely hard to measure. As a preliminary approach, I proxy for the convenience shocks using the yield spread between corporate and Treasury bonds for both long (more than ten year) and short (three to six months) maturities. By doing so, however, I replace an unobservable primitive object, i.e. the convenience shock, with an observable equilibrium object, i.e. the realized yield spread. Even though it is common practice in the literature (Choi et al., 2022; Klingler & Sundaresan, 2022), this is an issue for the identification of the ordering of the demand loadings on the convenience shocks. To mitigate this concern, I argue that elasticities to the Treasury spread are proportional to the parameters of interest. However, the convenience yield only explains a fraction of the yield spread of about 40 to 76 basis points (Krishnamurthy & Vissing-Jorgensen, 2012; van Binsbergen, Diamond, & Grotteria, 2022).

The goal of my empirical analysis is to rank sectors based on their exposure to convenience shocks. I build on the conceptual framework to define loadings on the convenience shock as the structural parameters of interest. These coefficients can be interpreted as capturing both the sensitivity to convenience shocks and the subjective valuation of non-pecuniary benefits. Estimation of the demand system recovers both the price elasticities and the loading on convenience shocks. However, parameter identification is subject to two identification challenges. On the one hand, estimates of the factor loadings suffer from omitted variable biases induced by the correlation of latent demand and convenience shocks. On the other hand, the heterogeneity in price elasticities implies that a univariate regression of prices on convenience shocks recovers a linear combination of the factor loadings and price elasticities. As in Koijen, Richmond, and Yogo (2020) and Gabaix and Koijen (2022), agents may be selling because they do not care about convenience or because they are price elastic.

Subsequently, I present conditions under which least squares estimates recover the ordering of the factor loadings. If price elasticities are approximately equal and convenience shocks are orthogonal to latent demand factors, a univariate regression of quantities on the convenience shock identifies a coefficient that is proportional to investors' convenience loadings. Least squares estimate reveal that a 1% increase in the long spread is associated to a -5.36% decline in Treasury holdings. Further, bivariate regressions of quantities on Treasury yields and yield spreads suggest that price elasticities differ in the cross section. These results are consistent with the negative relation between supply and interest rate spreads documented by Krishnamurthy and Vissing-Jorgensen (2012). In particular, yield spreads narrow when investors are holding a larger quantity of Treasury securities. Interestingly, the same result does not hold for the short term spread. This result confirms the findings in Nagel (2016) that supply effects are weaker for money-like securities, in particular when controlling for the opportunity costs of money. However, in the years after 2000, supply effects are present for short spreads as well, indicating a tighter connection between Treasury supply at the short end of the yield curve (Du, Hébert, & Li, 2022; D'Amico & King, 2013; d'Avernas & Vandeweyer, 2022).

Convenience shocks are potentially correlated with systematic factors and supply shocks, e.g. during a flight-to-quality (He et al., 2019; Krishnamurthy & Vissing-Jorgensen, 2012; Longstaff, 2004). In addition, the assumption of identical price elasticities contradicts the premise that agents value non-pecuniary attributes differently. To address these concerns, I perform an instrumental variable regression of Treasury flows on yields and convenience shocks. In this specification, yields and convenience shocks are endogenous. I instrument for Treasury yields with the granular instrumental variable (GIV) of Gabaix and Koijen (2020, 2022), which exploits idiosyncratic demand shocks of each sector as the source of exogenous variation. Given the well-established fact that yield spreads respond to supply, I build on Ramey (2011) and Ramey and Zubairy (2018) and instrument the yield spread with unexpected military expenditure shocks (Choi et al., 2022). The intuition behind the instrument is that military expenditure shocks are driven by military events that are orthogonal to latent demand (Choi et al., 2022), but that are potentially correlated with convenience or safety shocks. Another strength of this approach is that defence spending is often induced by foreign turmoils or major political events that are unrelated to the U.S. economy.

I implement the instrumental variable strategy to identify the structural parameters of the demand system. The estimated macro elasticity of Treasury demand varies from 14.70 to 18.49, but standard errors are big. A back-of-the-envelope calculation with a maturity of 15 years implies a price elasticity of 1.23 and 0.98. Assiming an average maturity of 5 years, the price elasticity jumps to 3.70 and 2.94. These magnitudes are comparable with a price elasticity of 4.2 for long term bonds from Koijen and Yogo (2020). Similarly, Choi et al. (2022) find a demand elasticity of 1.53. These results are also consistent with Brooks, Katz, and Lustig (2018), who estimate a demand elasticity of roughly 2.7, but also assume an average duration of 5 years.

In contrast, the evidence on the aggregate loading on the convenience shock is mixed. I find that a 1% increase in the yield spread induces an increase of 4.82% in Treasury demand. The positive sign is consistent with an aggregate positive exposure to convenience shock, but it is hard to reconcile with Krishnamurthy and Vissing-Jorgensen (2012) and Nagel (2016). A potential interpretation is that a military expenditure shock has a contemporaneous effect on the demand for safe assets. In fact, a positive realization of the convenience shock increases the marginal convenience of each additional Treasury bond. I then repeat the same procedure to rank sectors based on their exposure to convenience shocks. Households and long term investors have the highest sensitivity to yield spreads. On the other side of the spectrum, the sectors that have higher loadings on convenience shocks are state and local governments, the U.S. private depository institutions, and the security brokers and dealers. Mutual funds, insurance companies, and the foreign sector fall in the middle of the ranking.

The ranking suggests that safety is a secondary concern with regard to liquidity even for long term spreads. The importance of liquidity attributes even at longer maturities is consistent with an upward sloping term structure of liquidity premia during normal times (Joslin, Li, & Yang, 2021). Furthermore, it reveals that corporate and Treasury bonds are likely to be close substitutes for at least some sectors, but imperfect substitutes for many others. Hence, differences in the perceived substitutability between corporate bonds and Treasuries could be a key determinant of the loadings on convenience shocks, in particular given that institutional details and investment horizons differ across sectors. A tentative explanation is that convenience services of Treasury bonds are more valuable to banks and security brokers and dealers. In contrast, long term Treasuries and Aaa corporate bonds are better substitutes for households, pension funds, and insurance companies. In this regard, Nagel (2016) and Krishnamurthy and Li (2022) present estimates on the elasticity of substitution between Treasuries and corporate bonds. While Nagel (2016) finds an elasticity close to one, Krishnamurthy and Li (2022) argue that Treasury bonds and bank deposits are imperfect substitutes. It seems plausible that the substitutability of Treasury bonds and corporate bonds is not only a function of maturity, but that it varies in the cross section depending on the valuation of non-pecuniary benefits. In this regard, I find that supply effects are stronger when spreads are matched with the outstanding quantities of the corresponding maturity. These results are consistent with Greenwood and Vayanos (2014) and Greenwood, Hanson, and Stein (2015). While short term supply effects vanish after controlling for the opportunity costs of money, long term supply effects do not.

1.1 Related Literature

This paper contributes to the literature on convenience yields by investigating cross-sectional heterogeneity in the valuation of convenience services and their implications for the estimation of structural demand equations. The conceptual framework builds on Krishnamurthy and Vissing-Jorgensen (2012) and is close in spirit to Nagel (2016), Kekre and Lenel (2021), and Mota (2021). I extend Krishnamurthy and Vissing-Jorgensen (2012) by introducing heterogeneity in the shape of the utility function and by allowing sectors to load differently on convenience shocks. Although I focus on spreads between corporate and Treasury bonds, this paper relates to Du, Tepper, and Verdelhan (2018), Jiang et al. (2021), Du, Im, and Schreger (2018) and Jiang et al. (2020) by arguing that institutional details and regulatory constraints may affect both the price elasticity and the elasticity of substitution between Treasuries and similar assets. Convenience shocks can then be interpreted as regulatory shocks that induce special demand for Treasuries.

The derivation of a linear demand equation in presence of convenience services links theoretical models of convenience to demand system asset pricing. Estimation of demand systems with corporate and Treasury debt is discussed in Koijen and Yogo (2019) and Koijen and Yogo (2020). To the extent that non-pecuniary benefits can be interpreted as a characteristic of Treasury securities, I also relate to Koijen et al. (2020), but I allow valuations of convenience services to vary across sectors. By assuming that convenience shocks are related to debt to supply, I also draw from the literature of demand and supply estimation in situations where demand and supply curves move simultaneously (MacKay & Miller, 2022). Further, the relation of convenience shocks and supply shocks connects this paper to the literature on safe asset provision[1], in particular He et al. (2019) and Caballero and Farhi (2017).

The estimation of the structural demand equation builds on the literature of identification in macroeconomics (Chodorow-Reich, 2019; Nakamura & Steinsson, 2018; Ramey, 2011; Ramey & Zubairy, 2018). The identification strategy combines elements from the granular instrumental variable approach of Gabaix and Koijen (2020) with the military expenditure shock series from Ramey (2011) and Ramey and Zubairy (2018). By instrumenting for Treasury yields and convenience shocks, I relate to an active literature discussing exogenous supply shocks. Part of the literature uses these instruments to estimate fiscal multipliers (Auerbach & Gorodnichenko, 2012; Barro & Redlick, 2011; Blanchard & Perotti, 2002; Ramey, 2011), but recent papers exploit exogenous supply shocks to evaluate supply effects on yield spreads (Choi et al., 2022; Greenwood et al., 2015; Krishnamurthy & Li, 2022; Nagel, 2016).

The notion that the set of investors with special demand for short term and long term convenience may vary across maturity is consistent with a term structure hypothesis of the yield curve (Modigliani & Sutch, 1966; Vayanos & Vila, 2021). Early work of Krishnamurthy and Vissing-Jorgensen (2007) investigates the existence of clienteles for convenience services. I extend their results by implementing an instrumental variable strategy that also accounts for heterogeneous price elasticities. The implication that the liquidity motive also matter at longer maturities speaks to the literature on liquidity premia (Joslin et al., 2021; Longstaff, 2004). Financial frictions in the banking sectors could also explain the special demand for U.S. Treasuries (Haddad & Sraer, 2020; Klingler & Sundaresan, 2022).

Identifying the clienteles whose demand shocks are related to yield spreads is helpful to inform international macro models with financial frictions about the source of demand shocks that price liquidity and safety attributes into interest rate spreads (Bernanke & Gertler, 1989; Farhi & Gabaix, 2016; Farhi & Werning, 2016; Gabaix & Maggiori, 2015; Greenwood et al., 2015; Kekre & Lenel, 2021; Kiyotaki & Moore, 1997; Verdelhan, 2018). To the extent that foreign investors' valuation of dollar convenience affect exchange rates, my work is also tangential to the literature on currency pricing[2]. Finally, non-pecuniary benefits have implications for budget expenditures, linking this paper to the literature on government debt valuation (Chernov, Schmid, & Schneider, 2020; Cochrane, 2020; Favilukis, Ludvigson, & Van Nieuwerburgh, 2014; Jiang, 2021; Jiang, Lustig, Van Nieuwerburgh, & Xiaolan, 2022).

1.2 Organization

The remainder of the paper is organized as follows. Section 2 introduces the conceptual framework and presents conditions under which OLS and IV estimates recover the structural parameter of interest. Section 3 explains data sources, describes variable construction, and presents stylized facts about the Treasury and the corporate bond market. Building on the structural demand function, Section 4 presents the empirical results, emphasizing the ordering of the preference loadings on the convenience

[1] See also Holmström and Tirole (1998) and Greenwood et al. (2015).

[2] Among others, Gerko and Rey (2017); Gilchrist, Wei, Yue, and Zakrajšek (2022); Gourinchas and Rey (2007); Gourinchas, Rey, and Govillot (2010); Ivashina et al. (2015); Jiang, Krishnamurthy, and Lustig (2018); Jiang et al. (2021); Lustig, Roussanov, and Verdelhan (2011); Lustig and Verdelhan (2007); Menkhoff, Sarno, Schmeling, and Schrimpf (2012); Miranda-Agrippino and Rey (2015); Shin (2012)

shocks. Section 5 discusses extensions, limitations and future steps. Section 6 concludes

2 Theoretical Framework

I present a conceptual framework to formalize how valuations of non-pecuniary attributes affect the price and the demand elasticity of Treasury securities. In my setup, agents derive utility from consumption and their holdings of Treasury securities. The convenience function disciplines the benefits derived from convenience service, and it depends on income and a preference shifter, which I refer to as the convenience shock. I argue that the presence of non-pecuniary benefits determine price elasticities through the shape of the convenience function. Subsequently, I derive a linearized demand function for Treasury security to justify why asset demand responds to prices and convenience shocks, but not to the equilibrium price of the non-pecuniary services, which is the convenience yield.

2.1 A Demand System with Convenience Shocks

There are many ways in which asset pricing models can accommodate convenience services associated to specific assets. Krishnamurthy and Vissing-Jorgensen (2012) assume that consumption is a composite of an endowment c_t and convenience services $v(\cdot)$, where utility from convenience $v(\cdot)$ enters additively. Similarly, Kekre and Lenel (2021) consider recursive preferences in which convenience from real holdings has a multiplicative from. In both Krishnamurthy and Vissing-Jorgensen (2012) and Kekre and Lenel (2021), non-pecuniary benefits affect marginal utility of consumption. In contrast, Nagel (2016) and Mota (2021) separate utility from consumption and convenience. As a result, marginal utility $u'(C_t)$ is independent of the real stock of liquid assets Q_t.

I follow Krishnamurthy and Vissing-Jorgensen (2012) and Kekre and Lenel (2021), and study a model in which convenience services are not separable from standard utility of consumption $u(C_t)$. In this section, I assume an additive form, which makes it easier to derive pricing expressions and demand curves when there is a single convenience asset. The claim that the shape of the convenience function $v(\cdot)$ controls price elasticities and that demand responds to preference shocks holds in either framework. I assume that each agent seeks to maximize the objective

$$\mathbb{E}\left[\sum_{t=1}^{\infty} \beta^t \cdot u\left(C_{it}\right)\right] \tag{2.1}$$

where C_{it} is a consumption aggregator given by

$$C_{it} = c_{it} + \kappa_i \cdot v\left(\theta_{it}^A, \mathcal{A}_{it};\ \xi_{it}\right) \tag{2.2}$$

Agent i derives utility from consumption and by holding convenience assets, $j \in \{T, C\}$. Non-pecuniary benefits enter the agent's problem through $v\left(\theta_{it}^A, \mathcal{A}_{it};\ \xi_{it}\right)$. The first argument θ_{it}^A is the market value of the real holdings of convenience assets $\theta_{it}^A = \theta_{it}^T + \kappa^C \theta_{it}^C$. The constant $\kappa^C < 1$ measures the relative contribution of corporate debt holdings. The function $v(\cdot)$ depends on agent i's income $\mathcal{A}_{it}$. Income is assumed to be the sum of an aggregate and an idiosyncratic component, i.e. $\mathcal{A}_{it} = \iota_i \mathcal{C}_t + \varepsilon_{it}^T$, where $\iota_i \in (0, 1)$ is a fraction of the aggregate endowment $\mathcal{C}_t$ earned by agent i. I also introduce a preference shifter ξ_{it}, which I refer to as convenience shock or safety shock interchangeably. There are two sources of heterogeneity in the utility derived from convenience services. First, the parameter κ_i varies across investors. Second, agents load differently on the shocks $\xi_{it} = \psi_i^{\xi} \cdot \xi_t$.

I make the simplifying assumption that $\kappa^C = 0$, which means that only Treasuries provide convenience services. As a result, $\theta_{it}^A = \theta_{it}^T$. In Appendix B.3, I extend the analysis to the case with $\kappa^C \neq 0$ to allow for substitution between Treasuries and corporate debt. The first order condition for θ_{it}^T is

$$-\beta^t \cdot u'\left(C_{it}\right) \frac{P_t^T}{\Pi_t} + \beta^t \cdot u'\left(C_{it}\right) \kappa_i v'\left(\theta_{it}^T, \mathcal{A}_{it};\ \xi_{it}\right) \frac{P_t^T}{\Pi_t} + \mathbb{E}_t\left[\beta^{t+1} \cdot u'\left(C_{i,t+1}\right) \frac{P_{t+1}^T}{\Pi_{t+1}}\right] = 0 \tag{2.3}$$

where Π_t is the aggregate price level. The intuition behind (2.3) is that the purchase of an additional Treasury bond raises $C_{i,t+1}$ by $\frac{P_{t+1}^T}{\Pi_{t+1}}$, but it comes at the expense of $\frac{P_t^T}{\Pi_t^T}$ units of current consumption. At the same time, the market value of real bond holdings increases by $\frac{P_t^T}{\Pi_t^T}$. Solving for P_t^T gives

$$P_t^T = \frac{\mathbb{E}_t[M_{i,t+1} P_{t+1}^T]}{1 - \kappa_i \cdot v'\left(\theta_t^T, \mathcal{A}_{it};\ \xi_{it}\right)} \tag{2.4}$$

where $M_{i,t+1}$ denotes the stochastic discount factor for nominal payoffs. I refer to $\kappa_i \cdot v'(\cdot)$ in the denominator of (2.4) as the convenience yield. I then price a one-period Treasury bond, so that $P_{t+1}^T = 1$ with certainty. Given that $\mathbb{E}[M_{i,t+1}] = \frac{1}{R_t^f}$, where R_t^f is the gross risk-free rate, I obtain

$$P_t^T = \frac{\mathbb{E}_t[M_{t+1}]}{1 - \kappa_i \cdot v'\left(\theta_{it}^T, \mathcal{A}_{it};\ \xi_{it}\right)} \approx e^{\kappa_i \cdot v'\left(\theta_t^T, \mathcal{A}_{it};\ \xi_{it}\right)} \mathbb{E}_t[M_{t+1}] = e^{\kappa_i v'\left(\theta_t^T, \mathcal{A}_{it};\ \xi_{it}\right)} \frac{1}{R_t^f} \tag{2.5}$$

where I use the approximation $1 - \kappa_i \cdot v'(\cdot) \approx e^{-\kappa_i \cdot v'(\cdot)}$ for small $\kappa_i \cdot v'(\cdot)$[1]. Since $\frac{Q_{it}^T P_t^T}{\Pi_t} = \theta_{it}^T$, equation (2.5) implicitly defines a demand function for Treasuries. To derive a closed-form expression for Q_{it}^T, I specify a functional form for the convenience function $v'(\cdot)$. In particular, I model[2] $v'(\cdot)$ as

$$\kappa_i \cdot v'\left(\theta_{it}^T, \mathcal{A}_{it};\ \xi_{it}\right) = \kappa_i \cdot \left\{b_0 + b_1 \cdot \log \frac{\theta_{it}^T}{\mathcal{A}_{it}} - b_1 \cdot \xi_{it}\right\}$$

so that the safety shock ξ_t enters additively. Taking logs on both sides of (2.5) and substituting $\theta_{it}^T = \frac{P_t^T Q_{it}^T}{\Pi_t}$ gives

$$\log Q_{it}^T = \frac{(1 - \kappa_i b_1)}{\kappa_i b_1} \cdot \log P_t^T - \frac{b_0}{b_1} + \log\left(\mathcal{A}_{it} \cdot \Pi_t\right) + \psi_i^{\xi} \cdot \xi_t + \frac{1}{\kappa_i b_1} \cdot \log R_t^f \tag{2.6}$$

I denote the steady-state value of variable X as $\overline{X}$ and use lowercase variables to denote percentage

[1] The same approximation is used by Krishnamurthy and Vissing-Jorgensen (2012) to derive expressions for long term and short term yield spreads. It relies on the first-order Taylor approximation $e^{-x} \approx e^{-x_0} - e^{-x_0}(x - x_0)$, so that for $x_0 = 0$ I obtain $e^{-x} \approx 1 - x$. Implicitly, this assumes that $\kappa_i v'(\cdot)$ is rather small.

[2] The functional form $b_0 + b_1 \cdot \log \frac{\theta_{it}^T}{\mathcal{A}_{it}} + \xi_{it}$ is adapted from Krishnamurthy and Vissing-Jorgensen (2012), but it does not satisfy all properties of a convenience function $v'(\cdot)$. Among others, $v'(\cdot) \not\to 0$ when $\frac{\theta_{it}^T}{\mathcal{A}_{it}}$ grows large. In addition, decreasing marginal convenience $v''(\cdot) < 0$ requires $v''(\cdot) = \frac{b_1}{\theta_{it}^T} < 0$, so that $b_1 < 0$. Nevertheless, the same arguments go through also with a better-suited functional form of $v'(\cdot)$.

deviations, that is $x = \frac{X}{\overline{X}} - 1$. I get[3]

$$q_{it}^T = -\zeta_i^T \cdot p_t^T - \alpha_1 + a_{it} \cdot \pi_t + \psi_i^\xi \cdot \frac{\xi_t - \overline{\xi}_t}{\overline{\xi}_t} + \alpha_2 \cdot r_t^f \tag{2.7}$$

with $\alpha_{i1} \doteq \frac{b_0}{b_1}$, $\alpha_2 \doteq \frac{1}{\kappa_i b_1}$, $\zeta_i^T \doteq \frac{\kappa_i b_1 - 1}{\kappa_i b_1}$, and $r_t^f \doteq \log R_t^f$.

The demand function (2.7) illustrates three points. First, valuations of non-pecuniary benefits affect the price elasticity of the demand for Treasury securities. The magnitude of the elasticity $\zeta_i^T = \frac{\kappa_i b_1 - 1}{\kappa_i b_1}$ varies with κ_i. Second, heterogeneity in the convenience yield function $\kappa_i \cdot v'(\cdot)$ implies heterogeneity in ζ_i^T. Differences in marginal valuations of non-pecuniary benefits are another reason why price elasticities differ across agents. Third, equation (2.7) shows that Treasury demand is affected by output deviations from its steady state, the price level Π_t, and the risk-free rate (Nagel, 2016).

Even though they are closely related, ξ_t and the convenience yield are two distinct objects. ξ_t is an exogenous shock that moves around agent i's preferences for non-pecuniary benefits, whereas the convenience yield is an equilibrium outcome. Equation (2.7) clarifies the way in which time-varying preferences for non-pecuniary benefits should be modeled in a demand system. Importantly, the equilibrium price of convenience does not enter demand curves directly. This is relevant because movements in Treasury supply affect the equilibrium convenience yield, but not ξ_t unless supply shocks also alter investors' perception of safety and liquidity attributes (Kekre & Lenel, 2021).

Building on equation (2.7), I specify the demand curve for Treasury securities as

$$q_{it}^T = -\zeta_i^T \cdot p_t^T + \psi_i^\xi \cdot \xi_t + \nu_{it}^T \tag{2.8}$$
$$q_{it}^C = -\zeta_i^T \cdot p_t^C + \nu_{it}^C \tag{2.9}$$

where $\nu_{it}^j = \lambda_i^j \eta_t + \varepsilon_{it}^j$ is latent demand for security j. Latent demand is modeled as the sum of K common factors $\eta_t \in \mathbb{R}^K$ and idiosyncratic shocks ε_{it}^T. Idiosyncratic shocks are orthogonal to common factors $\mathbb{E}[\varepsilon_{it}^j \eta_t] = 0$. Further, I assume that $\mathbb{E}[\varepsilon_{it}^T \cdot \varepsilon_{it}^C] = 0$ and $\mathbb{E}[\varepsilon_{it}^T \cdot \varepsilon_{-it}^C] = 0$. Treasury demand q_{it}^T depends on prices p_t^T as well as on ξ_t. Based on equation (2.6), it seems natural to include real GDP growth and the output gap. This specification is similar to Gabaix and Koijen (2022). In principle, both η_t and ξ_t could be interpreted as common factors. However, the main difference is that ξ_t also controls the shape of the convenience function, whereas common shocks do not. For simplicity, I treat ξ_t as observable to abstract from measurement issues.

2.2 Parameters of Interest and Identification Challenges

The preference parameter of interest in the demand equation (2.8) is $\{\psi_i^\xi\}_{i=1}^N$. In this context, ψ_i^ξ is the sector i's demand loading on the convenience shock. A loading of zero indicates that sector i is not exposed to safety and liquidity shocks or that preferences are constant over time[4]. Nevertheless, even if $\psi_i^\xi = 0$, sector i's demand still depends indirectly on ξ_t through prices.

[3] I use the approximation that $\log X - \log \overline{X} \doteq \Delta \log X \approx x$.

[4] Treasury inconvenience in would be captured by a negative loading (He, Nagel, & Song, 2022).

For simplicity, I assume that Treasury supply is price-inelastic, but that it varies over time, whereas $s_t^C = 0$ is fixed. Accordingly, $s_t^T = \lambda^S \cdot \eta_t + \varepsilon_t^S$ combines common factors η_t and pure supply shocks ε_t^S. This framework can be extended to accommodate a price-elastic supply curve, as discussed in Section 5.2.4. Starting from the demand curves (2.8), market clearing implies that

$$p_t^T = \frac{1}{\zeta_{S^T}^T} \left\{ \psi_{S^T}^{\xi} \cdot \xi + \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} \tag{2.10}$$

$$p_t^C = \frac{\nu_{S^C}^C}{\zeta_{S^C}^C} \tag{2.11}$$

where $x_{S^j t} = \sum_{i=1}^N S_{it}^j x_{it}$ denotes the share-weighted average of variable x. Given that yields are related to prices by $y_t^j(\tau) = -\frac{1}{\tau} \log P_t^j(\tau)$, where τ denotes maturity, I write $\Delta y_t^j(\tau) \approx -\tau \cdot p_t^j(\tau)$. It follows that the change in the yield spread $\mathcal{S}_t(\tau)$ between the two securities is

$$\Delta \mathcal{S}_t(\tau) = \Delta y_t^C(\tau) - \Delta y_t^T(\tau) = -\frac{1}{\tau} \frac{\nu_{S^C}^C}{\zeta_{S^C}^C} + \frac{1}{\tau} \frac{1}{\zeta_{S^T}^T} \left\{ \psi_{S^T}^{\xi} \cdot \xi + \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} \tag{2.12}$$

Equation (2.12) shows that if the average exposure to safety shocks is positive, then a higher realization of ξ_t widens the spread between Treasury and corporate bonds[5]. However, convenience shocks ξ_t are only a part of the yield spread. Substituting equilibrium prices back into the demand curves gives

$$q_{it}^T = \left\{ \psi_i^{\xi} - \psi_{S^T}^{\xi} \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} \xi_t - \frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T \tag{2.13}$$

Hence, the loading of q_{it}^T on the convenience yield is no longer ψ_i^{ξ}, but a linear combination of price elasticities ζ_i^T and coefficients ψ_i^{ξ}.

The sign of the covariance of quantities q_{it}^T and ξ_t appears to have informative content about the demand loading on non-pecuniary benefits ψ_i^{ξ}. In fact, sectors who need Treasuries to meet regulatory requirements or to execute repo transactions may be willing to accept lowers returns on their debt portfolio. In contrast, sectors that do not draw convenience from Treasuries holdings are more price elastic, and the perceived substitutability with corporate bonds larger (Krishnamurthy & Li, 2022; Krishnamurthy & Vissing-Jorgensen, 2007). In general, however, $\mathbb{C}\mathrm{ov}(q_{it}^T, \xi_t)$ is not necessarily informative about the ordering of ψ_t^{ξ}.

Proposition 2.1 ((Non-)Identification of Preference Parameter ψ_i^{ξ}). *Consider a linear regression model $q_{it}^T = \beta_{i0}^T + \beta_{i1}^T \cdot \xi_t + \epsilon_{it}^T$ based on equation (2.16). Then, the least square estimator of the slope coefficient $\widehat{\beta}_{i1}^{T,OLS}$ converges in probability to*

$$\widehat{\beta}_{i1}^{T,OLS} \xrightarrow{p} \left\{ \psi_i^{\xi} - \psi_{S^T}^{\xi} \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} - \frac{\mathbb{C}ov\left(\frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T, \xi_t \right)}{\mathbb{V}ar(\xi_t)} \tag{2.14}$$

[5] A drawback of this framework is that supply does not show up explicitly in the interest rate spread, as in Kekre and Lenel (2021). For this reason, I later postulate that ξ_t varies with common shocks and Treasury supply.

Furthermore, if ξ_t is orthogonal to latent demand and supply shocks, then $\widehat{\beta}_{i1}^{T,OLS}$ recovers the demand loading on the convenience yield. If all sectors have the same price elasticity, then $\widehat{\beta}_{i1}^{T,OLS}$ is a consistent an unbiased estimator of the preference parameter ψ_i^{ξ}.

Proposition (2.1) reveals that there are two layers of identification challenges. The first is an omitted variable bias due to the fact that ξ_t is potentially correlated with latent demand and supply shocks. Safety or preference shocks are likely to comove with the business cycle, intermediaries constraints, and other latent economic forces, e.g. during a flight to safety, inducing $\mathbb{E}[\xi_t \cdot \eta_t] \neq 0$ (Krishnamurthy & Vissing-Jorgensen, 2012). To the extent that safety or liquidity concerns depend on the outstanding amount of government debt, safety shocks may also be correlated to supply shocks. As a result, the assumption that $\mathbb{E}\left[\xi_t \cdot \eta_t\right] \neq 0$ appears quite strong.

Second, even if supply is fixed and ξ_t is orthogonal to latent demand, the OLS estimator does not recover ψ_t^{ξ}, but a linear combination of price elasticities and convenience loadings ζ_i^T and ψ_i^{ξ}. This is an issue insofar as ζ_i^T varies in a way that makes the ordering of preferences differ from the ordering based on the demand loadings $\psi_i^{\xi} - \psi_{ST}^{\xi}\frac{\zeta_i^T}{\zeta_{ST}^T}$. As in Koijen et al. (2020), negative tilts could arise because sectors are price elastic, and not necessarily because of a high exposure to ξ_t. In this regard, the ordering is identical if $\zeta_i^T = \zeta^T$. However, equation (2.7) shows that heterogeneity in $v_i'(\cdot)$ produces cross-sectional variation of ζ_i^T. Hence, the assumption of identical elasticities is inconsistent with heterogeneity in the valuations of non-pecuniary benefits.

This result revisits the framework of Gabaix and Koijen (2022) by introducing time-varying preferences for non-pecuniary benefits into an otherwise standard demand curve. If elasticities were known, and $\mathbb{E}[\xi_t \cdot \nu_{i,t}^j] = 0$, then OLS estimates can be adjusted to recover ψ_i^{ξ}. Unfortunately, estimates of sector-level elasticities are hard to obtain (Gabaix & Koijen, 2020, 2022). To some extent, ξ_t can be thought of as a characteristic of Treasury securities that affect q_{it}^T (Koijen et al., 2020; Koijen & Yogo, 2019). The difference here, however, is that ξ_t is not only endogenous, but it may respond to supply shocks.

2.3 Identifying Assumptions and Coefficients Interpretation

Proposition (2.1) shows that under general conditions, OLS fails to identify ψ_i^{ξ} even under the strong assumption that latent demand is orthogonal to non-pecuniary benefits ξ_t. This section presents conditions under which $\widehat{\beta}_{i1}^{T,OLS}$ is a consistent estimator of ψ_i^{ξ}. Second, it discusses identifying assumptions under which the ordering of the $\left\{\beta_{i1}^T\right\}_{i=1}^N$ is the same as the ranking of $\left\{\psi_i^{\xi}\right\}_{i=1}^N$. In the latter case, a valid instrument for ξ_t can be used to rank sectors or investors according to their valuation for non-pecuniary benefits without the need to estimate own- and cross-price elasticities.

2.3.1 Identification with OLS

A crude approach is to simplify the demand system by imposing strong assumptions on price elasticities and latent demand. The idea is to restrict factor exposures and elasticities in such a way that latent demand is entirely driven by idiosyncratic shocks while price elasticities are identical across sectors.

Assumption OLS–1 (Identical Price Elasticities ζ_i^T)**.** *Own-price elasticities are the same for all sectors, i.e. $\zeta_i^{jj} = \zeta^{jj}$ for $j \in \{T, C\}$ for all $i \in \{1, \dots, N\}$.*

Assumption OLS–2 (Latent Demand and Idiosyncratic Shocks)**.** *There are no common factors in the demand disturbances* $\nu_{it}^{j} = \lambda_i^j \eta_t + \varepsilon_{it}^j$*, i.e.* $\lambda_i^j = 0$ *for all* $i \in \{1, \ldots, N\}$ *and for* $j \in \{T, C\}$*. Idiosyncratic shocks are uncorrelated to* ξ_t*, i.e.* $\mathbb{E}[\xi_t \varepsilon_{it}^j]$ *for all* $i \in \{1, \ldots, N\}$ *and for* $j \in \{T, C\}$*.*

Assumptions (OLS–1) and (OLS–2) are very strong and any identification strategy that relies on these restrictions is rather implausible. Nevertheless, the purpose of these assumptions is to help illustrate the layers of identification challenges associated to estimation of ψ_i^ξ. Equilibrium demand reduces to

$$q_{it}^T = \xi_t \left\{ \psi_i^\xi - \psi_{S^T}^\xi \right\} + \varepsilon_{it}^T - \varepsilon_{S^T t}^T$$

A linear regression of q_{it}^T on ξ_t recovers $\beta_{i1}^T = \psi_i^\xi - \psi_{S^T}^\xi$ since $\mathbb{E}\left[\xi_t \left(\varepsilon_{it}^T - \varepsilon_{S^T t}^T\right)\right] = 0$. Given that $\psi_{S^T}^\xi$ is the same for every i, the rankings implied by β_{i1}^T and ψ_i^ξ are identical. Yet, this is a very special case, and relaxing assumptions (OLS–1) and (OLS–2) immediately invalidate any identification result. In particular, if ζ_i^T varies across sectors and $\nu_{it}^T = \lambda_i^T \eta_t + \varepsilon_{it}^T$, then equilibrium demand is

$$q_{it}^T = \xi_t \left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} + \eta_t \left\{ \lambda_i^T - \lambda_{S^T}^T \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} + \varepsilon_{it}^T - \frac{\zeta_i^T}{\zeta_{S^T}^T} \varepsilon_{S^T t}^T \tag{2.15}$$

As opposed to Gabaix and Koijen (2022), the parameter of interest is not the own-price elasticity ζ_i^T, but the preference parameter ψ_i^ξ. Equation (2.15) reiterates the two key identification challenges from Proposition (2.1). First, if $\mathbb{E}[\eta_t \xi_t] = 0$, $\widehat{\beta}_{i1}^T$ suffers from an omitted variable bias unless all components of η_t are known and observable. Second, abstracting from biases, the ranking implied by the population parameter $\beta_{i1}^T = \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T}$ is not necessarily the same as the ordering of ψ_i^ξ. Equation (2.15) echoes Gabaix and Koijen (2022) by showing that common factors cannot be used to identify $\zeta_i^T / \zeta_{S^T}^T$.

2.3.2 Instrumental Variable Regression

I now relax assumptions (OLS–1) and (OLS–2) and show how instrumental variables may be useful in recovering ψ_i^ξ even when the price elasticity ζ_i^T varies in the cross section. Equilibrium demand is

$$q_{it}^T = \left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} \xi_t - \frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t} - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T \tag{2.16}$$

So far, I did not impose any structure on ξ_t or its dynamics. Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood et al. (2015) point out that the convenience yield depends on debt supply. Furthermore, it seems plausible that preference shocks are correlated with latent factors such as the business cycle, financing conditions (Du, Im, & Schreger, 2018), or intermediary constraints (Klingler & Sundaresan, 2022). For these reasons, I extend the framework (2.8) – (2.9) by modelling ξ_t as a function $\xi_t = \Lambda(\eta_t, s_t^T)$ of common factors η_t and Treasury supply s_t^T[6]. Accordingly,

$$\xi_t \doteq \Lambda(\eta_t, s_t^T) \tag{2.17}$$

The intuition behind (2.17) is that preference shocks are directly related to Treasury supply[7]. This may be the case if a larger debt float increases investors' perception of safety of Treasuries (He et al., 2019), or if a higher supply improves market liquidity (He et al., 2022; Longstaff, 2004). Additionally, equation (2.17) implies that supply and demand curves are allowed to move together. This approach is tangential to Koijen et al. (2020). A subset of asset characteristics may not be orthogonal to latent demand, i.e. $\mathbb{E}[\xi_t \nu_{it}^T] \neq 0$. Building on the demand system (2.8) – (2.9), I consider the linear model $q_{it}^T = \beta_{i0} + \beta_{1i} \cdot \xi_t + \beta_{2i} \cdot p_t^T + \epsilon_{it}^T$, where I include prices p_t^T in the panel regression model. The reason for doing this will become apparent further below. Market clearing implies

$$p_t^T = \frac{1}{\zeta_{S^T}^T} \left\{ \psi_{S^T}^{\xi} \cdot \xi_t + \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} \tag{2.18}$$

Substituting (2.17) and (2.18) in the linear model shows that in a regression of quantities on prices and ξ_t, both regressors are endogenous. In fact

$$\begin{aligned}
\mathbb{E}\left[\xi_t \cdot \nu_{it}^T\right] &= \mathbb{E}\left[\Lambda(\eta_t, s_t^T)\left(\lambda_i^T \eta_t + \varepsilon_{it}^T\right)\right] \neq 0 \\
\mathbb{E}\left[p_t^T \cdot \nu_{it}^T\right] &= \mathbb{E}\left[\left(\frac{1}{\zeta_{S^T}^T}\left\{\psi_{S^T}^{\xi} \cdot \xi_t + \nu_{S^T t}^T - \lambda^S \cdot \eta_t - \varepsilon_t^S\right\}\right)\left(\lambda_i^T \eta_t + \varepsilon_{it}^T\right)\right] \neq 0
\end{aligned}$$

As far as p_t^T is concerned, the granular instrumental variable (GIV) approach of Gabaix and Koijen (2020) can be used to construct an instrument for the price of Treasuries $Z_t^p \doteq Z_t^{\text{GIV}}$, albeit some adjustments are required to account for ξ_t. In this case, the source of exogenous variation are the idiosyncratic shocks to sector i's demand ε_{it}^T.

The system (2.8)–(2.9) provide guidance with respect to the criteria that instruments for ξ_t, i.e. Z_t^{ξ}, have to meet. Importantly, Z_t^{ξ} has be orthogonal to latent demand. A valid instrument generally satisfies the relevance condition $\mathbb{E}[\xi_t \cdot Z_t^{\xi}] \neq 0$ as well as instrument exogeneity $\mathbb{E}[Z_t^{\xi} \cdot \nu_{it}^T] = 0$ (Wooldridge, 2010). Moreover, the exclusion restriction requires that Z_t^{ξ} affects q_{it}^T solely through ξ_t. The relevance condition seems less of a concern given the recent empirical work on the determinants of interest rate spreads (Greenwood et al., 2015; Nagel, 2016), whereas the exclusion restriction generally depends on the specific applications and are usually harder to test.

[6] This extension is required because I do not observe the latent preference shock ξ_t, but only the equilibrium interest rate spread. In the spirit of Krishnamurthy and Vissing-Jorgensen (2012), the spread varies with supply because of a concave convenience function $v(\cdot)$, i.e. $v''(\cdot) < 0$. If supply increases, the representative agent has to mechanically hold a higher quantity of government debt to make sure that financial markets clear. If marginal convenience is declining, an increase in θ_t^T reduces $v'(\cdot)$, raising P_t^T (and lowering the yield $y_t^T(\tau)$) through the pricing equation (2.4). From this perspective, the convenience shock should be independent of s_t^T. Yet, because $\mathcal{S}_t(\tau)$ is observable but ξ_t is not, (2.17) turns out to be useful to justify instrument variable regressions to identify ψ_i^{ξ} and ζ_i^T.

[7] The economic content of this assumption is subtle, but it is required to bridge theory and data. In fact, in expression (2.12) there is no explicit link between debt supply s_t^T and the yield spread $\mathcal{S}_t(\tau)$ other than through market clearing prices. However, both Krishnamurthy and Vissing-Jorgensen (2012) and Kekre and Lenel (2021) argue that the supply affects the spread through a convenience function. In particular, the convenience yield is exogenous in Kekre and Lenel (2021), and it depends on both a safety shock ω^d and debt supply $-B'_{Ht,s}$. As a result, the function $\Lambda(\eta_t, s_t^T)$ mechanically links s_t^T to $\mathcal{S}_t(\tau)$ by assuming that also the preference shifter varies with supply s_t^T.

In contrast, instrument exogeneity turns out to be much more challenging. A valid instrument for ξ_t has to be orthogonal to latent demand $\nu_{it}^T = \lambda_i^T \eta_t + \varepsilon_{it}^T$. It follows that any instrument for ξ_t^T that exploits exogenous variation from common factors η_t violates instrument exogeneity. For this reason, standard approaches in the literature using aggregate shocks are not well-suited for ξ_t (e.g. Nakamura and Steinsson (2018)). Conversely, a supply shifter may be used as an instrument for the convenience shock ξ_t. Let

$$Z_t^\xi \doteq \varepsilon_t^S \tag{2.19}$$

$$Z_{it}^p \doteq \sum_{i'=1;i'\neq i'}^{N} S_{i't}^T \cdot \varepsilon_{i't}^T \tag{2.20}$$

where Z_t^ξ is given by exogenous supply shocks ε_t^S and Z_{it}^p is the GIV for sector i's demand using the idiosyncratic shocks of all other sectors. Instrument exogeneity is satisfied since

$$\mathbb{E}\left[Z_t^\xi \nu_{it}^T\right] = \mathbb{E}\left[\varepsilon_t^S \nu_{it}^T\right] = 0$$
$$\mathbb{E}\left[Z_{it}^p \nu_{it}^T\right] = \mathbb{E}\left[\left(\lambda_i^T \eta_t + \varepsilon_{it}^T\right) \sum_{i'=1;i'\neq i'}^{N} \varepsilon_{i't}^T\right] = 0$$

given the assumptions that $\mathbb{E}[\varepsilon_{i't}^T \varepsilon_{it}^T] = 0$ and $\mathbb{E}[\eta_t \varepsilon_{it}^T] = 0$. Furthermore, instrument relevance holds because idiosyncratic shocks affect yields through market clearing and supply shocks affect ξ_t via the postulated dependence $\xi_t = \Lambda(\eta_t, s_t^T)$.

Equation (2.16) makes it clear that it is necessary to control for the Treasury price in order for supply shifters Z_t^ξ to be valid instruments. By omitting prices from the linear model, supply shocks and share-weighted shocks ν_{it}^T enter the error term through market clearing. Yet, controlling for prices takes all the supply shocks out of the error term. This comes at the cost of requiring a second instrument Z_{it}^p for Treasury prices. A second advantage of including prices in the panel specification is that an IV regression of quantities on ξ_t does not identify ψ_i^ξ, but a linear combination of $\{\psi_i^\xi\}_{i=1}^N$ and $\{\zeta_i^T\}_{i=1}^N$. The argument holds even if Z_t^ξ is a valid instrument that satisfies both exogeneity and relevance conditions. As a result, IV approaches may be useful to mitigate biases in $\widehat{\beta}_{i1}^T$, but cannot account for heterogenous elasticities unless prices are part of the estimating equation.

3 Data and Variable Construction

I now describes data sources as well as measurement and construction of main variables of interest. The key ingredients for the estimation of the demand curve (2.8) are Treasury quantities q_{it}^T, yields $y_t^T(\tau)$, and the convenience shock ξ_t. I then discuss potential solutions to the problem that convenience shocks are unobservable. Finally, I consider alternate measures of Treasury supply.

3.1 Ownership Structure and Portfolio Shares

Data on holdings and flows at the sector level is from the U.S. Financial Accounts. I denote holdings and transactions as $\mathcal{W}_{it}^{j}$ and F_{it}^{j}, respectively. I follow Gabaix and Koijen (2022) and define the relation between levels and flows as $F_{it}^{j} = \mathcal{W}_{it}^{j} - \mathcal{W}_{i,t-1}^{j} R_{t}^{j}$, where R_{t}^{j} denotes the gross capital gain of security j. I use quarterly unadjusted flows (FU) and holdings reported at market values (LM) whenever possible. To construct changes in quantities q_{it}^{j} adjusted for mechanical price effects, I divide relative flows $\frac{F_{it}^{j}}{\mathcal{W}_{i,t-1}}$ by R_{t}^{j}. I implicitly assume that all transaction happen at the quarter-end. I discuss measurement issues and details about data adjustments in Appendix A.2.

I denote the portfolio share of security $j \in \{C, T\}$ as $\omega_{it}^{j} \equiv \frac{\mathcal{W}_{it}^{j}}{\mathcal{W}_{it}^{D}}$. Total debt securities $\mathcal{W}_{it}^{D}$ include open market paper, Treasury securities, agency- and GSE-backed securities, municipal securities, and corporate and foreign bonds. This has the advantage that portfolios are comparable across sectors. Money market fund shares and security repurchase agreements could in principle be included in that category, but market values are rarely available and data coverage is not uniform for all sectors. I also compute portfolio shares using total financial assets $\mathcal{W}_{it}^{F}$ and as a fraction of total debt and equity securities. $\mathcal{W}_{it}^{D+E}$. Sector i's market share of security j, S_{it}^{j}, is defined as the ratio of sector i's holding $\mathcal{W}_{it}^{j}$ divided by the total amount outstanding. I denote Treasury shares relative to corporate bonds as $\omega_{it}^{R} \doteq \omega_{it}^{T}/\omega_{it}^{C}$.

Sector	N	Start	ω_{it}^{T}	ω_{it}^{C}	S_{it}^{T}	S_{it}^{C}	ω_{it}^{R}
Foreign sector	281	Q1–1952	64.16	18.85	24.36	11.79	5.51
U.S. banks	281	Q1–1952	31.50	10.46	17.67	6.30	5.50
Households and nonprofits	281	Q1–1952	26.28	19.15	11.02	11.52	2.10
State and local governments	281	Q1–1952	55.09	4.49	7.80	0.76	19.86
State and local retirement funds	281	Q1–1952	27.96	44.30	3.68	9.04	0.83
Private pension funds	281	Q1–1952	21.50	51.05	3.22	10.30	0.51
Money market funds	193	Q1–1974	21.41	4.05	3.19	1.02	33.82
Mutual funds	281	Q1–1952	18.79	39.38	2.54	5.51	0.58
Life insurers	281	Q1–1952	7.61	67.01	2.51	34.19	0.12
Property-casualty insurers	281	Q1–1952	20.19	21.16	2.29	3.52	1.35
Brokers and dealers	281	Q1–1952	14.04	31.52	0.16	1.28	1.04

Table 3.1: The table reports sample averages of portfolio weights and market shares for the ten largest sectors by Treasury market share, in addition to the security brokers and dealers. ω_{it}^{T} denote the Treasury share as a fraction of total debt securities $\mathcal{W}_{it}^{D}$. The market share S_{it}^{T} is the ratio between sector i's Treasury holdings and the total amount outstanding. ω_{it}^{C} and S_{it}^{C} are defined analogously for corporate bonds. I adjust for domestic holdings of corporate bonds in Gabaix and Koijen (2022). Data is from the U.S. Financial Accounts and the quarterly sample is from Q1–1952 o Q1–2022.

A major drawback is that the Financial Accounts aggregate holdings of Treasuries and corporate bonds across various dimensions. First, the distinction between Treasury bills and bonds is only available for few selected sectors. Second, holdings of foreign and domestic bonds are pooled together. Third, corporate bonds are pooled together irrespective of maturity and credit rating. As a result, holdings of Aaa corporate bonds and high-grade commercial paper suffers from numerous measurement issues. To address these concerns, I adjust holdings and transactions of corporate bonds and equities for foreign holdings as in Gabaix and Koijen (2022). In addition, I separate marketable and nonmarketable securities based on table L.210, imputing each item to the appropriate sectors as explained in Appendix

A.2. I subsequently recompute total debt securities to ensure that markets clear.

Table 3.1 presents descriptive statistics for portfolio and market shares for the ten sectors with the largest Treasury market share in addition to security brokers and dealers. Table 3.1 shows that long term investors such as pension funds, insurance companies, and retirement funds generally have a higher portfolio share in corporate bonds. In contrast, the debt portfolios of U.S. banks and the foreign sector are more tilted towards Treasuries. The foreign sector is the largest holder of Treasuries, followed by depository institutions and households. Insurance companies and mutual funds together hold less than 10% of the market. Conversely, most of the U.S. corporate debt is held by life insurers, foreign investors, and households.

3.2 Yield Spreads and Convenience Shocks

I follow Krishnamurthy and Vissing-Jorgensen (2012) and define the yield spread $\mathcal{S}_t(\tau)$ between corporate and Treasury securities for long ($\tau = \ell$) and short ($\tau = s$) maturities as

$$\mathcal{S}_t(\tau) = y_t^C(\tau) - y_t^T(\tau) \tag{3.1}$$

Equation (2.12) states that changes in yield spreads are

$$\Delta\mathcal{S}_t(\tau) = \Delta y_t^C(\tau) - \Delta y_t^T(\tau) = -\frac{1}{\tau}\frac{\nu_{SC}^C}{\zeta_{SC}^C} + \frac{1}{\tau}\frac{1}{\zeta_{ST}^T}\left\{\psi_{ST}^{\xi}\cdot\xi_t + \nu_{ST}^T{}_t - \lambda^S\cdot\eta_t - \varepsilon_t^S\right\} \tag{3.2}$$

The variation in $\Delta\mathcal{S}_t(\tau)$ comes from three sources. The contribution of the preference shock is $\frac{\psi_{ST}^{\xi}}{\tau\zeta_{ST}^T}\cdot\xi_t$. The other terms are driven by latent demand ν_{it}^j for Treasuries and corporate bonds. The expression for $\Delta\mathcal{S}_t(\tau)$ is consistent with Krishnamurthy and Vissing-Jorgensen (2012), who decompose yield spreads into a convenience yield, a compensation for expected default of corporate bonds, and a risk-premium that depends on the covariance of default and the stochastic discount factor. The convenience yield on Treasuries only explains a fraction of the yield spread of about 40 to 76 basis points (Krishnamurthy & Vissing-Jorgensen, 2012; van Binsbergen et al., 2022).

A major empirical challenge is that the preference shifter ξ_t is unobservable and hard to measure. A potential solution is to study yield spreads of securities that are virtually identical but for clearly observable non-pecuniary attributes. Nagel (2016) matches the yield on T-Bills with three-month general collateral (GC) repo rates, since both investments are free of credit risk but differ in terms of liquidity. Similarly, Klingler and Sundaresan (2022) consider the maturity-matched overnight index swap (OIS) and the yield on Federal Home Loan Bank (FHLB) discount notes. Although these are likely to be reasonable proxies for ξ_t, I do not observe quantities and holdings specific to these prices in the Financial Accounts. Moreover, despite being available at higher frequencies, these time series generally cover a shorter time period.

For these reasons, I measure ξ_t as the spread between corporate bonds and Treasuries following Krishnamurthy and Vissing-Jorgensen (2012) and Choi et al. (2022)[1]. I construct the long spread as the difference between the Moody's Seasoned Aaa Corporate Bond Yield and the yield long term U.S. Government Securities. The short spread is the difference between the yield on high-grade commercial papers and the yield on T-Bills. Table A.1 in the Appendix describes data sources, and figure A.1 and figure A.2 in the Appendix plot the time series of the yields and the yield spreads, respectively.

	$\mu(\ell)$	$\mu(s)$	$\sigma(\ell)$	$\sigma(s)$	$\rho(\ell,s)$	$\rho_1(\ell)$	$\rho_1(s)$	$\rho_4(\ell)$	$\rho_4(s)$
					Panel A: Levels				
Q1–1920	0.81	0.62	0.41	0.52	0.29	0.93	0.73	0.79	0.49
Q4–1951	0.85	0.52	0.43	0.49	0.21	0.91	0.64	0.74	0.38
Q1–2000	1.03	0.22	0.33	0.27	0.23	0.77	0.60	0.37	0.31
					Panel B: First Differences				
Q1–1920	-0.00	-0.01	0.16	0.38	0.24	-0.15	-0.15	0.05	0.05
Q4–1951	0.00	-0.00	0.18	0.42	0.26	-0.11	-0.11	0.03	0.03
Q1–2000	-0.00	-0.01	0.22	0.25	0.49	-0.16	-0.16	0.03	0.03

Table 3.2: The table reports summary statistics for the long term ($\tau = l$) and the short term ($\tau = s$) yield spread between corporate bonds and Treasuries. I follow Krishnamurthy and Vissing-Jorgensen (2012) and construct the long spread as the difference between the yield on Aaa seasoned bonds and long term government securities. The short spread is the difference between the yield on high-grade commercial papers and three- to six-months Treasury bills. $\mu(\tau)$ and $\sigma(\tau)$ denote average and standard deviation. Further, $\rho(\ell, s)$ is the correlation coefficient between the long and the short spread. whereas $\rho_h(\tau)$ is the h-lag autocorrelation. The quarterly sample is from Q1–1920 to Q4–2021. Data sources are described in Appendix A.1.

Table 3.2 reports summary statistics for long and short term yield spreads. The average long term spread $\mathcal{S}_t(\ell)$ is 0.81%, with a standard deviation of 0.41%. The level of the long spread is highly persistent, whereas changes in $\mathcal{S}_t(\ell)$ are less. The one-lag autocorrelation $\rho_{1,\ell}$ is very close to one, and even at four lags it remains close to 0.80. I also report descriptives for the subsamples after Q1–1951 and Q1–2000. These choices are motivated by the coverage of the Financial Accounts and the regime changes in the U.S. Treasury market, respectively (Du et al., 2022). After Q1–2000, $\mathcal{S}_t(\ell)$ has risen to roughly 1%, but it has become less persistent, whereas the short spread $\mathcal{S}_t(s)$ has narrowed, declining from 0.62% to approximately 0.22% (Du, Im, & Schreger, 2018; He et al., 2022). The long and the short spreads move together, but the linear dependence is moderate. Yet, the correlation has roughly doubled in the years after Q1–2000 as compared to the full sample.

3.3 Treasury Supply and Control Variables

Alternate measurements of Treasury supply follow Greenwood and Vayanos (2014) and Greenwood et al. (2015). I obtain monthly data from the CRSP historical bond database. I aggregate outstanding debt by maturity at each point in time, and then construct a quarterly series using the last available observation. Given that the total outstanding amount held by the public is not always available, I follow Greenwood and Vayanos (2014) and consider the total amount of outstanding debt, which

[1] Rearranging for ξ_t in (3.2) gives $\xi_t = \frac{\tau \Delta \mathcal{S}_t(\tau) \cdot \zeta^T_{ST}}{\psi^\xi_{ST}} + \dot{\nu}^j_{it} + \frac{\lambda^S \cdot \eta_t + \varepsilon^S_t}{\psi^\xi_{ST}}$, where $\dot{\nu}^j_{it}$ is a linear combination of latent demand $\{\nu^j_{it}\}^N_{i=1}$. Therefore, isolating exogenous variation in $\mathcal{S}_t(\tau)$ identifies $\psi^\xi_i \cdot \frac{\tau \Delta \mathcal{S}_t(\tau) \cdot \zeta^T_{ST}}{\psi^\xi_{ST}}$. Given that ζ^T_{ST} and ψ^ξ_{ST} are constants that do not vary across sectors, the ordering of ζ^T_{ST} and ψ^ξ_{ST} is the same.

includes both public and intragovernmental holdings. I separate coupon and principal payments to construct maturity-weighted debt supply. To ensure that all outstanding securities are accounted for, I cross-check the aggregate series with the monthly statement of public debt (MSPD) and table L.210 of the Financial Accounts. I plot debt supply in figure A.3 in the Appendix and refer to Greenwood and Vayanos (2014) for data construction. I then construct the yield on the portfolio of government debt as the weighted average of yields across all maturities, where the weights are given by the amount outstanding with a given maturity divided by total debt.

I obtain quarterly series on gross (real) domestic product, inflation, and industrial production from FRED[2]. I measure the output gap by running a Hodrick and Prescott (1997) filter on log GDP. As far as financial variables are concerned, I download time series on oil prices, TED spread, the implied volatility index (VIX), and the Federal Funds Rate from FRED[3]. Following the literature on intermediary constraints, I compute the primary dealer tender-to-cover ratio using auction data from TreasuryDirect (Klingler & Sundaresan, 2022). Finally, I obtain data on repo volume from the Primary Dealer statistics. Tables E.1, E.2, and E.3 in the Appendix report exploratory regressions of yield spreads on macroeconomic indicators, financial constraints, and measures of intermediaries balance sheet costs. Since these regressions only measure correlations across variables, I do not discuss the results any further.

4 Empirical Results

I build on Section 2.1 and specify the demand curve for Treasuries as in (2.8), that is

$$q_{it}^T = -\zeta_i^T \cdot p_t^T + \psi_i^\xi \cdot \xi_t + \nu_{it}^T \tag{4.1}$$

I follow the structure of the theoretical analysis, but I replace prices with yields using $p_t^j \approx -\tau \Delta y_t^j$. I present least squares and instrumental variable estimates under the assumption that $\kappa^C = 0$. I perform robustness checks with portfolio weights, market shares, and auction allotments.

4.1 OLS Estimates of Preference Parameters

In the baseline specification, I maintain assumptions (OLS–1) and (OLS–2). I first consider the panel regression model

$$q_{Et}^T = \beta_0 + \beta_1 \cdot \Delta \mathcal{S}_t(\tau) + \boldsymbol{\beta}_2 \boldsymbol{x}_t^{\text{macro}} + \boldsymbol{\beta}_3 \boldsymbol{x}_t^{\text{fin}} + \boldsymbol{\beta}_4 \boldsymbol{x}_t^{\text{int}} + \epsilon_{it}^T \tag{4.2}$$

where q_{Et}^T denotes the equally-weighted average $\frac{1}{N}\sum_{i=1}^N q_{it}^T$ of the flows across sectors, and $\boldsymbol{x}^k$ is a vector of controls that includes macroeconomic variables $\boldsymbol{x}_t^{\text{macro}}$, financial indicators $\boldsymbol{x}_t^{\text{fin}}$, and measures of intermediaries balance sheet constraints $\boldsymbol{x}_t^{\text{int}}$. Table 4.1 reports OLS estimates of specification (4.2) for both the long term and the short term spread. In column (2), a one percentage point increase in the long term spread $\mathcal{S}_t(\ell)$ is associated with a 6.77% decline in Treasury holdings. Coefficient estimates

[2] The series codes are GDP, GDPC1, CPILFESL, DPCERD3Q086SBEA, and INDPRO.
[3] The series codes are WTISPLC, TEDRATE, VIXCLS, and FEDFUNDS.

are stable when controlling for macroeconomic and financial indicators, as reported in columns (3) and (4). The inclusion of measures of intermediaries excess demand does not substantially alter the estimates, but some significance is lost. In contrast, columns (6) through (9) reveal that Treasury flows do not respond to changes in short term spreads. The exception is column (10), which shows a negative and statistically significant relation between Treasury demand and the short spread $\mathcal{S}_t(s)$. A one percentage point increase in the short term spread reduces Treasury holdings by 4.10%.

	q^T_{Et} – **Long term spread**				q^T_{Et} – **Short term spread**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\mathcal{S}_t(\ell)$	-6.77***	-5.41***	-5.75***	-5.44***				
	[-5.69]	[-4.50]	[-4.43]	[-4.11]				
$\Delta\mathcal{S}_t(s)$					-1.50	-0.67	-1.13	-4.10***
					[-1.63]	[-0.68]	[-0.98]	[-3.26]
Macro	No	Yes	No	No	No	Yes	No	No
Fin	No	No	Yes	No	No	No	Yes	No
Int.	No	No	No	Yes	No	No	No	Yes
N	143	143	128	55	143	143	128	55
R^2	0.16	0.21	0.35	0.48	0.01	0.12	0.26	0.15

Table 4.1: The dependent variable is the average percentage change in holdings q^T_{Et} across sectors. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. Financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q1–1986 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

A potential interpretation is that the marginal convenience $v'(\cdot)$ is lower when agents are holding more Treasuries. In fact, yield spreads are lower when Treasury debt supply is large relative to gross domestic product. Since the demand side must hold the total amount of outstanding debt, an increase in debt supply means that some sectors must be holding a larger quantity of Treasuries. Hence, the negative coefficient mirrors the supply effects shown in Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood et al. (2015). This resonates with the established negative relation between long term spreads and Treasury supply. It also suggests that supply effects are more modest for money market assets such as T-Bills. Nagel (2016) shows that the explanatory power of Treasury supply disappears once the opportunity cost of money is accounted for. The larger magnitude in column (10), however, hints at a regime change in the Treasury market in the later part of the sample. d'Avernas and Vandeweyer (2022) document supply effects for money market assets in the period after 2008. Given that the sample in column (10) is much shorter, these results indicate that yield spreads respond to supply changes at all maturities, and especially so in the aftermath of the Great Financial Crisis. This seems to be consistent with the existence of local supply effects in the yield curve (D'Amico & King, 2013).

I then repeat the same analysis, but I now control for the yield on Treasuries. Accordingly, I estimate the panel regression

$$q_{Et}^T = \beta_0 + \beta_1 \cdot \Delta\mathcal{S}_t(\tau) + \beta_2 \cdot \Delta y_t^T(\tau) + \boldsymbol{\beta}_3\boldsymbol{x}_t^{\text{macro}} + \boldsymbol{\beta}_4\boldsymbol{x}_t^{\text{fin}} + \boldsymbol{\beta}_5\boldsymbol{x}_t^{\text{int}} + \epsilon_{it}^T \tag{4.3}$$

The purpose of specification (4.3) is to explore if yield spreads have explanatory power over and above Treasury yields. I assess the seriousness of omitted variable biases, by providing benchmark estimates for instrumental variable regressions later in this section. Table 4.2 reports regression estimates of specification (4.3). The negative and significant relation between long spreads and Treasury holdings is robust to the inclusion of Treasury yields. In contrast, short spreads lose any explanatory power once I control for $\Delta y_t^T(s)$. The magnitudes of the coefficients are comparable to table 4.1.

	q_{Et}^T – **Long term spread**				q_{Et}^T – **Short term spread**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta\mathcal{S}_t(\ell)$	-5.36***	-3.48**	-4.27***	-5.56***				
	[-3.70]	[-2.37]	[-2.75]	[-3.14]				
$\Delta y_t^T(\ell)$	1.15*	1.47**	1.14	-0.09				
	[1.67]	[2.16]	[1.63]	[-0.10]				
$\Delta\mathcal{S}_t(s)$					-0.93	0.36	-0.70	-1.81
					[-1.01]	[0.36]	[-0.62]	[-1.16]
$\Delta y_t^T(s)$					2.08***	2.37***	1.89**	3.95**
					[2.77]	[3.25]	[2.49]	[2.28]
Macro	No	Yes	No	No	No	Yes	No	No
Fin	No	No	Yes	No	No	No	Yes	No
Int.	No	No	No	Yes	No	No	No	Yes
N	143	143	128	55	143	143	128	55
R^2	0.18	0.23	0.36	0.48	0.09	0.20	0.31	0.25

Table 4.2: The dependent variable is the average percentage change in holdings q_{Et}^T across sectors. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. Financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q1–1986 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

Even though tables 4.1 and 4.2 illustrate a suggestive relation between Treasury holdings and long spreads, specification (4.2) and specification(4.3) identify the aggregate loading ψ_i^ξ on convenience shocks ξ_t under the very restrictive assumptions (OLS–1) and (OLS–2).

4.1.1 Heterogeneous Loadings on Convenience Shocks

Estimates in table 4.1 and 4.2 explores how aggregate flows react to yields and spreads. I allow for heterogeneous slope coefficients β_{i1} by interacting $\mathcal{S}_t(\tau)$ with sector dummies. I maintain assumptions (OLS–1) and (OLS–2) so that a linear regression of quantities q_{it}^T on non-pecuniary benefits recovers $\psi_i^\xi - \psi_{ST}^\xi$. Because the share-weighted valuation ψ_{ST}^ξ is the same for all sectors, the preference rankings implied by $\psi_i^\xi - \psi_{ST}^\xi$ and ψ_i^ξ are identical.

I therefore augment specification (4.3) such that

$$q_{it}^T = \beta_0 + \beta_{i1} \cdot \Delta \mathcal{S}_t(\tau) + \beta_{i2} \cdot \Delta y_t^T(\tau) + \boldsymbol{\beta}_3 \boldsymbol{x}_t^{\text{macro}} + \boldsymbol{\beta}_4 \boldsymbol{x}_t^{\text{fin}} + \boldsymbol{\beta}_5 \boldsymbol{x}_t^{\text{int}} + \delta_i + \epsilon_{it}^T \tag{4.4}$$

Specification (4.4) is the estimating equation corresponding to (2.8). I control for macroeconomic and financial indicators, as well as measures of intermediary excess demand.

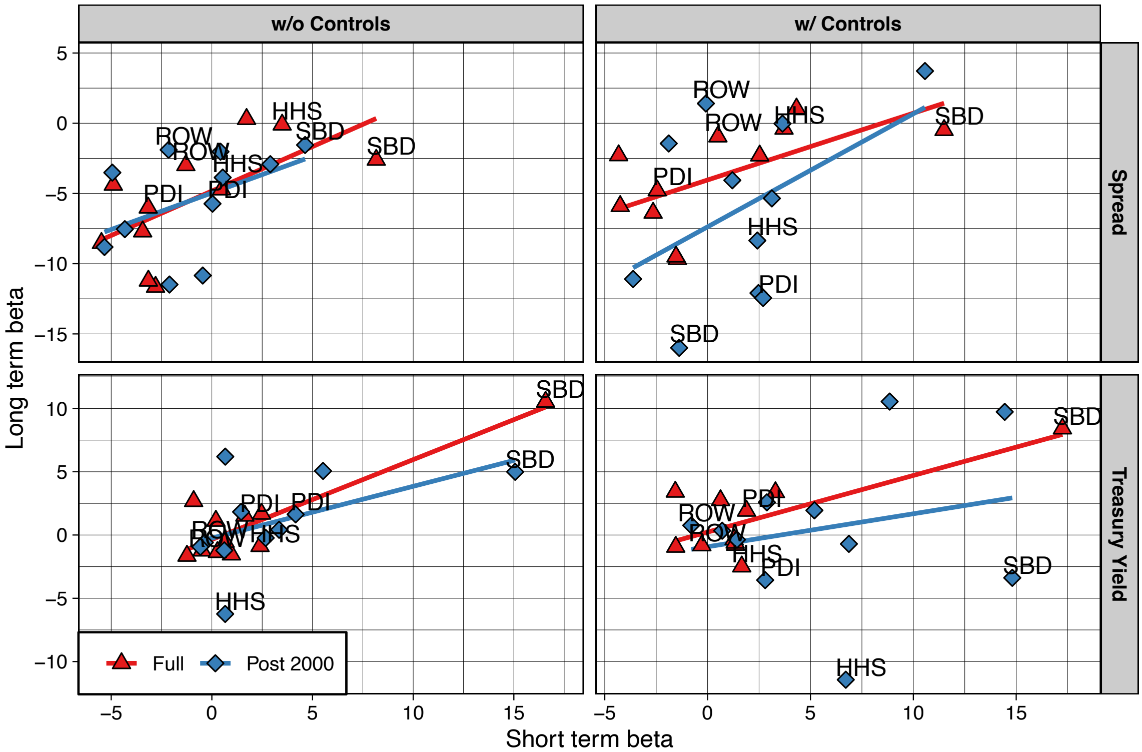

Figure 4.1: The figure plots slope coefficient estimates for specification (4.3). The long (short) term beta is the coefficient obtained when long (short) term spreads are included in the regression. The two top and bottom panels plot the slope coefficients for the change in yield spreads and the change in yield, respectively. The dependent variable is the percentage change in holdings q_{it}^T across sectors. The long and the short term yield spreads $\Delta \mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). I control for macroeconomic and financial indicators. The macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. The financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. The quarterly sample is from Q1–1986 to Q4–2021. The subsample is from Q1–2000 to Q4–2021.

Figure 4.1 plots the coefficient estimates for β_{i1} and β_{i2} obtained with and without controls. I repeat the same analysis in the subsample after the year 2000 to assess the extent to which regime changes in the Treasury market may have affected the perception and the valuation of non-pecuniary benefits (Du et al., 2022; d'Avernas & Vandeweyer, 2022). The horizontal axis depicts the short term flow β_{i1}, whereas the vertical axis plots its long term counterpart.

There is a positive relation between long term and short term β_{i1}. Sectors that are more sensitive to changes in long term spreads also tend to be more responsive to changes in short term spreads. The slope remains positive in both subsamples and after including the vector of controls $\boldsymbol{x}_t$. In contrast, the relation between short term and long term price elasticities is more muted. The positive slope seems to be driven by the high price elasticity of security brokers and dealers (SBD in figure 4.1). There is substantial variation in the coefficient estimates both $\mathcal{S}_t(\tau)$, whereas yield elasticities are clustered around zero with the exception of security brokers and dealers.

Figure 4.1 produces preliminary evidence that loadings on ξ_t are most likely different across sectors. Although the magnitude is hard to interpret because of endogeneity concerns, the substantial cross-sectional variation in coefficient estimates is unlikely to be solely driven by estimation biases. Indeed, to the extent that latent demand ν_{it}^T is positively correlated cross-section, the sign of the omitted variable bias is presumably the same for at least a subset of the sectors. This occurs whenever $\mathbb{E}[\nu_{it}^T \cdot \nu_{i't}^T] = \lambda_i^T \cdot \Sigma_\eta \cdot \lambda_{i'}^T$, where Σ_η denotes the variance matrix of η_t. Nevertheless, a major issue with specification (4.4), however, is that both the Treasury yield and $\mathcal{S}_t(\tau)$ are endogenous.

4.2 Instrumental Variable Estimates

In this section, I relax assumptions (OLS–1) and (OLS–2) by building on the postulated relation between convenience shocks ξ_t and supply through $\Lambda(\eta_t, s_t)$. I show that exogenous shocks to Treasury supply are associated to the level of the long term spread, but not to the short spread. Subsequently, I present instrumental variable estimates of ψ_i^ξ and ζ_i^T.

4.2.1 Unexpected Military News

To construct an instrument for $\mathcal{S}_t(\ell)$, I follow Choi et al. (2022) and build on Ramey (2011) and Ramey and Zubairy (2018). Note that the dependent variable is no longer the change in the yield spread $\Delta\mathcal{S}_t(\tau)$, but its level $\mathcal{S}_t(\tau)$. This choice is motivated by theoretical models linking supply and the level of the yield spread (Kekre & Lenel, 2021; Krishnamurthy & Vissing-Jorgensen, 2012). To some extent, a similar relation should be observed in first differences[1]. Yet, both the debt-to-GDP ratio and the yield spread are highly persistent. Hence, there is not enough variation to induce changes in the yield spread at quarterly frequencies.

Ramey (2011) constructs a series of military expenditure shocks based on a narrative approach in the spirit of Romer and Romer (2010). The intuition behind the instrument is that defence expenditure is driven by military events that are orthogonal to latent demand (Choi et al., 2022), but that are potentially correlated with convenience or safety shocks. The point can be made that safety and liquidity attributes could become more valuable during times of higher uncertainty and market turmoils, providing another channel through which military shocks affect Treasury convenience. The approach differs from VAR analysis à la Blanchard and Perotti (2002) in the sense that shocks to public expenditures are identified by reviewing historical sources and newspapers. Another strength of this approach is that defence spending is often induced by foreign turmoils or major political events that are unrelated to the U.S. economy.

[1] To better reconcile this section with the identification framework, the supply effects should be present in first differences as well. Nevertheless, the high-frequency variation in debt-to-GDP ratios is fairly small. Further, depending on the functional form of $v(\cdot)$, equation (2.7) could in principle accommodate both the level of ξ_i or its change.

I obtain the military shock series from Ramey and Zubairy (2018), which I denote as $\mathcal{N}_t^{\text{Military}}$. I follow Choi et al. (2022) and construct the instrument Z_t^{ξ} as

$$Z_t^{\xi} = \sum_{s=t-t_1}^{s=t-t_2} \mathcal{N}_t^{\text{Military}}$$

so that the shock series $\mathcal{N}_t^{\text{Military}}$ only affects public debt with a certain lag. I select the time interval $(t_1, t_2) = (34, 10)$ that maximizes the first-stage F-statistic from a bivariate regression of $\mathcal{S}_t(\tau)$ on Z_t^{ξ} and $\Delta y_t^T(\tau)$. I report the first-stage estimates in E.4. To inspect the sensitivity of Z_t^{ξ} to the choice of t_1 and t_2, Figure A.5 plots first-stage F-statistics for a range of values $t_1 \in [1, 10]$ and $t_2 \in [1, 50]$. The first stage is robust to different selection of leads and lags, and the pattern is qualitatively similar to Choi et al. (2022). Yet, the magnitude of the F-statistics is generally an order of magnitude lower. I repeat the same procedure with arbitrary values $t_1 = 40$ and $t_2 = 5$ as in Choi et al. (2022) and find no substantial difference. Figure A.3 in the Appendix plots the military expenditure shock series from Ramey and Zubairy (2018).

Column (1) of table E.4 in the Appendix documents a positive relation between military shocks and long spreads. An increase in Z_t^{ξ} raises the long spread, and the effect is strongly significant even when controlling for the long term yield. The negative effect of $\Delta y_t^T(\ell)$ is mostly a mechanical effect. In contrast, military shocks do not induce movements in short term spreads. Overall, the F-statistic is very low irrespective of the selection of t_1 and t_2. The increase in column (5) and (6) is mostly due to the inclusion of control variables that have a strong explanatory power for short spreads. Estimates remain positive but the magnitude declines when controlling for macroeconomic indicators. Controlling for intermediary constraints reduces both the magnitude and significance of the estimates. This may be due to the shorter sample for which data on repo activities and Treasury auctions are available or by regime changes in the Treasury market. An interpretation for the positive coefficient is that military shocks partially capture convenience of safety shocks, rendering the safety attributes of Treasuries more attractive.

The positive link between supply shocks and yield spreads in table E.4 is hard to reconcile with the existing evidence that yield spreads are inversely related to supply. Krishnamurthy and Vissing-Jorgensen (2012) debate that Treasury supply is unlikely to react in order to accommodate demand shocks ξ_t. However, Choi et al. (2022) suggest that the U.S. government may act as a monopolist over non-pecuniary benefits. That would introduce an upward bias in the relation between spreads and Treasury supply. Most importantly, supply shocks may be correlated to convenience shocks ξ_t through a safety channel. To the extent that both debt-to-GDP and demand for safe assets increase during times of uncertainty or market turmoil, the decline in marginal utility from holding more Treasuries may be partly offset by convenience shocks ξ_t.

A second candidate interpretation is that unanticipated military expenditures capture some component of the safety shocks. Equation (3.2) shows that the spread is positively related to ξ_t provided that aggregate exposure to convenience shocks ψ_t^{ξ} is positive. As a result, an higher realization of ξ_t increases the spread $\mathcal{S}_t(\tau)$. He et al. (2019) argue that a decline in world absolute fundamentals further reinforces the safe asset status of the U.S. debt. Furthermore, a military foreign event is likely associated with a decline in the global supply of safe assets, driving up the premium that investors are willing to pay to hold Treasuries during a flight-to-safety (Caballero & Farhi, 2017).

Other popular supply shifters are less suitable to this application. The seasonal IV proposed by Greenwood et al. (2015) cannot be used at quarterly frequency. Interpolating quarterly series to monthly series as in Krishnamurthy and Li (2022) could be a solution, but it would lead to other issues pertaining the interpolation method. In a similar analysis, Krishnamurthy and Vissing-Jorgensen (2007) instrument sector i's Treasury holdings with the total stock of Treasury debt, arguing that the instrument is valid unless changes in the stock of Treasury debt are correlated with sector i's latent demand ν_{it}^T beyond the observable controls. While that may be plausible, the instrument is endogenous unless the specification does not explicitly control for Treasury yields $y_t^T(\tau)$. Finally, military expenditure shocks seem to be better-suited to capture safety and convenience shocks.

4.2.2 Demand Elasticities and Preference Parameters

Given the absence of a strong first stage for the short term spread, I implement the IV procedure for the long spread $\mathcal{S}_t(\ell)$ only. Table 4.3 presents two-stage least square estimates of the panel specification

$$q_{Et}^T = \beta_0 + \beta_1 \cdot \mathcal{S}_t(\ell) + \beta_2 \cdot \Delta y_t(\ell) + \beta_3 \boldsymbol{x}_t^{\text{controls}} + \varepsilon_t^T \tag{4.5}$$

where q_{Et}^T is the equally-weighted average of Treasury flows. I instrument for $\mathcal{S}_t(\ell)$ and $\Delta y_t(\ell)$ with Z_t^ξ and Z_t^p, respectively. Columns (1) to (3) report OLS estimates as a benchmark, whereas columns (4) through (9) report IV estimates. I first instrument only the spread $\mathcal{S}_t(\ell)$ in order to assess omitted variables biases when prices are endogenous and not instrumented for. I exploit the granular instrumental variable to instrument for the Treasury yield $\Delta y_t(\ell)$ in columns (7) to (9). In specification (4.5), β_1 is the semi-elasticity of Treasury demand to the yield spread, whereas β_2 is the demand elasticities to yields. Since $\tau \Delta y_t^T(\tau) \approx -p_t^T$, estimates can be directly converted into price elasticities.

Columns (7)–(9) in table 4.3 report estimates for the macro yield $-\tau\zeta_{ST}^T$ and the aggregate demand loading ψ_{ST}^ξ. With no controls, the estimated macro elasticity is 15.72 and it is statistically significant at the 10% level. The macro elasticity is 18.49 when controlling for real GDP growth, but standard errors are big. The coefficient estimate declines slightly to 14.70 after accounting for the output gap. A back-of-the-envelope calculation assuming a maturity of $\tau = 15$ gives a price elasticity of 1.23 and 0.98 for column (8) and column (9), respectively[2]. With an average maturity of $\tau = 5$ years, the price elasticity jumps to 3.70 and 2.94. These magnitudes are comparable with a price elasticity of 4.2 for long term bonds from Koijen and Yogo (2020). Similarly, Choi et al. (2022) find a demand elasticity of 1.53, which is very close to the estimates in columns (8) and (9). These results are also consistent with Brooks et al. (2018), who estimate a demand elasticity of roughly 2.7, but also assume an average duration of 5 years.

[2] The long-term spread is given by the the difference between the yield on long term Treasuries and the yield on seasoned Aaa corporate bonds. Until 2000, Krishnamurthy and Vissing-Jorgensen (2012) use the average yield on Treasuries with no less than 10 years to maturity. They use the yield on 20 year maturity bond only from 2000 onwards. Hence, setting $\tau = 15$ seems reasonable and in line with the underlying time series.

In contrast, the evidence about β_1 is mixed. Estimates in columns (7)–(9) are positive and have reasonable magnitude, but standard errors are very large. Based on the estimates in column (8), a 1% increase in the yield spread induces an increase of 4.82% in Treasury demand. The positive sign is consistent with an aggregate positive exposure to convenience shock $\psi^{\xi}_{ST} > 0$ as shown in equation (2.6). On the one hand, the sign of the coefficient is not consistent with Krishnamurthy and Vissing-Jorgensen (2012) and Nagel (2016). Rather, it implies that investors are buying more Treasuries when the spread increases. On the other hand, a military expenditure shock is arguably a safety shock ξ_t. A positive ξ_t increases the marginal convenience of each additional Treasury bond, so that the same quantity of Treasuries produces a higher marginal convenience. Potentially, investors may seek refuge in Treasuries during periods of global turmoil and uncertainty. As compared to the baseline OLS specification, estimates move from slightly positive to negative, indicating that the IV is somewhat effective at mitigating omitted variable biases. Nevertheless, standard errors are very large, and I cannot reject the null $\beta_1 = 0$ even at a 10% significance level.

	OLS			**Military News**			**Military News + GIV**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\mathcal{S}_t(\ell)$	0.41	0.33	0.38	8.15	10.59	11.06	7.28	4.82	6.57
	[0.24]	[0.26]	[0.32]	[1.45]	[1.33]	[1.43]	[1.05]	[0.39]	[0.59]
$\Delta y^T_t(\ell)$	2.00***	2.02***	1.81***	3.24***	2.93**	2.84**	15.72*	18.49	14.70
	[3.45]	[3.38]	[3.17]	[2.70]	[2.54]	[2.55]	[1.93]	[1.24]	[1.10]
GDP Growth		-0.09	0.20		2.21	2.49		-2.07	-0.82
		[-0.42]	[0.87]		[1.16]	[1.32]		[-0.38]	[-0.17]
Output Gap			-61.99***			-107.39**			-85.58
			[-2.78]			[-2.17]			[-1.41]
Constant	-0.36	-0.23	-0.52	-7.37	-10.94	-11.54	-5.89	-2.27	-4.83
	[-0.22]	[-0.19]	[-0.46]	[-1.52]	[-1.36]	[-1.48]	[-0.96]	[-0.15]	[-0.36]
				Weak identification test					
CD Statistic				(18.05)	(12.04)	(11.87)	2.96	1.02	0.91
SY Critical Value							[3.95]	[3.95]	[3.95]
N	144	144	144	120	120	120	120	120	120
R^2	0.07	0.07	0.16						

Table 4.3: The dependent variable is the average percentage change in holdings q^T_{Et} across sectors. The long term yield spread $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries is measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). I instrument yield spreads using the unexpected military expenditure series of Ramey (2011) and Ramey and Zubairy (2018). I obtain military news from Ramey and Zubairy (2018), but the sample ends in Q4–2015. I instrument the Treasury yield with the granular instrumental variable of Gabaix and Koijen (2022). I report Cragg and Donald (1993) statistics together with Stock and Yogo (2005) critical values to test the hypothesis of weak instruments. Newey and West (1987) t-statistics (4 lags) are reported in brackets. The quarterly sample is Q1–1986 to Q4–2015.

The large standard errors are most likely explained by a weak first stage when both the Treasury yield and the spread $\mathcal{S}_t(\ell)$ are instrumented for. Table 4.3 reports Cragg and Donald (1993) together with the Stock and Yogo (2005) critical values to test for weak identification. In columns (4) to (6) I report CD statistics in parenthesis only for completeness[3] because I am not instrumenting for all endogenous regressors. In columns (7) to (9), the CD statistic is very small, and I cannot reject the

[3] Given that I am not instrumenting for all endogenous regressor, the a comparison with the Stock and Yogo (2005) critical values is hard to interpret.

null of a weak instrument at the 5% significance level. Hence, granular instrumental variable and the military expenditure shocks appear to be weak instruments. Although some power can be gained by extending the time series of military shocks and q_{it}^T, this raises some concerns about the IV approach.

In order to provide some support for the macro elasticity estimates in table 4.3 , I estimate the demand elasticity for Treasuries but ignoring convenience shocks. To this purpose, I borrow again from Gabaix and Koijen (2022) and implement the granular instrumental variable in the Treasury market. I report GIV estimates in table C.2 in the Appendix. I estimate a yield elasticity of 12.30 when controlling for GDP growth and a single principal component. Assuming again an average maturity of 5 years, this implies that the price elasticity is roughly 2.5. The magnitudes of the estimates are in line with those reported in columns (7) and (9) of table 4.3.

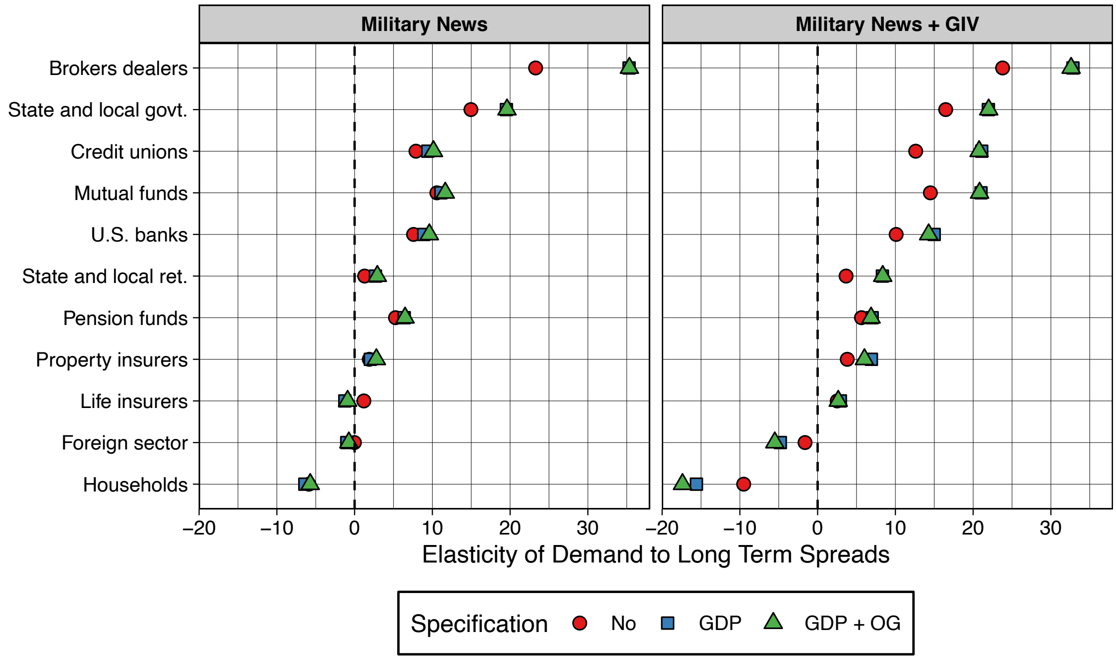

Figure 4.2: The figure plots the sector-level ranking of ψ_i^ξ implied by the IV estimates of specification 4.5 estimated for each sector. The dependent variable is the average percentage change in holdings q_{Et}^T across sectors. The long term yield spread $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries is measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). I instrument yield spreads using the unexpected military expenditure series of Ramey (2011) and Ramey and Zubairy (2018). I obtain military news from Ramey and Zubairy (2018), but the sample ends in Q4–2015. I instrument the Treasury yield with the granular instrumental variable of Gabaix and Koijen (2022). The baseline specification has no controls. I subsequently add GDP and output gap (OG). The quarterly sample is from Q1–1986 to Q4–2015.

I repeat the same estimation procedure and regress q_{it}^T on the Treasury yield and the yield spread for each sector separately. While Z_t^ξ does not require any adjustment, the granular instrumental variable hat to exclude sector i's own idiosyncratic demand shocks to ensure that instrument exogeneity holds. The rest of the procedure is otherwise identical to specification 4.5. Abstracting from measurement issues, the yield spread can be thought of as capturing some aspects of ψ_i^ξ. A less elastic response to $\mathcal{S}_t(\tau)$ does, in all likelihood, reflect a comparatively higher loading on ξ_t. In contrast, sectors who do not draw benefits from convenience services are likely to be more sensitive to price differentials. In some sense, β_{i1} captures some elements related to degree of substitutability that sector i imputes to

Treasuries and corporate bonds (Nagel, 2016).

The right panel depicts estimates obtained by instrumenting both the spread and the Treasury yield. For comparison, the left panel of figure 4.2 plots the estimated demand semi-elasticities to the long term spread $\mathcal{S}_t(\ell)$ obtained by only instrumenting the yield spread. For clarity, I rank sectors based on the estimated loadings that I obtain after instrumenting both endogeneous regressors $\mathcal{S}_t(\ell)$ and $y_t^T(\ell)$ and controlling for real GDP growth. I only report estimates for the sectors that have positive holdings of corporate bonds at any time throughout the sample, as that rules out ex-ante any interpretation in terms of substitution between corporate bonds and Treasuries. I also drop money market funds because they mostly hold near-money assets and short term securities.

Households and long term investors have the smallest loading on yield spreads. On the other side of the spectrum, the sectors that care the most about convenience are the state and local governments, the U.S. private depository institutions, and the security brokers and dealers. Estimates for mutual funds, insurance companies, and the foreign sector fall somewhere in between. Semi-elasticities range from a minimum of roughly -20 for households to a maximum of approximately 35 for security brokers and dealers. The ordering is stable across specifications, but estimates have a smaller magnitude with no controls are included. A major concern of these estimates is that standard errors are very large[4]. In fact, despite a substantial cross-sectional variation in the demand semi-elasticities to $\mathcal{S}_t(\tau)$, estimates are virtually never statistically significant.

State and local governments have the second highest loading on yield spreads, suggesting that they do not perceive corporate bonds and long term Treasuries as close substitutes. Special demand from state and local governments is consistent with the arguments of Chalmers (1998) that municipal bonds are generally secured using long term Treasury bonds. The extent to which the financing of municipalities relies on availability of Treasuries may help rationalize the fact that state and local governments are less sensitive to price spreads than other sectors. Foreign demand is quite sensitive to convenience shocks. Insofar as foreign investors are driven by safety motives rather than by liquidity concerns, Aaa corporate bonds are potentially closer substitutes to Treasuries. To the extent that the perception of safety has declined in recent years, anecdotal evidence seems to support this interpretation. During the Great Financial Crisis, a sharp increase in foreign demand was associated with a large increase of the spread between AAA corporate bonds and Treasuries. During the recent Covid-19 crisis, the convenience yield vaporized after a drop in foreign demand (He et al., 2022).

Endogeneity concerns may still affect point estimates. However, this is less of a concern for the ordering $\{\psi_i^\xi\}_{i=1}^N$. The inclusion of Treasury yields addresses the concern that price elasticities may vary in the cross-section. Furthermore, it ensures that Z_t^ξ is a valid instrument by taking out supply shocks from the error term. The ordering is broadly consistent with Krishnamurthy and Vissing-Jorgensen (2007), and it confirms that groups less concerned by liquidity and neutrality motives are more sensitive to variation in long spreads. In contrast, the demand of the sectors for which liquidity attributes are

[4]The granular instrumental variable exploits exogenous variation from the idiosyncratic shocks of each sector. Unfortunately, the Financial Accounts provide a very aggregated description of the Treasury market, and the number of sectors is fairly small. A potential approach is to assume $\zeta_i^T = \zeta^T$ for all i. Yet, this is likely inconsistent with the heterogeneous valuations of non-pecuniary attributes.

more valuable is less responsive to ξ_t. This is the case for depository institutions, security brokers and dealers, and credit unions[5].

The ordering of the β_{i1} in figure 4.2 suggests that safety is a secondary concern with regard to liquidity and neutrality even for long term spreads. Furthermore, it reveals that corporate and Treasury bonds are close substitutes for at least some sectors, but imperfect substitutes for many others. In particular, convenience services of Treasury bonds are more valuable to banks and security brokers and dealers. In contrast, long term Treasuries and Aaa corporate bonds are better substitutes for households, pension funds, and insurance companies. Hence, an increase in the yield spread generates smaller flows from sectors that hold Treasuries for convenience services that cannot be found elsewhere. The ownership structure in table 3.1 is consistent with the claim that corporate bonds are better substitutes for life insurers and private pension funds, whereas U.S. banks and brokers dealers use Treasuries for regulatory or liquidity purposes that cannot be otherwise fulfilled by corporate bonds.

4.3 Long Term and Short Term Convenience

Krishnamurthy and Vissing-Jorgensen (2012) emphasize that the type of safety attributes associated to convenience yields are potentially a function of maturity. Hence, there is a sharp distinction in convenience drawn from long term assets relative to short term assets. This interpretation points towards a preferred habitat hypothesis of the term structure (Modigliani & Sutch, 1966), which partially attributes differences in the underlying sources of special demand at various maturities to heterogeneity of long term and short term convenience services. While $\mathcal{S}_t(s)$ likely reflects short term safety and liquidity attributes, $\mathcal{S}_t(\ell)$ captures long term safety (Krishnamurthy & Vissing-Jorgensen, 2012).

Figure 4.2 shows that perceived non-pecuniary benefits and exposure to convenience shocks vary in the cross-section of investors. Sectors with longer investment horizons, such as pension funds and insurance companies, are less willing to accept lower returns on their debt portfolios, and also appear less responsive to convenience shocks. In contrast, the sectors with a higher ψ_i^{ξ} are those for which the liquidity motives matter the most (Krishnamurthy & Vissing-Jorgensen, 2007). This is the case for private depository institutions and brokers dealers. These sectors are willing to pay a premium to hold Treasuries over corporate bonds. Regulatory requirements and institutional features are also likely to play a role, given that long term Treasuries are eligible for repo transactions with the Federal Reserve system, as well as to meet risk-weighted capital requirements.

4.3.1 Drivers of Long and Short Spreads

In the context for Section 2.1, the distinction between long term and short term safety is modeled by augmenting the function $v(\cdot)$ such that

$$v_{i,\tau}(\cdot) = v_{i,\text{liq}}\left(\frac{\theta_t^T + \kappa^{\text{liq}}\theta_t^{C,\text{liq}}}{\text{GDP}_t}; \xi_{it}^{\text{liq}}\right) + v_{i,\text{liq}}\left(\frac{\theta_t^T + \kappa^{\text{safe},\tau}\theta_t^{C,\text{safe},\tau}}{\text{GDP}_t}; \xi_{it}^{\text{safe},\tau}\right) \tag{4.6}$$

[5]Treasury bonds are used in Tri-Party/GCF repurchase agreement and are generally considered a safe collateral.

for both $\tau \in \{s, \ell\}$. Hence, spreads $\mathcal{S}_t(\tau)$ are likely to be driven by the demand shocks of a subset of market participants that have a higher loading on the maturity specific safety shock $\xi_{it}^{\text{safe},\tau}$. To the extent that the loadings on $\xi_{it}^{\text{safe},\tau}$ vary with τ, the set of investors whose demand shocks ξ_t are moving yield spreads are potentially a function of the maturity τ.
This extends the idea of a segmented yield curve to convenience services (Vayanos & Vila, 2021), so as to allow the ordering of convenience loadings ψ_i^{ξ} to vary with the maturity as well. As far as equation (4.6) is concerned, Krishnamurthy and Vissing-Jorgensen (2012) assume that long term and short term Treasuries are equally liquid (Longstaff, 2004). However, Joslin et al. (2021) establish that, in normal times, the liquidity term structure is upward sloping. Potentially the liquidity of long term Treasuries is a more important feature of the long term spread $\mathcal{S}_t(\ell)$, and less so at shorter maturities. Hence, it seems reasonable to believe that loadings on ξ_{it}^{liq} may vary with τ as well.

To provide exploratory evidence of the drivers of yield spreads at long and short maturities, I decompose the time variation into a Treasury and a corporate component in the spirit of De La O and Myers (2021) and Cochrane (2020). Given that $\mathbb{V}\text{ar}(\mathcal{S}_t(\tau)) = \mathbb{C}\text{ov}\left(\mathcal{S}_t(\tau), y_t^C(\tau) - y_t^T(\tau)\right)$, it follows that

$$1 = \underbrace{\frac{\mathbb{C}\text{ov}\left(\mathcal{S}_t(\tau), y_t^C(\tau)\right)}{\mathbb{V}\text{ar}(\mathcal{S}_t(\tau))}}_{\textit{Corporate (\%)}} - \underbrace{\frac{\mathbb{C}\text{ov}\left(\mathcal{S}_t(\tau), y_t^T(\tau)\right)}{\mathbb{V}\text{ar}(\mathcal{S}_t(\tau))}}_{\textit{Treasury (\%)}} \tag{4.7}$$

By construction, the two terms add up to one. Given that yield spreads are highly persistent, I repeat the same exercise in first differences, and I report the level decomposition only for completeness. Table 4.4 shows that the covariance between $\Delta\mathcal{S}_t(\ell)$ with the Treasury yield accounts for virtually 100% of the variation in $\Delta\mathcal{S}_t(\ell)$. In contrast, the variation in short term yields is mostly explained by the comovements of $\Delta\mathcal{S}_t(\ell)$ and short term corporate yields. Yet, the proportion of variation explained by Treasury yields increases in the years after the year 2000. In the last part of the sample, the covariance of Treasuries and short term spreads accounts for roughly 50% of the variation in $\Delta\mathcal{S}_t(s)$.

	Levels		First Differences	
	Treasury (%)	Corporate (%)	Treasury (%)	Corporate (%)
Long term spread				
Q1–1920	−1.60	2.60	1.01	−0.01
Q1–1951	−1.16	2.16	1.10	−0.10
Q1–2000	0.92	0.08	1.06	−0.06
Short term spread				
Q1–1920	−2.27	3.27	−0.04	1.04
Q1–1951	−3.71	4.71	−0.23	1.23
Q1–2000	−2.67	3.67	0.44	0.56

Table 4.4: The table shows the variance decomposition (4.7) of both long and short term spreads. Treasury (%) denotes the fraction of variation in yield spreads due to the covariance of Treasury yields and $\mathcal{S}_t(\tau)$, whereas Corporate (%) is computed analogously for corporate bonds. The quarterly sample is Q1–1920 to Q4–2021.

To provide further evidence for clienteles of short and long term convenience, I investigate comovements of yield spreads with market shares S_{it}^T and portfolio weights ω_{it}^T at the sector level. The idea behind these simple descriptive regressions is to observe who is holding Treasuries when spreads are higher

(S_{it}^T), and who is more willing to accept lower returns on their investment portfolio (ω_{it}^T). Figure 4.3 plots coefficient estimates from univariate regression of market shares and portfolio weights on yield spreads. The horizontal (vertical) axis plots the coefficient on the long (short) term spread. I repeat the same analysis using only the sample after the year 2000 to explore if regime changes in the Treasury market had any implication on the relation between short term and long term betas (Du et al., 2022).

The left panel of figure 4.3 illustrates a negative relation between short term and long term betas using market shares as the dependent variable. In the full sample, the long term spread is higher when the foreign sector owns a larger share of the market. However, the ordering flips in the shorter sample. The right panel also illustrates a negative relation between long term and short term portfolio betas. It seems that sectors valuing long term convenience are less willing to accept lower yields at shorter horizon, but this could be driven simply by different investment horizons. In addition, given the high degree of persistence of market shares, portfolio weights, and yield spread I suspect that OLS coefficient are picking up common trends.

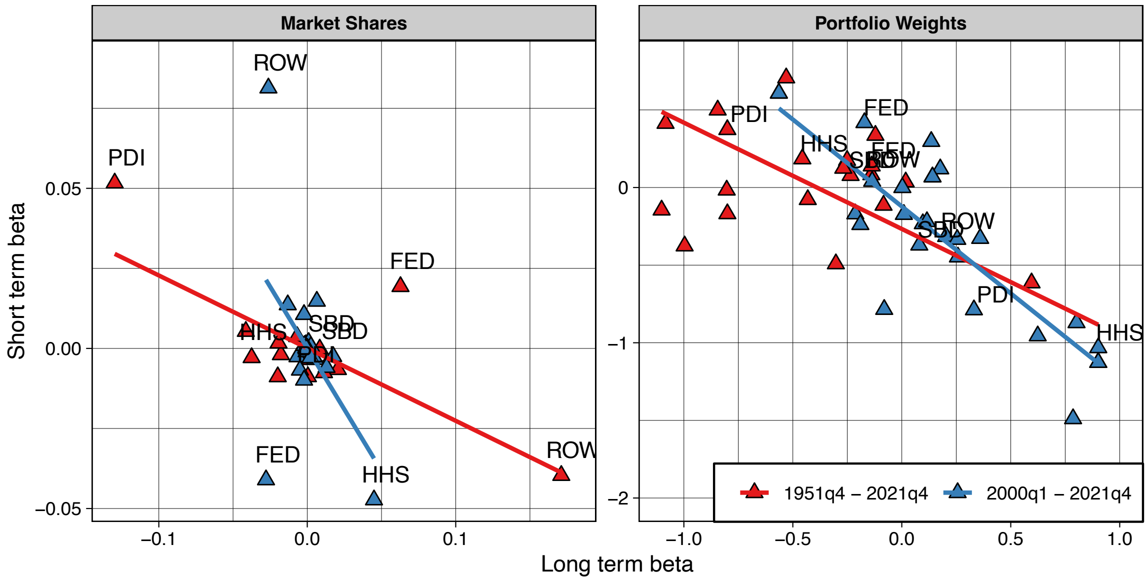

Figure 4.3: The left panel plots coefficient estimates of univariate regressions $S_{it}^T = \beta_{i0} + \beta_{i1} \cdot \mathcal{S}_t(\tau) + \epsilon_{it}$, where S_{it}^T denotes sector i's Treasury market share and $\mathcal{S}_t(\tau)$ is the yield spread. The right panel plots coefficient estimates of univariate regressions $\omega_{it}^T = \beta_{i0} + \beta_{i1} \cdot \mathcal{S}_t(\tau) + \epsilon_{it}$, where ω_{it}^T is the ratio of Treasury holdings to sector i's holdings of Treasury securities. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Data for market shares and portfolio weights is from the Financial Accounts. The quarterly sample is Q1–1951 to Q4–2021.

4.3.2 Supply Effects

Nagel (2016) shows that supply effects vanish once accounting for opportunity costs of money. I here revisit the empirical evidence on the relation between yield spreads and supply effects, and show that the opportunity cost of money does not account for supply effects at longer maturities. In contrast, Krishnamurthy and Li (2022) argue that Treasury bonds and deposits are imperfect substitutes, so that the long term spread is presumably explained by factor other the opportunity costs of money.
I follow Krishnamurthy and Vissing-Jorgensen (2012),Greenwood et al. (2015) and Nagel (2016) and

consider the time series regression

$$\mathcal{S}_t(\tau) = \beta_0 + \beta_1 \cdot q_t^T(s) + \beta_2 \cdot q_t^T(\ell) + \beta_3 \cdot t + \beta_4 \cdot i_t^{\text{FFR}} + \epsilon_t \tag{4.8}$$

where $q_t^T(\tau)$ denotes the log of the ratio between outstanding debt with maturity τ and GDP. Specification (4.8) separates quantities of long and short term debt. The construction of $q_t^T(\tau)$ mirrors Greenwood and Vayanos (2014), and figure A.3 in the Appendix plots the time series of long term debt-to-GDP together with alternate measures of the debt supply. Lastly, i_t^{FFR} denotes the federal funds rate and I include a time trend. Table 4.5 reports OLS estimates of specification (4.8).

	Long term spread $\mathcal{S}_t(\ell)$					Short term spread $\mathcal{S}_t(s)$				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
q_t^D	-0.63***	-0.03	-0.51*			-0.66***	-0.69***	-0.67***		
	[-4.17]	[-0.15]	[-1.66]			[-3.98]	[-3.59]	[-3.28]		
$q_t^T(\ell)$		-0.53***		-0.57***	-0.60***		0.03		-0.04	-0.15
		[-5.21]		[-5.61]	[-5.58]		[0.18]		[-0.24]	[-1.13]
$q_t^T(s)$			-0.21	0.09	0.34			0.03	-0.83***	0.07
			[-0.44]	[0.32]	[1.06]			[0.11]	[-2.64]	[0.34]
i_t^{FFR}					0.02**					0.08***
					[2.11]					[6.83]
Constant	-0.32	-1.07***	-0.59	-0.96**	-0.68	-0.19	-0.15	-0.16	-1.12**	-0.09
	[-1.57]	[-4.48]	[-0.89]	[-2.18]	[-1.37]	[-0.89]	[-0.44]	[-0.40]	[-2.28]	[-0.32]
Time trend	0.00***	0.00***	0.00***	0.00***	0.00***	0.00	0.00	0.00	-0.00	-0.00
	[6.06]	[6.48]	[5.98]	[7.02]	[7.57]	[0.24]	[0.19]	[0.25]	[-0.82]	[-0.40]
N	270	270	270	270	270	270	270	270	270	270
R^2	0.30	0.47	0.30	0.47	0.50	0.27	0.27	0.27	0.23	0.46

Table 4.5: The dependent variables are the long term and the short term spread. I select controls following Greenwood and Vayanos (2014) and Nagel (2016). q_t^D denotes the log debt-to-GDP ratio using the total amount of outstanding debt. $q_t^D(\ell)$ and $q_t^D(s)$ denote log debt-to-GDP ratio using the quantity of long term and short term debt outstanding. Finally, i_t^{FFR} denotes the federal funds rate and I include a time trend. Newey and West (1987) t-statistics (4 lags) are reported in brackets. The quarterly sample is from Q3–1954 to Q4–2021.

Columns (1) and (6) confirm the results of Krishnamurthy and Vissing-Jorgensen (2012). The slope coefficient of -0.63 in column (1) is very close to the estimate of -0.74 in Krishnamurthy and Vissing-Jorgensen (2012) despite the measurement of debt supply being different. Separating long term and short term debt quantities reveals that supply effects are stronger when maturities are matched. These results are consistent with Greenwood and Vayanos (2014) and Greenwood et al. (2015). In line with Nagel (2016), controlling for the federal funds rate reduces supply effects for $\mathcal{S}_t(s)$. Yet, the supply effect on $\mathcal{S}_t(\ell)$ remain negative and statistically significant.

4.4 Additional Results and Robustness Checks

In this section, I perform a series of alternate descriptive analyses. First, I repeat the same procedure by swapping flows with Treasury portfolio shares. Second, I turn to Treasury auctions and investigate how yield spreads vary as Treasury issuances are absorbed differently across sectors.

4.4.1 Evidence from Portfolio Weights

I consider the Treasury share as a fraction of total holdings of debt securities and the log ratio of Treasury holdings to corporate debt holdings. I repeat the analysis of Section 4.1 and 4.2 by swapping flows q^j_{it} with portfolio shares ω^j_{it}. I control for the same set of macroeconomic, financial, and intermediaries variables, and I always include an intercept. I report coefficient estimates in Appendix E.3 and Appendix E.4. The relation between the long spread and ω^T_{it} is negative and statistically significant across a range of specifications. With sector fixed effects, a 1% increase in the long term spread reduces the Treasury portfolio share by 48%. The effects are much weaker when controlling for financial indicators and balance sheet costs. In contrast, Treasury shares are less sensitive to short term spreads $\mathcal{S}_t(s)$. The fact that the time series of $\boldsymbol{x}^{\text{int}}_t$ is shorter could again explain the different results of columns (5) and (10).

As opposed to flows, portfolio weights are highly non-stationary, so that OLS estimates may pick up common trends and produce spurious estimates. For this reason, I replace ω^T_{it} with the log portfolio share of Treasuries relative to corporate bonds. By doing so, I remove common trends of corporate bonds and Treasury securities. Further, I also consider a differenced specification as in Nagel (2016). Table E.7 and table E.8 in the Appendix show that the there is still a negative effect, but it is much weaker than in E.6. An increase in the yield spread is negatively associated to the Treasury to corporate debt ratio. However, while first difference coefficients estimates remain marginally negative, I cannot reject the null that the slope coefficient is different than zero. Potential explanations are that standard errors increase when differentiating highly persistent variables (Nagel, 2016) or that the quarterly variation in portfolio weights is not sufficiently large.

4.4.2 Evidence from Treasury Auctions

As a second robustness check, I move to the primary market for Treasuries. Given that I observe the investors' demand at the instrument level, auction data are well-suited to study the role of preferred habitats with respect to Treasury demand (Droste, Gorodnichenko, & Ray, 2021). I define sector i's relative allotment of security j at time t as $\varrho^T_{it}(\tau) = \frac{Q_{it}(\tau)}{\mathcal{A}_{jt}}$. The ratio $\varrho^T_{it}(\tau)$ is the fraction of newly issued debt of maturity τ that is purchased by sector i. The main advantage is that I can study ownership shares at the instrument by maturity level. However, the sample only starts in 2001. I consider the specification

$$\varrho^T_{it}(\tau) = \beta_0 + \beta_1 \cdot \mathcal{S}_t(\tau) + \beta_2 \cdot \boldsymbol{x}_t + \beta_3 \cdot \boldsymbol{x}_{it} + \delta_j + \varepsilon_{it}(\tau) \tag{4.9}$$

where $\boldsymbol{x}_t$ is a vector of economy-wide controls, and $\boldsymbol{x}_{it}$ is a vector of sector-specific characteristics. Further, δ_j are instrument fixed effects for T-Bonds, Floating Rate Notes (FRN), T-Notes, TIPS Bonds, and TIPS Notes. Specification (4.9) is for exploratory purposes only, and I refrain from making any identification claims about β_1. Further, I do not control for the Treasury yield, not taking into account differences in price elasticities ζ^T_i. I consider the same specification for both the long and the short term spread, controlling for instrument maturity τ, GDP growth and the trade deficit. Table E.9 and E.10 in the Appendix report OLS coefficient estimates for each sector.

Regression estimates reveal that the sign and the magnitude of β_1 both across sectors and maturities. Column (1) of table E.9 shows that a 1% point increase in the long spread is associated to decline of 14.3% in $\varrho_{it}(\tau)$ for the Federal Reserve. I observe a positive relation between the long spread and the auction shares of security brokers and dealers, investment funds, and the foreign sector. It follows that the long spread is higher when these sectors absorb a larger fraction of Treasury issuances. Short term spreads decline when δ^T_{it} is higher for investment funds and foreign investors. In general, sectors who load positively on long spreads tend to load negatively on short spreads, and vice versa. These results are qualitatively similar with the preference ordering in Section 4.2. Security brokers dealers are willing to accept lower returns to hold Treasury securities, and their demand appears to be less sensitive to changes in yield spreads. This points to a fundamental role of security brokers and dealers in pricing yield spreads between Treasuries and corporate bonds (He et al., 2022; Klingler & Sundaresan, 2022). The positive coefficient for the foreign sector is likely be driven by a combination of safety and liquidity motives. In contrast to the ordering in figure 4.2, I do not find evidence that private depository institutions value liquidity attributes of long term bonds, but there seems to be a negative relation between banks' allotments and short term spreads.

5 Discussion

In this section, I briefly discuss implications for macroeconomic models of convenience yields. I then turn to limitations and extensions of the analysis, emphasizing future plans and improvements

5.1 Implication for Macroeconomic Models

The empirical analysis has two major implications for theoretical models of convenience yields. On the one hand, it seems that the perceived substitutability between corporate bonds and Treasury securities varies across agents. In this regard, the framework of Nagel (2016) may be extended by allowing heterogeneity in the elasticity of substitutions between Treasuries and other money-like securities to vary across sectors. Differences in regulatory constraints and investment horizons could mechanically alter the substitutability of the convenience services drawn from Treasury bonds. In the models of Mota (2021) and Kekre and Lenel (2021), heterogeneity in valuations can be captured by different loadings on the convenience shock Θ_t and ω^d, respectively.

On the other hand, theoretical models should account for the fact that the liquidity components appears to be relevant even at longer maturity. Modeling approaches such as Jiang et al. (2021) usually introduce convenience yields by endowing agents with safety motives. However, it seems interesting to introduce convenience in a way that is closer to institutional constraints and liquidity concerns, as argued for example in Du, Tepper, and Verdelhan (2018). Similarly, it seems that households have relatively lower valuations of convenience services that the banking sectors. Hence, introducing real holdings of Treasuries in the utility of the agents may not correctly model the true source of special demand. Finally, such models should account for heterogeneity in the price elasticities implied by differences in the perception of convenience services.

5.2 Limitations and Extensions

Although Appendix B extends the conceptual framework to accommodate convenience of corporate bonds, the current results are subject to a series of limitations related to both the conceptual framework and the econometric analysis issues that I now present in more detail. I plan to address each of the following issues in future revisions of the paper.

5.2.1 Measurement of Convenience Shocks and Conceptual Framework

The major limitation of my results is that I cannot observe latent convenience shocks. Hence, I approximate the process ξ_t by proxying it with yield spreads. Essentially, I impute the entirety of the spreads between corporate bonds and Treasuries to non-pecuniary benefits. However, convenience yields only account for a tiny fraction of the yield spread in the range of 40 to 76 basis points (Krishnamurthy & Vissing-Jorgensen, 2012; van Binsbergen et al., 2022). In some sense, however, ξ_t could also subsume liquidity and safety needs of each agent, so that the framework might still be consistent with this approximation. Most importantly, I replace an unobservable primitive object, i.e. the convenience shock, with an observable equilibrium object, i.e. the realized yield spread. Even though this is common practice in the literature (Choi et al., 2022; Klingler & Sundaresan, 2022), this becomes a severe issue if the goal is to identify the ordering of the demand loadings on the convenience shocks, and not their sensitivity to yield spreads. To partially mitigate this concern, I argue that elasticities to the Treasury spread only proportional to the parameters of interest.

In addition, measuring the convenience shock with the yield spreads partially disconnects the empirical analysis from the conceptual framework. To the extent that the supply effects act on the yield spread, instrumenting yield spreads with military expenditure shocks is a reasonable approach (Greenwood et al., 2015; Krishnamurthy & Vissing-Jorgensen, 2012; Nagel, 2016). However, the structural demand function relates quantities to prices and convenience shocks, not to the yield spread. As a result, it becomes difficult to illustrate instrument validity through the lens of the conceptual framework without imposing additional structure through the function $\Lambda(\cdot)$.

To reconcile the empirical analysis with the demand system, I impose that convenience shocks depend on latent factors and on Treasury supply. The assumption is based on the insight that investors' perception of the non-pecuniary attributes and the demand for safe assets may depend on the size of the debt float (He et al., 2019). Importantly, this represents a different channel through which an increase in supply affects yield spreads. Krishnamurthy and Vissing-Jorgensen (2012) show that debt supply is inversely related to yield spread because of a diminishing marginal convenience yield. Here, I postulate that debt size contemporaneously affects also the perception of non-pecuniary attributes. The primary reason behind this assumption is, again, to justify instrument relevance of a supply shifter to instrument for the safety shock ξ_t. I implicitly assume that convenience shocks generate a contemporaneous movement in both the supply and demand for Treasuries (MacKay & Miller, 2022). Nevertheless, this specification is clearly ad-hoc, and future research should improve on the framework.

5.2.2 Instrument Relevance and Standard Errors

A second limitation of the results is that IV estimates produce wide standard errors. This is most likely due to a weak first stage, as shown by the tiny Cragg and Donald (1993) statistics. In addition, the number of sectors in the Financial Accounts may not be sufficiently large to reliably extract idiosyncratic shocks. For this reason, Gabaix and Koijen (2022) impose that all sectors have the same price elasticity. Yet, identical price elasticities are not compatible with the premise that investors have heterogenous valuations of convenience services. A reliable identification of the preference ordering requires tighter standard errors and better data. In this regard, I plan to unpack each sector by looking at disaggregated holdings data to better estimate sector-level elasticities. For example, the FFIEC call reports are informative about Treasury holding data for all reporting institutions. Similarly, Treasury International Capital report international Treasury flows disaggregated by investor country (Fang, Hardy, & Lewis, 2022). I plan to extend the sample to cover a longer period, although it is unclear whether earlier observations are representative of the current Treasury market (Du et al., 2022). In addition, the construction of the granular instrumental variable may require some adjustments to account for the convenience shocks ξ_t. Perhaps, however, to the extent that ξ_t is a systematic factor, performing principal component analysis is sufficient to isolate pure idiosyncratic shocks.

5.2.3 Agency Securities and Refcorp Spreads

Another important limitation of the analysis pertains the aggregate nature of holdings data. The Financial Accounts provide only a coarse overview of both the corporate and the Treasury bond market. First, Treasury holdings are pooled by maturity, and the distinction of short term and long term is only available for few sectors. Second, corporate bond holdings do not differentiate across credit rating and maturity. However, Aaa rated bonds only represent a tiny fraction of the corporate bond market (Nozawa, 2017). Hence, the measurement of bond holdings is at best a rough approximation of the actual holdings of safe corporate bonds. Third, the Financial Accounts pools holdings of domestic and foreign corporate bonds under the same item. Adjusting for domestic holdings as in Gabaix and Koijen (2022) partially addresses this issue. Nevertheless, measurement concerns remain a problem to be addressed. A feasible remedy to this issue is to consider yield spread with other securities that are directly observed in the Financial Accounts but that are also similar in terms of liquidity and safety to Treasury debt. A good candidate for this role are agency and GSE-backed securities.

5.2.4 Private Supply of Safe-Assets

Throughout the analysis, I assume the supply of corporate debt is fixed, i.e. $s_t^C = 0$. However, Greenwood, Hanson, and Stein (2010) and Greenwood et al. (2015) argue that private corporations are likely to respond to changes in Treasury supply. Krishnamurthy and Vissing-Jorgensen (2012) acknowledge this possibility, and argue that supply effects are positive whenever the private sector reduces its supply of substitutes by more than the increase in debt supply. A natural extension to the conceptual framework is to allow corporate bond supply to respond to convenience shock. In particular, firms and banks may have incentives to privately produce safe assets.

6 Conclusion

I investigate heterogeneity in investors' valuations of the convenience services associated with U.S. Treasuries. The goal of the paper was to determine which groups of investors draw benefits from holding Treasuries and the reason why they are willing to pay a premium over comparatively safe and liquid corporate bonds. The conceptual framework formalizes how valuations of non-pecuniary attributes affect the price and the demand elasticity of Treasury securities. It turns out that the presence of non-pecuniary benefits determine price elasticities through the shape of the convenience function. In addition, a structural demand function responds to prices and convenience shocks, but not to the equilibrium price of the non-pecuniary services, which is the convenience yield.

My empirical results suggest that the convenience derived from holding Treasury securities varies across agents. Estimates reveal that the convenience of long term Treasuries is mostly valuable for U.S. private depository institutions, and security brokers and dealers, whereas it is less attractive to households, pension funds, and insurance companies. The ordering suggests that safety is a secondary concern with regard to liquidity and neutrality even for long term spreads. Nevertheless, there is seemingly sharp distinction in the convenience drawn from long term assets relative to short term assets, pointing towards a preferred habitat hypothesis of the term structure.

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Appendices

A Data Construction

A.1 Data Sources

I document data sources and plot the time series of the yields and the yield spreads. I then reconstruct the main measures of debt supply from Greenwood and Vayanos (2014), and plot the time series.

Time	Description	Source	Mnemnonic
	Long spread		
Treasury Securities			
1919 – 1924	Yield on long-maturity T-Bonds	IBS	Table 128
1925 – 1999	Average yield on long-term T-Bonds	St. Louis Fed	LTGOVTBD
2000 – 2022	Yield on 20-year maturity T-Bonds	St. Louis Fed	GS20
Corporate Securities			
1919 – 2022	Moody's AAA index	St. Louis Fed	AAA
	Short spread		
Treasury Securities			
1920 – 1930	3-6 month T-Bills	NBER Macrohistory	M13029A
1931 – 1958	3-6 month T-Bills	NBER Macrohistory	M13029B
1959 – 1970	6-month T-Bills	St. Louis Fed	TB6MS
1971 – 2022	3-month T-Bills	St. Louis Fed	TB3MS
Corporate Securities			
1920 – 1940	Yield on high-grade commercial paper	IBS	Table 120
1941 – 1970	Yield on high-grade commercial paper	IBS	Table 12.5
1971 – 1996	Commercial paper yield	St. Louis Fed	CP3M
1997 – 2022	Commercial paper yield	St. Louis Fed	CPN3M

Table A.1: Data sources for interest rate time series. Data construction closely follows the data appendix of Krishnamurthy and Vissing-Jorgensen (2012). Data is at a monthly frequency, but a subsample of the series is available at daily and weekly frequency. IBS refers to the International Banking Statistics.

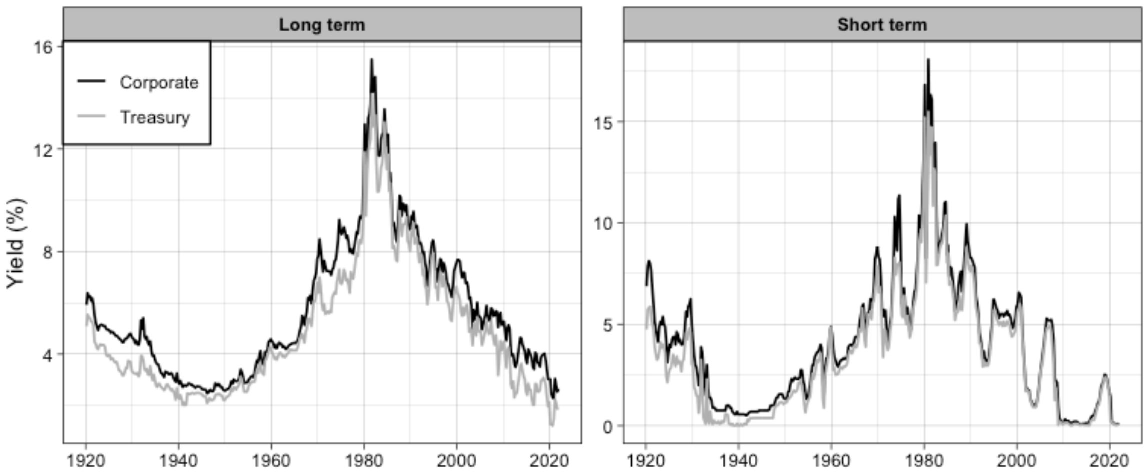

Figure A.1: The figure plots time series for both long and short term yields on corporate bonds and Treasury securities. The series are constructed as in Krishnamurthy and Vissing-Jorgensen (2012). The quarterly sample is from Q1–1920 to Q4–2021.

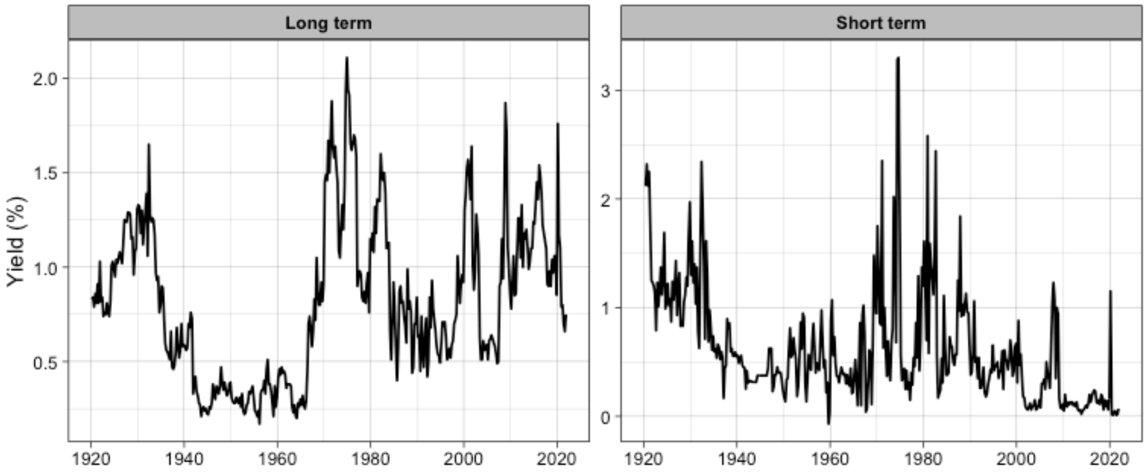

Figure A.2: The figure plots time series for both long and short term yield spreads between corporate bonds and Treasury securities. The series are constructed as in Krishnamurthy and Vissing-Jorgensen (2012). The quarterly sample is from Q1–1920 to Q4–2021.

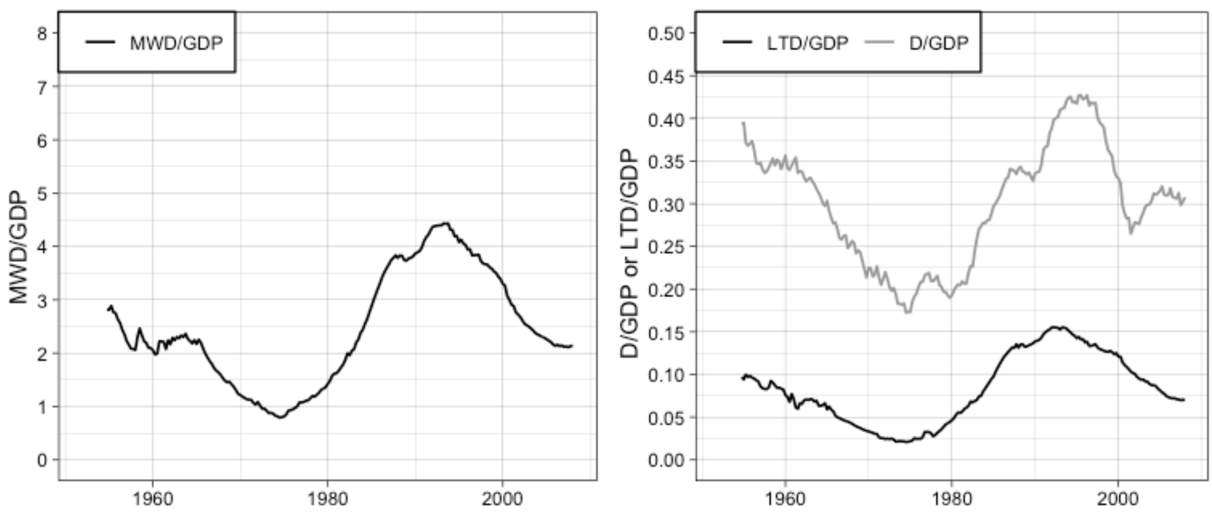

Figure A.3: The figure replicates data construction in Greenwood and Vayanos (2014). I compute alternate measures of debt supply. The left panel plots the ratio of maturity-weighted debt to GDP. The right panel plots total debt to GDP as well as long term debt to GDP.

A.2 Financial Accounts

The U.S. Financial Accounts report seasonally adjusted annualized flows (prefix FA) and quarterly unadjusted flows (FU). I follow Gabaix and Koijen (2022) and use unadjusted flows. Holdings and transaction data for all sectors is from Table L.100 to Table L.133. With regard to debt instruments, I consider open market papers (30691), Treasury securities (30611), Agency- and GSE-backed securities (30617), Municipal securities (30620), and corporate and foreign bonds (30630). To asses the validity of the GIV procedure, I also include corporate equities (30641) and mutual fund shares (30642).

Treasury holdings pool marketable and nonmarketable securities. Given that the object of interest is the demand for *marketable* Treasury securities, I subtract the holdings of nonmarketable Treasury securities from the appropriate sectoral accounts. In particular, I subtract holdings of U.S. savings securities (31614) from household's holdings (sector 15). Second, I remove Federal government defined benefit pension plans as well as Thrift Savings Plan G Fund from the holdings of Federal government retirement funds (sector 34). In fact, these are federal liabilities that are pooled together with Treasury securities, but that do not affect the supply of T-Bonds, T-Bills, T-Notes and other marketable debt instruments. Third, I subtract state and local government series (SLGS) from the holdings of the state and local government sector (sector 21). Lastly, nonmarketable Treasury securities held by the Federal Reserve credit facility LLCs and other nonmarketable securities are imputed to other financial business (sector 50) and Government-sponsored enterprises (sector 40)[1] I then recompute aggregate holdings of debt securities by adding up the individual holdings of all debt instruments listed above. Finally, I follow Appendix C of Gabaix and Koijen (2022) and correct for domestic holdings of corporate sectors. I also implement all the other adjustments mentioned in the paper.

A.3 Military Expenditure Shocks

I plot the military news shock of Ramey and Zubairy (2018) normalized by nominal GDP and the first-stage F-statistics for the instrumental variable regression.

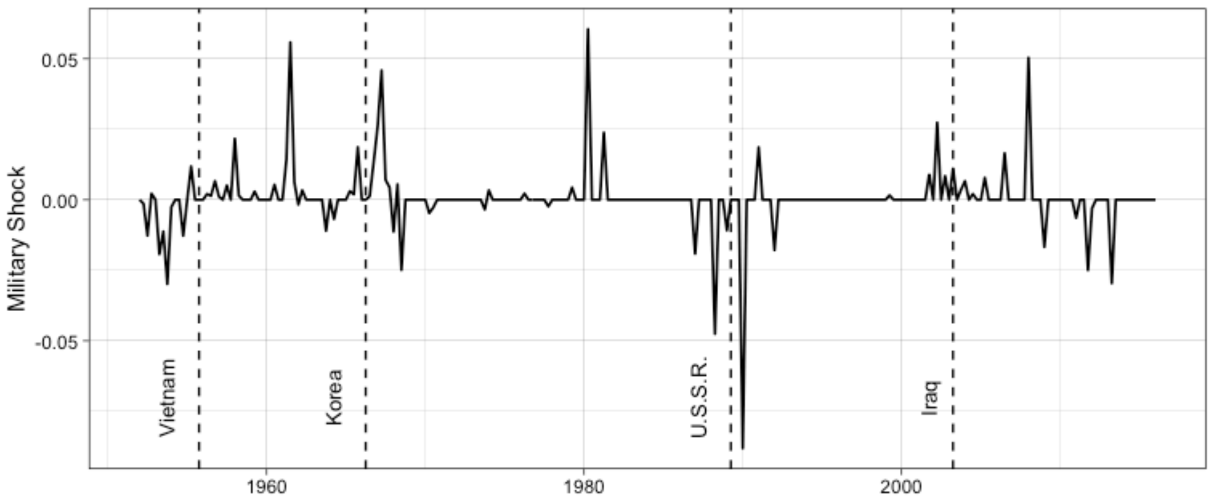

Figure A.4: The figure plots the military expenditure shock of Ramey (2011) and Ramey and Zubairy (2018) normalized by nominal GDP. Vertical lines highlight the Vietnam was, the Korea War, the fall of the Soviet Union, and the Iraq was.

[1] The Federal Reserve credit facility LLCs falls under other financial business, whereas GSE holdings also include special U.S. Treasury securities held by FHLB.

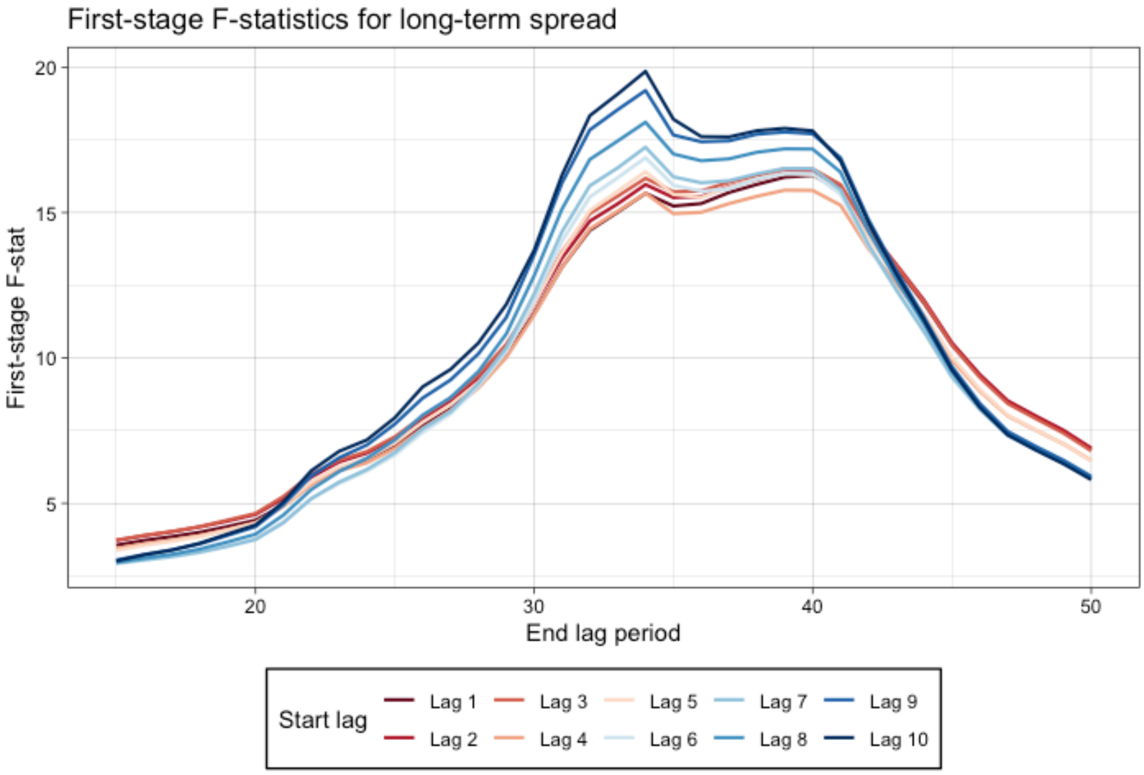

Figure A.5: I report the first-stage F-statistics for bivariate regressions as a function of the lead and lags chosen to accumulate military shocks of Ramey and Zubairy (2018). The procedure follows Choi et al. (2022)

B Convenience Yield and Supply

I present extensions to the conceptual framework outlined in Section 2. I first review the theoretical model of Krishnamurthy and Vissing-Jorgensen (2012). I then investigate the implications of $\kappa^C \neq 0$ for the estimation of ψ_i^ξ.

B.1 Demand for Convenience Assets

I present further details on the Krishnamurthy and Vissing-Jorgensen (2012) and asset pricing implications of non-pecuniary benefits attributes to Treasury securities. The analysis follows Krishnamurthy and Vissing-Jorgensen (2012) and derives an expression for the spread between to . The representative agent chooses C_t to maximize expected discounted utility

$$\mathbb{E}\left[\sum_{t=1}^{T} \beta^t u\left(C_t\right)\right] \tag{B.1}$$

where C_t is a consumption aggregate of an endowment c_t and convenience benefits

$$C_t = c_t + v\left(\theta_t^A, \mathrm{GDP}_t; \xi_t\right) \tag{B.2}$$

The agent not only derives utility from consumption, but also from holding convenience assets. θ_t^A is the market value of the convenience assets held by the agent, which is given by $\theta_t^A = \theta_t^T + \kappa^P \theta_t^P$. A standard perturbation argument reveals that in the optimum

$$-\frac{P_t^T}{Q_t} u'\left(C_t\right) + \beta \mathbb{E}_t\left[\frac{P_{t+1}^T}{Q_{t+1}} u'\left(C_{t+1}\right)\right] + \frac{P_t^T}{Q_t} v'\left(\theta_t^A / \mathrm{GDP}_t; \xi_t\right) u'\left(C_t\right) = 0 \tag{B.3}$$

It follows that the price of Treasuries is given by

$$P_t^T = \frac{\mathbb{E}_t[M_{t+1} P_{t+1}^T]}{1 - v'\left(\theta_t^A / \mathrm{GDP}_t; \xi_t\right)} \tag{B.4}$$

where

$$M_{t+1} = \beta \frac{u'\left(C_{t+1}\right)}{u'\left(C_t\right)} \cdot \frac{Q_t}{Q_{t+1}}$$

is the pricing kernel for nominal payoffs, and Q_t is the price level. In contrast, since bonds offer no convenience but are subject to default with probability λ_t

$$P_t^C = \lambda_t \mathbb{E}_t\left[M_{t+1}(1 - L_{t+1}) | \mathrm{Default}\right] + (1 - \lambda_t) \mathbb{E}_t\left[M_{t+1} P_{t+1}^C | \mathrm{No\ Default}\right] \tag{B.5}$$

Considering one-periods bonds, $e^{-i_t^T} = P_t^T$ and $e^{-i_t^C} = P_t^C$, so that

$$\mathcal{S}_t(1) \equiv i_t^C - i_t^T = \underbrace{v'\left(\frac{\theta_t^T + \kappa^P\theta_t^P}{\text{GDP}_t}; \xi_t\right)}_{\text{Convenience}} + \underbrace{\lambda_t \mathbb{E}_t[L_{t+1}]}_{\text{Expected Default}} + \underbrace{\frac{\mathbb{C}\text{ov}_t\left(M_{t+1}, \widetilde{L}_{t+1}\right)}{\mathbb{E}_t\left[M_{t+1}\right]}}_{\text{Risk Premium}} \tag{B.6}$$

B.2 Multiple Asset Framework and Cross-price Elasticties

An important assumption of Section 2.1 is that agents do not draw convenience from corporate bonds, i.e. $\kappa^C = 0$. This section discusses the implications of $\kappa^C \neq 0$ for identification of the ranking of ψ_i^ξ. I sketch an informal argument to justify why $\kappa^C \neq 0$ implies that cross-price and own-price elasticities are different than zero. I then assess the extent to which this result deviates from standard mean-variance demand, and I provide preliminary estimates comparing relative flows of Treasury and bonds.

If $\kappa^C \neq 0$, the pricing equation for Treasury securities takes the form

$$P_t^T = \frac{\mathbb{E}_t[M_{i,t+1}P_{t+1}^T]}{1 - v_i'\left(\theta_{it}^A, \iota_i \cdot \text{GDP}_t;\ \xi_{it}\right)} \tag{B.7}$$

where $\theta_{it}^A = \theta_{it}^T + \kappa^C\theta_{it}^C$ includes real holdings of both Treasuries and corporate bonds. Analogously, the price of a corporate bond satisfies

$$P_t^C = \frac{\mathbb{E}_t[M_{i,t+1}P_{t+1}^C]}{1 - v_i'\left(\theta_{it}^A, \iota_i \cdot \text{GDP}_t;\ \xi_{it}\right)} \tag{B.8}$$

Abstracting from liquidity and safety concerns, (B.7)–(B.8) defines a system of two equations in two unknowns, i.e. Q_{it}^T and Q_{it}^C.

To accommodate that $\kappa^C \neq 0$, I generalize the demand system (2.8)–(2.9) by introducing cross-price effects. Accordingly, I specify the demand system[1] as

$$q_{it}^T = -\zeta_i^T \cdot p_t^T + \zeta_i^{TC} p_t^C + \psi_i^\xi \cdot \xi_t + \nu_{it}^T \tag{B.9}$$
$$q_{it}^C = -\zeta_i^C p_t^C + \zeta_i^{CT} p_t^T + \nu_{it}^C \tag{B.10}$$

where $\zeta_i^{jj'}$ denotes the demand elasticity of asset j with respect to the price of asset j'. Whenever $j = j'$, ζ_i^{jj} is the own-price elasticity, whereas $\zeta_i^{jj'}$ is referred to as the cross-price elasticity. The system (2.8)–(2.9) is a special case of (B.9)–(B.10) in which cross-price elasticities are set to zero ($\kappa^C = 0$). Furthermore, the system (B.9)–(B.10) nests the special case in which q_{it}^T and q_{it}^C only depend on the yield spread, that is $\zeta_i^T = \zeta_i^{TC}$ and $\zeta_i^C = \zeta_i^{CT}$. In Appendix B.3, I sketch a portfolio selection problem with non-pecuniary benefits in order to provide an alternative justification to (B.9)–(B.10).

It seems natural that own-price elasticities are negative, so that $\zeta_i^{jj} > 0$. In contrast, the sign and the magnitude of cross-price elasticities likely depends on the degree of substitutability between Treasuries

[1] Whenever $\kappa_C \neq 0$, the convenience yield $v'(\cdot)$ shows up in the pricing equations of both corporate and Treasury bonds. Hence, I obtain a system of two equations in two unknowns, which can be approximated by (B.9)–(B.10)

and corporate bonds. If sector i perceives Aaa corporate bonds and Treasuries as substitutes (Nagel, 2016), then $\zeta_i^{jj'} > 0$, and the larger the magnitude the better substitutes j and j' are. Intuitively, market participants reallocate wealth towards Treasuries when Aaa corporate bonds become relatively more expensive than Treasuries. However, for some sectors Treasuries may be a necessity, e.g. in order to meet regulatory requirements, execute repo transactions or for safety purposes, so that ζ_i^{TC} is closer to zero. Even though convenience shocks only enter explicitly in the demand for q_{it}^T , the following proposition reveals that the market clearing yields of both securities depend on ξ_t.

Proposition B.1 (Market Clearing Prices)**.** *Consider the demand system with price spillovers (B.9)-(B.10). Let S_{it}^j denote the market share of sector i for security j, and $x_{Sj} = \sum_{i=1}^N S_{it}^j x$ be the size-weighted average of a variable x using security j's market shares. The market clearing yields are*

$$\Delta y_t^T = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^C \left[\psi_{ST}^\xi \xi_t + \nu_{ST}^T{}_t\right] + \zeta_{ST}^{TC} \nu_{SC}^C{}_t}{\zeta_{ST}^T \zeta_{SC}^C - \zeta_{SC}^{CT} \zeta_{ST}^{TC}} \tag{B.11}$$

$$\Delta y_t^C = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{CT} \left[\psi_{ST}^\xi \xi_t + \nu_{ST}^T{}_t\right] + \zeta_{ST}^T \nu_{SC}^C{}_t}{\zeta_{ST}^T \zeta_{SC}^C - \zeta_{SC}^{CT} \zeta_{ST}^{TC}} \tag{B.12}$$

Further, the change in the yield spread is

$$\Delta y_t^C - \Delta y_t^T = \frac{1}{\tau} \frac{\left(\zeta_{SC}^C - \zeta_{SC}^{CT}\right) \left[\psi_{ST}^\xi \xi_t + \nu_{ST}^T{}_t\right] + \left(\zeta_{ST}^{TC} - \zeta_{ST}^T\right) \nu_{SC}^C{}_t}{\zeta_{ST}^T \zeta_{SC}^C - \zeta_{SC}^{CT} \zeta_{ST}^{TC}} \tag{B.13}$$

Proposition (B.1) shows that convenience shocks may affect the yields on both securities. The effect is more pronounced when the magnitude of the cross-price sensitivity ζ_{SC}^{CT} is larger or when the aggregate valuation of non-pecuniary attributes ψ_{ST}^ξ is higher. In contrast, if $\zeta_{SC}^{CT} = 0$, then the yield on corporate bonds is independent of ξ_t, and changes in non-pecuniary benefits move interest rate spreads only through Δy_t^T.

Furthermore, equation (B.13) implicitly hints at economic restrictions on the difference between own cross-price elasticity ζ_{SC}^C and the cross-price elasticity ζ_{SC}^{CT}. Krishnamurthy and Vissing-Jorgensen (2012) suggest that the difference in yields on Aaa corporate bonds and Treasuries is too large to be explained solely by risk premia. It seems desirable to have a framework in which convenience shocks induce movements in interest rate spreads over and above credit risk and other asset-specific factors. In equation (B.13), this occurs whenever substitution effects produce parallel movements of Δy_t^C and Δy_t^T, i.e. $\zeta_{SC}^C = \zeta_{SC}^{CT}$. In the same spirit, if the aggregate exposure to convenience shocks is zero, $\psi_{ST}^\xi = 0$, then yield spreads are insensitive to ξ_t. Given that Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood and Vayanos (2014) provide pervasive evidence that non-pecuniary attributes affect yield spreads, it seems natural to require that $\zeta_{SC}^C \neq \zeta_{SC}^{CT}$ and that $\psi_{ST}^\xi > 0$.

Since ξ_t appears in the equilibrium yields of both C and T, equilibrium demand for both assets is responsive to the variation in non-pecuniary benefits. On the one hand, a shock to ξ_t affects q_{it}^T through two channels. First, it increases quantity demanded q_{it}^T directly through (B.9). Second, it lowers the yield on security T, making it more expensive. On the other hand, non-pecuniary benefits enter the demand q_{it}^C only via cross-price effects.

Proposition B.2 (Equilibrium Demand and Non-pecuniary Benefits)**.** *In equilibrium, sector i's demand for security $j \in \{C, T\}$ is given by*

$$q_{it}^T = \xi_t \cdot \left\{\psi_i^\xi - \zeta_i^T \cdot \psi_{ST}^\xi \cdot \kappa_1 + \zeta_i^{TC} \cdot \psi_{ST}^\xi \cdot \kappa_2\right\} + \ddot{\nu}_{it}^T + \ddot{\nu}_{it}^C \tag{B.14}$$

$$q_{it}^C = \xi_t \cdot \left\{\zeta_i^{CT} \cdot \psi_{ST}^\xi \cdot \kappa_1 - \zeta_i^C \cdot \psi_{ST}^\xi \cdot \kappa_2\right\} + \dddot{\nu}_{it}^T + \dddot{\nu}_{it}^C \tag{B.15}$$

where $\ddot{\nu}_{it}^j$, $\dddot{\nu}_{it}^j$ are linear combinations of latent demand, and κ_1 and κ_2 are constants given by

$$\kappa_1 = \frac{\zeta_{SC}^C}{\zeta_{ST}^T \zeta_{SC}^C - \zeta_{SC}^{CT} \zeta_{ST}^{TC}}$$

$$\kappa_2 = \frac{\zeta_{SC}^{CT}}{\zeta_{ST}^T \zeta_{SC}^C - \zeta_{SC}^{CT} \zeta_{ST}^{TC}}$$

The demand loading on ξ_t has the interpretation of sector i's demand exposure to non-pecuniary benefits for security j. Proposition (B.2) shows that the sign of the relation between ξ_t and demand q_{it}^j is ambiguously related to ψ_i^ξ. In particular, equation (B.14) emphasizes that a shock to non-pecuniary attributes affects the demand for Treasuries through three channels, that is

$$q_{it}^T = \xi_t \left\{ \underbrace{\psi_i^\xi}_{\textit{Loading on convenience}} - \underbrace{\zeta_i^T \cdot \psi_{ST}^\xi \cdot \kappa_1}_{\textit{Own-price Effect}} + \underbrace{\zeta_i^{TC} \cdot \psi_{ST}^\xi \cdot \kappa_2}_{\textit{Cross-price Effect}} \right\} + \ddot{\nu}_{it}^T + \ddot{\nu}_{it}^C \tag{B.16}$$

The force that dominates depends on ψ_i^ξ, ζ_i^T, and ζ_i^{TC}. When ζ_i^T is very large, a modest decline in the yield of security T generates a strong negative response of q_{it}^T. While it is true that sector i values the non-pecuniary attributes, the own-price elasticity is sufficiently large to offset the demand increase. More formally, assuming that $\psi_{ST}^\xi > 0$, q_{it}^T and ξ_t are positively related when

$$\frac{\psi_i^\xi}{\psi_{ST}^\xi} > \zeta_i^T \cdot \kappa_1 - \zeta_i^{TC} \cdot \kappa_2 \tag{B.17}$$

It follows that sector i' demand for Treasuries increases with ξ_t when (i) its loading on ξ_t is large ($\psi_i^\xi \uparrow$) (ii) its Treasury own-price elasticity is small ($\zeta_i^T \downarrow$) or (iii) its cross-price elasticity is large ($\zeta_i^{TC} \uparrow$). The main economic implication of (B.17) is that a large own-price elasticity may offset any increase in demand driven by ξ_t even if sector i values the non-pecuniary attributes $\psi_i^\xi > 0$.

Section 2.3 presents conditions under which OLS and IV strategies recover the ranking of the preference parameters ψ_i^ξ. In principle, these approaches can be improved by considering information about ψ_i^ξ incorporated in the demand for assets that are substitutes to Treasuries. Subtracting the second line in proposition (B.2) from the first gives

$$q_{it}^T - q_{it}^C = \xi_t \left\{\psi_i^\xi - \kappa_1 \cdot \psi_{ST}^\xi \cdot \left[\zeta_i^T + \zeta_i^{CT}\right] + \kappa_2 \cdot \psi_{ST}^\xi \cdot \left[\zeta_i^{TC} + \zeta_i^{CC}\right]\right\} + \ddot{\nu}_{it}^T + \ddot{\nu}_{it}^C - \dddot{\nu}_{it}^T - \dddot{\nu}_{it}^C \tag{B.18}$$

The loading on ξ_t suffers from the issue that own- and cross-price elasticities differ across sectors. However, if own- and cross-price elasticities satisfy certain conditions, the expression simplifies without the need to estimate $\{\zeta_i^{jj'}\}_{i=1}^N$ for j, $j' \in \{C, T\}$. In the single asset framework of Section 2.1, equation

(2.7) shows that the shape of the function $v(\cdot)$ affects price elasticities. Therefore, heterogeneity in valuations of non-pecuniary entail that cross-price and own-price elasticities differ across agents. In Appendix B.4, I inspect the predictions of a standard asset pricing model in which agents have mean-variance preferences. Elasticities implied by mean-variance preferences are consistent with (2.1) and (2.2) only under very restrictive assumption on preferences $u(\cdot)$ and on the convenience function $v(\cdot)$. Unfortunately, these assumptions do not accommodate a diminishing marginal convenience of asset holdings $v''(\cdot) < 0$.

B.3 Multiple Asset Framework and Mean-Variance Demand

I provide a slightly different microfoundation to the demand curves assuming the investors have mean-variance preferences. My goal is to understand the model prediction with respect to own- and cross-price elasticities so as to simplify (B.18). I adapt (2.1) and (2.2) so that agents have mean-variance preferences. I consider a portfolio selection problem where investor i's chooses portfolio weights $\boldsymbol{\omega}$ taking the vector of expected returns $\boldsymbol{\mu}$ and the covariance matrix Σ as given, that is

$$\max_{\boldsymbol{\omega}} \boldsymbol{\mu}'\boldsymbol{\omega} - \frac{1}{2}\gamma_i \boldsymbol{\omega}'\Sigma\boldsymbol{\omega} + \xi_{it} \cdot \log\left(v(\boldsymbol{\omega})\right) \tag{B.19}$$

Subject to the portfolio constraint $\mathbb{1}'\boldsymbol{\omega} = 1$. I specify $v(\cdot)$ as a CES aggregator of convenience benefits as in Nagel (2016) such that

$$v(\cdot) = \left[\sum_{j=1}^{J} \left(\kappa^j \cdot \theta_{it}^j\right)^{\rho}\right]^{\frac{1}{\rho}} \tag{B.20}$$

where ρ denotes the elasticity of the degree of substitution, and κ^j is the relative contribution of non-pecuniary benefits produces by security j. For simplicity, I consider the case in which the securities are perfect substitutes, so that $\rho = 1$ and the aggregator (B.20) becomes linear. While ω_{it}^j denotes portfolio weights, it can also be seen as the market value of real Treasury holdings divided by income. With a risk-free asset, the solution is given by

$$\boldsymbol{\omega} = \frac{1}{\gamma_i}\Sigma^{-1}\left(\boldsymbol{\mu} + \frac{\xi_{it}}{\boldsymbol{\kappa} \cdot \boldsymbol{\omega}}\boldsymbol{\kappa}\right) \tag{B.21}$$

Equation (B.21) defines an implicit equation for quantities Q_{it}^T. The presence of non-pecuniary benefits affect both the cross-price and the own-price elasticities $\frac{d \ln Q_{it}^j}{d \ln P^j}$ unless $v(\cdot)$ is linear. The latter assumption, however, is inconsistent with a diminishing marginal convenience $v''(\cdot) < 0$.

B.4 Mean-Variance Demand and Price Elasticities

I now consider a mean-variance portfolio selection problem where agent's i chooses portfolio weights $\boldsymbol{\omega}$, but I omit $v(\cdot)$. The setup is otherwise identical to (B.19), that is

$$\max_{\boldsymbol{\omega}} \boldsymbol{\mu}'\boldsymbol{\omega} - \frac{1}{2}\gamma_i \boldsymbol{\omega}'\Sigma\boldsymbol{\omega}$$

Without a risk-free asset, the solution can be written as

$$\boldsymbol{\omega} = \frac{1}{\gamma_i}\Sigma^{-1}\left(\boldsymbol{\mu} + \lambda\mathbb{1}\right) \tag{B.22}$$

$$\lambda = \frac{\gamma_i - \mathbb{1}'\Sigma^{-1}\boldsymbol{\mu}}{\mathbb{1}'\Sigma^{-1}\mathbb{1}} \tag{B.23}$$

where λ is a scalar. Turning to the price elasticity of demand $\zeta^{jk} = -\frac{\partial \ln Q_j}{\partial \ln P_k}$, the relation between quantities, prices, and portfolio weights is

$$P_j Q_j = \omega_j \cdot W \implies \ln(Q_j) = \ln(\omega_j \cdot W) - \ln(P_j)$$

There are three concurrent forces, namely (i) price effects (ii) wealth effects, and (iii) portfolio rebalancing effects. Given (B.22) and (B.23), portfolio effects matter insofar as expected returns $\boldsymbol{\mu}$ or conditional variances Σ are sensitive to prices.

Proposition B.3 (Own- and Cross-Price Elasticities with Mean-Variance Preferences)**.** *Consider a change from $\overline{P}^j$ to P^j. If all securities initially have the same expected return $\overline{\mu}^j = \overline{\mu}$, then own- and cross-price elasticities are given by*

$$\frac{dQ^j}{dP^j}\frac{\overline{P}^j}{\overline{Q}^j} = -\left(1 - \overline{\omega}^j\right)\Theta^j \tag{B.24}$$

$$\frac{dQ^{j'}}{dP^j}\frac{\overline{P}^j}{\overline{Q}^{j'}} = \overline{\omega}^j\Theta^j \tag{B.25}$$

where

$$\Theta^j \equiv \left\{1 - \frac{\phi^j}{\gamma_i}\mathbb{1}'\Sigma^{-1}\mathbb{1}\right\}$$

and $\phi^j \equiv \frac{\partial \mu^j}{\partial P^j}\overline{P}^j$ is the own-price semi-elasticity of expected returns μ_j.

Equation (B.24) and equation (B.25) are a special case of the framework in Section 2.1 in which investors have mean-variance preferences and the convenience function $v(\cdot)$ is linear.

Assumption STR–1 (Shape of the Convenience Function $v(\cdot)$)**.** *The convenience function is linear in θ^j_{it}.*

Assumption STR–2 (Preferences and Elasticities)**.** *Each sector i's has mean-variance preferences with risk-aversion $\gamma_i = \gamma$ for all i. Hence, sector i's own- and cross-price elasticities are given by*

$$\zeta_i^{jj} = \left(1 - \overline{\omega}_i^j\right)\Theta^j \tag{B.26}$$

$$\zeta_i^{jj'} = \overline{\omega}_i^{j'}\Theta^{j'} \tag{B.27}$$

where $\Theta^j \equiv \left\{1 - \frac{\phi^j}{\gamma}\mathbb{1}'\Sigma^{-1}\mathbb{1}\right\}$ is a constant that only depends on j but not on i.

Using assumption (STR–2), I substitute (B.26) and (B.27)into (B.18) to obtain

$$q^T_{it} - q^C_{it} = \xi_t\left\{\psi^\xi_i - \vartheta\left(\{S^j_i\}^N_{i=1}, \{\omega^j_i\}^N_{i=1}\right)\cdot\psi^\xi_{ST}\right\} + \ddot{\nu}^T_{it} + \ddot{\nu}^C_{it} - \dddot{\nu}^T_{it} - \dddot{\nu}^C_{it} \tag{B.28}$$

where

$$\vartheta \equiv \vartheta\left(\{S_i^j\}_{i=1}^N, \{\omega_i^j\}_{i=1}^N\right) = \frac{\sum_{i=1}^N S_i^C\left(\omega_i^T + \omega_i^C - 1\right)}{\sum_{i=1}^N S_i^T(1-\omega_i^T)\sum_{i=1}^N S_i^C(1-\omega_i^C) - \sum_{i=1}^N S_i^C\omega_i^T\sum_{i=1}^N S_i^T\omega_i^C} \tag{B.29}$$

is a function of portfolio weights $\{\omega_i^j\}_{i=1}^N$ and market shares $\{S_i^j\}_{i=1}^N$ for $j \in \{T, C\}$. Equation (B.28) shows that the preference ordering implied by $\beta_{i1} = \psi_i^\xi - \vartheta \cdot \psi_{S^T}^\xi$ is the same as the preference ordering based on ψ_i^ξ. Hence, demand sensitivities to non-pecuniary benefits ξ_t can be ranked without estimating own- and cross-price elasticities. As a result, if each sector has mean-variance preferences with the same risk-aversion parameter $\gamma_i = \gamma$, then a regression of $q_{it}^T - q_{it}^C$ on ξ_t is informative about ψ_i^ξ and preferences for non-pecuniary benefits, provided that unbiased estimates of $\beta_{i1} = \psi_i^\xi - \vartheta \cdot \psi_{S^T}^\xi$ are available.

However, there is another important challenge with regard to estimating β_{i1}. The reason is that an omitted variable bias emerges whenever non-pecuniary benefits vary with Treasury supply s_t^T. If supply is not fixed, i.e. $s_t \neq 0$, then the error term ϵ_{it}^T of the linear model $q_{it}^T - q_{it}^C = \beta_{i0} + \beta_{i1} \cdot \xi_t + \epsilon_{it}^T$ includes a linear combination of latent demand ν_{it}^j and any supply shock ε_t^S. To the extent that ξ_t varies with s_t^T, this immediately implies that $\mathbb{E}[\xi_t \epsilon_t^T] \neq 0$, so that $\widehat{\beta}_{i1}^{OLS} \overset{p}{\nrightarrow} \beta_{i1}$. In addition, the supply shifter Z_t is no longer a valid instrument given that $\mathbb{E}[Z_t \epsilon_{it}] \neq 0$, and instrument exogeneity no longer holds. To account for this, I augment $q_{it}^T - q_{it}^C = \beta_{i0} + \beta_{i1} \cdot \xi_t + \epsilon_{it}^T$ with supply s_t^T and a vector of controls $\boldsymbol{x}_t$ such that

$$q_{it}^T - q_{it}^C = \beta_{i0} + \beta_{i1} \cdot \xi_t + \beta_{i2} \cdot s_t^T + \boldsymbol{\beta}_{i3} \cdot x_t + \epsilon_{it}^T \tag{B.30}$$

Controlling for supply and η_t partially alleviates omitted variable biases associated to β_{i1}. In the special case that $x_t = \eta_t$, then the error term only includes idiosyncratic shocks that are uncorrelated to η_t and ε_t^S. In this special case, $\widehat{\beta}_{i1}^{OLS} \xrightarrow{p} \beta_{i1}$, where β_{i1} recovers the preference ranking based on ψ_i^ξ. Assumption (STR–3) shares some similarities with Gabaix and Koijen (2022) given that a major threat to identification is failing to properly control for common factors η_t.

Assumption STR–3 (Common Factors in Latent Demand)**.** *The vector x_t includes all common factors η_t that affect latent demand, i.e. $x_t = \eta_t$.*

C Granular Instrumental Variable

C.1 GIV Instrument Construction

I follow Gabaix and Koijen (2022) and I construct the granular instrumental variable Z_t^{GIV} as detailed in section 4.3 and in appendix B.2. of their paper. I implement the same algorithm to construct the GIV for Treasuries and corporate bonds. Data adjustments and sample selection are described in Appendix A.2. I use the June 2022 vintage of the Financial Accounts.

Consistently with the theoretical framework, I model sector i's demand as

$$q_{it}^T = \tau \cdot \zeta_i^T \Delta y_t^T + \psi_i^T B_t + \nu_{it}^T \tag{C.1}$$

where $\nu_{it}^T = \lambda_i^T \eta_t + \varepsilon_{it}^T$. I then follow appendix B.2. of Gabaix and Koijen (2022) and implement the following procedure.

1. I construct pseudo-equal value weights $\widetilde{E}_{i,t-1}^j$. I compute $\widetilde{E}_i^j$ as $\min\left\{\xi^j \widetilde{E}_i^{j,\sigma}, \frac{1.5}{N}\right\}$, where $\widetilde{E}_i^{j,\sigma} = \frac{\sigma_i^{-2}}{\sum_{k=1}^N \sigma_k^{-2}}$ and $\sigma_i^j = \sigma\left(q_{it}^j\right)$ for $j \in \{T, C, E\}$. I use $\xi^T = 1.95$, $\xi^C = 2.23$, and $\xi^E = 1.60$ so that weights add up to one. Gabaix and Koijen (2022) argue that this adjustment ensures that equal weights are not too concentrated for sectors with stable q_{it}^T.

2. I run the panel regression

$$q_{it}^j = \alpha_i + \beta_t + \gamma_i \Delta y_t + \delta_i \cdot t + \breve{q}_{it}^j \tag{C.2}$$

   where α_i and β_t are sector and time fixed effects, respectively. Δy_t^T is real GDP growth, and t denotes a time trend. I estimate (C.2) for equities, corporate bonds, and Treasuries ignoring the presence of non-pecuniary benefits. I then extract the residuals $\breve{q}_{it}^j$.

3. I extract the principal components of $\widetilde{E}_i^{\frac{1}{2}} \breve{q}_{it}^j$ and denote them as $\eta_t^{PC,e}$.

4. I construct the GIV instrument

$$Z_t^{j,\text{GIV}} = \sum_{i=1}^N S_{i,t-1}^j \breve{q}_{it}^j \tag{C.3}$$

5. For equities, I estimate the multiplier M and the aggregate elasticity ζ^E. In particular, I consider the specification

$$p_t^E = \alpha + M \cdot Z_t^{E,\text{GIV}} + \lambda^P \eta_t^e + e_t \tag{C.4}$$

for the multiplier and

$$q_{Et}^{E} = \alpha_E - \zeta^E \cdot p_t^E + \lambda^P \eta_t^e + e_t \tag{C.5}$$

for ζ^E, where $\eta_t^e = \left(\eta_t^{PC,e}, \Delta y_t\right)$. I do not estimate the supply elasticity.

6. For Treasuries, I instrument the interest rate using $Z_t^{T,\text{GIV}}$. I estimate elasticities sector by sector and I adapt the GIV appropriately by excluding sector i's demand shock from its own instrument.

$$Z_{it}^{j,\text{GIV}} = \sum_{\substack{i'=1 \\ i' \neq i}}^{N} S_{i',t-1}^{j} \breve{q}_{i't}^{j} \tag{C.6}$$

Given that the number of sectors is small, the first stage is weak for some $Z_{it}^{j,\text{GIV}}$. By doing so, I deviate from Gabaix and Koijen (2022), and I do not assume that $\zeta_i^{TT} = \zeta^{TT}$ for all sectors.

C.2 Aggregate Elasticity of Treasury Demand

Sector	$\overline{S}_{it}\sigma\left(u_{it}\right)$	$\sigma\left(u_{it}\right)$
Households and nonprofits	1.53	13.14
Foreign sector	1.46	3.25
Money market funds	0.56	11.81
U.S. banks	0.52	7.93
State and local governments	0.42	5.06
Mutual funds	0.33	5.82
State and local retirement funds	0.27	4.94
Private pension funds	0.18	4.09
Foreign banking offices in U.S.	0.14	10.28
Life insurers	0.11	3.97
Property-casualty insurers	0.11	3.89
Closed-end funds and ETFs	0.05	7.08
Credit unions	0.03	8.05
Other financial business	0.02	8.86
Holding companies	0.02	14.90
Brokers and dealers	0.00	18.60

Table C.1: Volatility of idiosyncratic demand shocks for Treasuries by sector of the U.S. Financial Accounts. $\overline{S}_{it}$ is the time series average of sector i's equity market share. I use the June 2022 vintage of the U.S. Financial Accounts. I do not include the Federal Reserve because holdings for corporate bonds are always zero. Hence, I cannot compute relative changes in quantities.

	$\Delta y_t^T(\ell)$			$\Delta y_t^T(s)$			Δq_E		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Z_t^{T,\text{GIV}}$	-0.05**	-0.05***	-0.05**	-0.02	-0.04	-0.04			
	[-2.57]	[-2.63]	[-2.60]	[-0.98]	[-1.55]	[-1.49]			
$\Delta y_t^T(\ell)$							12.71***	12.30***	12.47***
							[2.63]	[2.75]	[2.73]
GDP Growth	0.05	0.05	0.05	0.08*	0.08*	0.08*	-0.68	-0.66	-0.68
	[1.50]	[1.49]	[1.50]	[1.78]	[1.79]	[1.82]	[-1.42]	[-1.42]	[-1.45]
η_1		0.00	0.00		0.04***	0.04**		-0.06	-0.05
		[0.28]	[0.26]		[2.66]	[2.57]		[-0.34]	[-0.28]
η_2			-0.01			-0.03*			0.41*
			[-0.62]			[-1.71]			[1.93]
Constant	-0.08*	-0.08*	-0.08*	-0.10*	-0.10**	-0.10**	1.02*	0.99*	1.00*
	[-1.81]	[-1.80]	[-1.80]	[-1.96]	[-1.99]	[-2.00]	[1.74]	[1.75]	[1.77]
N	143	143	143	143	143	143	143	143	143
R^2	0.072	0.073	0.075	0.060	0.110	0.133	.	.	.

Table C.2: Estimates of the macro elasticity for Treasuries. The sample is Q1–1986 to Q1-2022. I use the June 2022 vintage of the U.S. Financial Accounts. t-statistics are reported in brackets and asterisks refer to 10%, 5% and 1% significance level, respectively.

C.3 Aggregate Elasticitiy of Equity Demand

Sector	$\overline{S}_{it}\sigma(u_{it})$	$\sigma(u_{it})$
Households and nonprofits	0.66	1.57
Mutual funds and ETFs	0.28	1.13
State and local retirement funds	0.20	2.63
Foreign sector	0.16	1.41
Private pension funds	0.13	1.28
Life insurers	0.03	1.46
Brokers and dealers	0.03	4.97
Property-casualty insurers	0.02	1.48
State and local governments	0.02	3.43
Federal retirement funds	0.01	3.07
Closed-end funds	0.01	3.32
U.S. banks	0.01	2.65

Table C.3: Volatility of idiosyncratic demand shocks by sector of the U.S. Financial Accounts. $\overline{S}_{it}$ is the time series average of sector i's equity market share. I use the June 2022 vintage of the U.S. Financial Accounts.

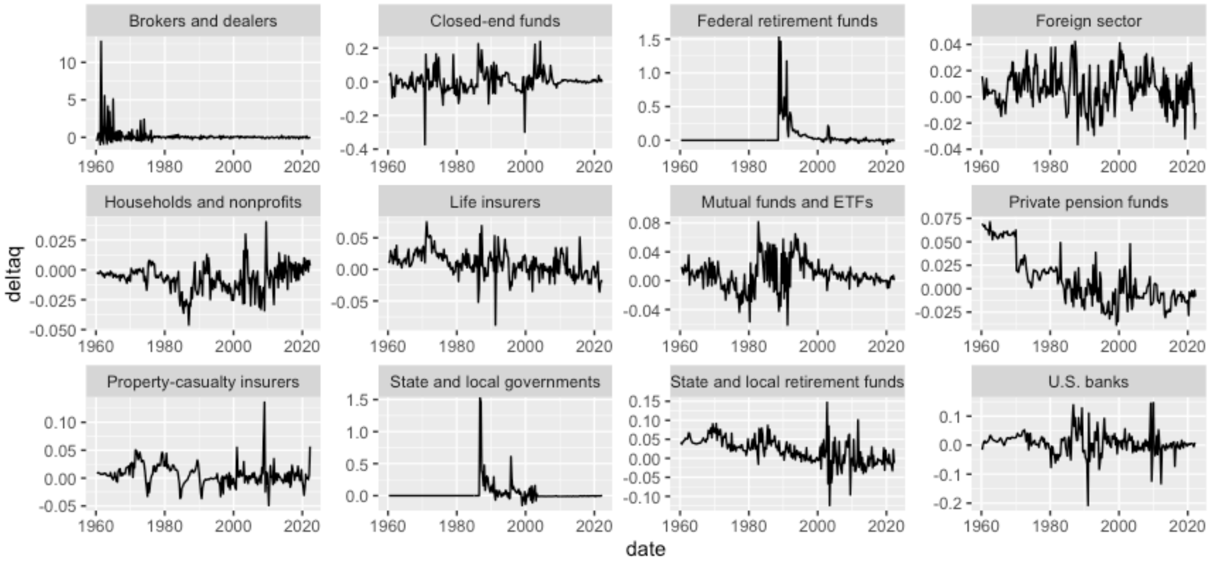

Figure C.1: Dynamics of equity flows across sectors. The figure shows the equity flows q_{it}^E as in figure C.3 of Gabaix and Koijen (2022). The sample is Q1–1960 to Q4–2018, and I use the June 2022 vintage of the U.S. Financial Accounts.

	p			q_E		
	(1)	(2)	(3)	(4)	(5)	(6)
$Z_t^{E,\text{GIV}}$	7.25***	3.52***	3.47***			
	[5.89]	[2.79]	[2.72]			
Δp				-0.12***	-0.29**	-0.28**
				[-4.02]	[-2.49]	[-2.44]
GDP growth	6.31***	6.10***	6.09***	0.51*	1.48**	1.45*
	[5.72]	[6.32]	[6.29]	[1.87]	[1.99]	[1.92]
η_1	1.52*	0.71	0.70	0.29***	0.31**	0.31**
	[1.93]	[1.01]	[0.99]	[3.32]	[2.00]	[2.06]
η_2		4.58***	4.61***		1.48**	1.44**
		[5.63]	[5.63]		[2.16]	[2.12]
η_3			-0.35			0.13
			[-0.46]			[0.56]
Constant	-0.42	-1.40	-1.46	0.10	-0.37	-0.35
	[-0.29]	[-1.12]	[-1.16]	[0.56]	[-0.86]	[-0.83]
N	104	104	104	104	104	104
R^2	0.396	0.544	0.545	.	.	.

Table C.4: Estimates of the macro elasticity from the U.S. Financial Accounts. This table replicates columns (1) to (4) of table 3 in Gabaix and Koijen (2022) and includes an additional principal component η_3. I use the June 2022 vintage of the U.S. Financial Accounts. t-statistics are reported in brackets and asterisks refer to 10%, 5% and 1% significance level, respectively.

D Proofs

Proposition D.1 ((Non-)Identification of Preference Parameter ψ_i^ξ)**.** *Consider a linear regression model $q_{it}^T = \beta_{i0}^T + \beta_{i1}^T \cdot \xi_t + \epsilon_{it}^T$ based on equation (2.16). Then, the least square estimator of the slope coefficient $\widehat{\beta}_{i1}^{T,OLS}$ converges in probability to*

$$\widehat{\beta}_{i1}^{T,OLS} \xrightarrow{p} \left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} - \frac{\mathbb{C}ov\left(\frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t} - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T, \xi_t \right)}{\mathbb{V}ar(\xi_t)} \tag{D.1}$$

Furthermore, if ξ_t is orthogonal to latent demand and supply shocks, then $\widehat{\beta}_{i1}^{T,OLS}$ recovers the demand loading on the convenience yield. If in addition all sectors have the same price elasticity, then $\widehat{\beta}_{i1}^{T,OLS}$ is a consistent an unbiased estimator of the preference parameter ψ_i^ξ.

Proof. Starting from the linear model $\beta_{i0}^T + \beta_{i1}^T \cdot \xi_t + \epsilon_{it}^T$, it immediately follows that OLS estimator $\widehat{\beta}_{i1}^{T,OLS}$ converges in probability to

$$\begin{aligned}
\widehat{\beta}_{i1}^{T,OLS} \xrightarrow{p} \frac{\mathbb{C}\mathrm{ov}(q_{it}^T, \xi_t)}{\mathbb{V}\mathrm{ar}(\xi_t)} &= \frac{\mathbb{C}\mathrm{ov}\left(\left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} \xi_t - \frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t} - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T, \xi_t \right)}{\mathbb{V}\mathrm{ar}(\xi_t)} \\
&= \left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\} - \frac{\mathbb{C}\mathrm{ov}\left(\frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t} - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T, \xi_t \right)}{\mathbb{V}\mathrm{ar}(\xi_t)}
\end{aligned}$$

If ξ_t is orthogonal to, common factors, idiosyncratic shocks, and supply shocks, then $\mathbb{E}[\xi_t \cdot \varepsilon_t^T] = \mathbb{E}[\xi_t \cdot \eta_t] = \mathbb{E}[\xi_t \cdot \varepsilon_t^S] = 0$. Given that $\nu_i^T = \lambda_i^T \eta_t + \varepsilon_{it}^T$, it follows $\mathbb{E}[\xi_t \cdot \nu_i^T] = 0$. Therefore,

$$\frac{\mathbb{C}\mathrm{ov}\left(\frac{\zeta_i^T}{\zeta_{S^T}^T} \left\{ \nu_{S^T t} - \lambda^S \cdot \eta_t - \varepsilon_t^S \right\} + \nu_{it}^T, \xi_t \right)}{\mathbb{V}\mathrm{ar}(\xi_t)} = 0$$

and

$$\widehat{\beta}_{i1}^{T,OLS} \xrightarrow{p} \left\{ \psi_i^\xi - \psi_{S^T}^\xi \frac{\zeta_i^T}{\zeta_{S^T}^T} \right\}$$

Finally, if price elasticities are the same for all sectors, then $\zeta_i^T = \zeta^T = \zeta_{S^T}^T$ and $\frac{\zeta_i^T}{\zeta_{S^T}^T} = 0$. Thus

$$\widehat{\beta}_{i1}^{T,OLS} \xrightarrow{p} \psi_i^\xi - \psi_{S^T}^\xi$$

Since $\psi_{S^T}^\xi$ is the same for all $i \in \{1, \ldots, N\}$, the ordering of ψ_i^ξ is the same as the ordering based on $\psi_i^\xi - \psi_{S^T}^\xi$, leading to the desired result. ∎

Proposition D.2 (Market Clearing Prices)**.** *Consider the demand system with price spillovers (B.9)-(B.10). Let S_i^j denote the market share of sector i for security j, and $x_{S^j} = \sum_{i=1}^N S_i^j x$ be the size-*

weighted average of a variable x using security j's market shares. The market clearing yields are

$$\Delta y_t^T = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{C} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{TC}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \tag{D.2}$$

$$\Delta y_t^C = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{CT} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{T}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \tag{D.3}$$

Further, the change in the yield spread is

$$\Delta y_t^C - \Delta y_t^T = \frac{1}{\tau}\frac{\left(\zeta_{SC}^{C} - \zeta_{SC}^{CT}\right)\left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \left(\zeta_{S^T}^{TC} - \zeta_{S^T}^{T}\right)\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \tag{D.4}$$

Proof. Market clearing requires

$$\sum_{i=1}^{N} S_{it}^{j} q_{it}^{T} = 0 \Longrightarrow \tau \cdot \zeta_{S^T}^{T}\Delta y_t^T - \tau \cdot \zeta_{S^T}^{TC}\Delta y_t^C + \psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T} = 0$$

$$\sum_{i=1}^{N} S_{it}^{j} q_{it}^{C} = 0 \Longrightarrow -\tau \cdot \zeta_{SC}^{CT}\Delta y_t^T \tau \cdot \zeta_{SC}^{C}\Delta y_t^C + \nu_{SC t}^{C} = 0$$

Using matrix notation, the system can be written as

$$\tau \cdot \begin{bmatrix} \zeta_{S^T}^{T} & -\zeta_{S^T}^{TC} \\ -\zeta_{SC}^{CT} & \zeta_{SC}^{C} \end{bmatrix} \begin{bmatrix} \Delta y_t^T \\ \Delta y_t^C \end{bmatrix} = \begin{bmatrix} -\psi_{S^T}^{\xi}\xi_t - \nu_{S^T t}^{T} \\ -\nu_{SC t}^{C} \end{bmatrix}$$

Solving for the market clearing yields gives

$$\begin{bmatrix} \Delta y_t^T \\ \Delta y_t^C \end{bmatrix} = \frac{1}{\tau} \cdot \frac{1}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \cdot \begin{bmatrix} \zeta_{SC}^{C} & \zeta_{S^T}^{TC} \\ \zeta_{SC}^{CT} & \zeta_{S^T}^{T} \end{bmatrix} \cdot \begin{bmatrix} -\psi_{S^T}^{\xi}\xi_t - \nu_{S^T t}^{T} \\ -\nu_{SC t}^{C} \end{bmatrix}$$

or

$$\Delta y_t^T = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{C} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{TC}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}}$$

$$\Delta y_t^C = -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{CT} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{T}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}}$$

It follows that change in yield spread, i.e. $\Delta y_t^C - \Delta y_t^T = \Delta(y_t^C - y_t^T)$ is

$$\begin{aligned} \Delta y_t^C - \Delta y_t^T &= -\frac{1}{\tau} \cdot \frac{\zeta_{SC}^{CT} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{T}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} + \frac{1}{\tau} \cdot \frac{\zeta_{SC}^{C} \left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \zeta_{S^T}^{TC}\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \\ &= \frac{1}{\tau}\frac{\left(\zeta_{SC}^{C} - \zeta_{SC}^{CT}\right)\left[\psi_{S^T}^{\xi}\xi_t + \nu_{S^T t}^{T}\right] + \left(\zeta_{S^T}^{TC} - \zeta_{S^T}^{T}\right)\nu_{SC t}^{C}}{\zeta_{S^T}^{T}\zeta_{SC}^{C} - \zeta_{SC}^{CT}\zeta_{S^T}^{TC}} \end{aligned}$$

■

Proposition D.3 (Own- and Cross-Price Elasticities with Mean-Variance Preferences)**.** *Consider a change from $\overline{P}^j$ to P^j. If all securities initially have the same expected return $\overline{\mu}^j = \overline{\mu}$, then own- and cross-price elasticities are given by*

$$\frac{dQ^j}{dP^j}\frac{\overline{P}^j}{\overline{Q}^j} = -\left(1-\overline{\omega}^j\right)\Theta^j \tag{D.5}$$

$$\frac{dQ^{j'}}{dP^j}\frac{\overline{P}^j}{\overline{Q}^{j'}} = \overline{\omega}^j\Theta^j \tag{D.6}$$

where

$$\Theta^j \equiv \left\{1-\frac{\phi^j}{\gamma_i}\mathbb{1}'\Sigma^{-1}\mathbb{1}\right\}$$

and $\phi^j \equiv \frac{\partial\mu^j}{\partial P^j}\overline{P}^j$ is the own-price semi-elasticity of expected returns μ_j.

Proof. To simplify notation I write $\gamma_i = \gamma$. First, note that

$$\frac{\partial\boldsymbol{\omega}}{\partial P_j} = \frac{\partial}{\partial P_j}\left(\frac{1}{\gamma}\Sigma^{-1}\left(\boldsymbol{\mu}+\lambda\mathbb{1}\right)\right) = \frac{1}{\gamma}\Sigma^{-1}\left(\frac{\partial\boldsymbol{\mu}}{\partial P_j}+\frac{\partial\lambda}{\partial P_j}\mathbb{1}\right)$$

Further, the second term can be written as

$$\frac{\partial\lambda}{\partial P_j} = -\frac{1}{\mathbb{1}'\Sigma^{-1}\mathbb{1}}\mathbb{1}'\Sigma^{-1}\frac{\partial\boldsymbol{\mu}}{\partial P_1} = -\overline{\boldsymbol{\omega}}'\frac{\partial\boldsymbol{\mu}}{\partial P_1}$$

where the last equality uses that assets initially have the same expected return $\mu_j = \mu$, which implies that $\boldsymbol{\mu} = \mathbb{1}\mu$. Hence

$$\overline{\boldsymbol{\omega}} = \frac{1}{\gamma}\Sigma^{-1}\left(\boldsymbol{\mu}+\lambda\mathbb{1}\right) = \frac{1}{\gamma}\Sigma^{-1}\mathbb{1}\left(\mu+\lambda\right) = \frac{1}{\gamma}\Sigma^{-1}\mathbb{1}\frac{\gamma}{\mathbb{1}'\Sigma^{-1}\mathbb{1}} = \frac{\Sigma^{-1}\mathbb{1}}{\mathbb{1}'\Sigma^{-1}\mathbb{1}} \Longrightarrow \overline{\boldsymbol{\omega}}' = \frac{\mathbb{1}'\Sigma^{-1}}{\mathbb{1}'\Sigma^{-1}\mathbb{1}}$$

where $\mathbb{1}'\Sigma^{-1} = \Sigma^{-1}\mathbb{1}$ uses the fact that Σ^{-1} is symmetric and that $\sum_{j=1}\varsigma_{j,k} = \sum_{j=1}\varsigma_{k,j}$, where $\{\varsigma_{j,k}\}_{j,k=1,\dots n}$ denote the elements of Σ^{-1}. Putting thing together gives

$$\Upsilon \equiv \frac{\partial\boldsymbol{\omega}}{\partial P_j} = \frac{1}{\gamma}\Sigma^{-1}\left(\frac{\partial\boldsymbol{\mu}}{\partial P_j}-\overline{\boldsymbol{\omega}}'\frac{\partial\boldsymbol{\mu}}{\partial P_j}\mathbb{1}\right) = \frac{1}{\gamma}\Sigma^{-1}\frac{\partial\mu_j}{\partial P_j}(\iota_j-\overline{\omega}_j\mathbb{1})$$

where the last line follows from the fact that $\frac{\partial\mu_k}{\partial P_j} = 0$ for $k \neq j$ implies $\overline{\boldsymbol{\omega}}'\frac{\partial\boldsymbol{\mu}}{\partial P_1} = \overline{\omega}_j$. Note that $\iota_j' \equiv (0,0,\dots,1\dots,0,0)$ is an n-dimensional vector with one in the j^{th} entry and zero elsewhere. For future reference, note that the k^{th} entry of Υ is equal to

$$\Upsilon_{(k)} = \begin{cases} \frac{1-\overline{\omega}_j}{\gamma}\frac{\partial\mu_j}{\partial P_j}\sum_{n=1}^N\varsigma_{kn} & : \quad k=j \\ \frac{-\overline{\omega}_j}{\gamma}\frac{\partial\mu_j}{\partial P_j}\sum_{n=1}^N\varsigma_{kn} & : \quad k\neq j \end{cases}$$

The identity $\ln(Q_j) = \ln(\omega_j\cdot W) - \ln(P_j)$ implies that

$$\frac{\partial\ln Q_j}{\partial\ln P_k} = \frac{\partial\omega_j}{\partial P_k}\cdot\frac{\overline{P}_j}{\overline{\omega}_j}+\frac{\partial W}{\partial P_k}\cdot\frac{P_k}{W}-\frac{\partial\ln P_j}{\partial\ln P_k}$$

If $j = k$, it immediately follows from previous results that

$$\frac{\partial \ln Q_j}{\partial \ln P_j} = \Upsilon_{(j)} \frac{\overline{P}_j}{\overline{\omega}_j} + \overline{\omega}_j - 1 = \frac{1 - \overline{\omega}_j}{\gamma} \frac{\partial \mu_j}{\partial P_j} \sum_{n=1}^{N} \varsigma_{jn} \frac{\overline{P}_j}{\overline{\omega}_j} + \overline{\omega}_j - 1 = (\overline{\omega}_j - 1) \left\{ 1 - \frac{1}{\gamma} \sum_{n=1}^{N} \varsigma_{jn} \frac{\partial \mu_j}{\partial P_j} \frac{\overline{P}_j}{\overline{\omega}_j} \right\}$$

Repeating the same steps as before but for Q_k, I get $\ln(Q_k) = \ln(\omega_j \cdot W) - \ln(P_k)$. Therefore

$$\frac{\partial \ln Q_k}{\partial \ln P_j} = \Upsilon_{(k)} \frac{\overline{P}_j}{\overline{\omega}_k} + \overline{\omega}_j = -\overline{\omega}_j \frac{1}{\gamma} \sum_{n=1}^{N} \varsigma_{kn} \frac{\partial \mu_j}{\partial P_j} \frac{\overline{P}_j}{\overline{\omega}_k} + \overline{\omega}_j = \overline{\omega}_j \left\{ 1 - \frac{1}{\gamma} \sum_{n=1}^{N} \varsigma_{kn} \frac{\partial \mu_j}{\partial P_j} \frac{\overline{P}_j}{\overline{\omega}_k} \right\}$$

Finally, recall that $\overline{\boldsymbol{\omega}} = \frac{\Sigma^{-1}\mathbb{1}}{\mathbb{1}'\Sigma^{-1}\mathbb{1}}$. Hence,

$$\overline{\omega}_k = \overline{\boldsymbol{\omega}}_{(k)} = \frac{1}{\mathbb{1}'\Sigma^{-1}\mathbb{1}} \sum_{n=1}^{N} \varsigma_{kn}$$

As a result

$$\frac{1}{\overline{\omega}_j} \sum_{n=1}^{N} \varsigma_{jn} = \frac{\mathbb{1}'\Sigma^{-1}\mathbb{1}}{\sum_{n=1}^{N} \varsigma_{jn}} \sum_{n=1}^{N} \varsigma_{jn} = \mathbb{1}'\Sigma^{-1}\mathbb{1}$$

for all k. In summary,

$$\zeta^{jj} = -\frac{\partial \ln Q_j}{\partial \ln P_j} = (1 - \overline{\omega}_j)\, \xi_j$$
$$\zeta^{kj} = -\frac{\partial \ln Q_k}{\partial \ln P_j} = -\overline{\omega}_j \xi_j$$

where

$$\xi_j \equiv \left\{ 1 - \frac{\phi_j}{\gamma} \mathbb{1}'\Sigma^{-1}\mathbb{1} \right\}$$

and $\phi_j \equiv \frac{\partial \mu_j}{\partial P_j} \overline{P}_j$ is the semi-elasticity of μ_j with regard to prices. This gives the desired result and concludes the proof. ■

E Additional Results

E.1 Determinants of Convenience Yields

			$\mathcal{S}_t(\ell)$					$\mathcal{S}_t(s)$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
g_t^{GDP}	-0.09***				-0.02	-0.08*				-0.05*
	[-2.90]				[-0.68]	[-1.86]				[-1.90]
π_t^{CPI}		0.20***			0.21***		0.45***			0.43***
		[5.37]			[6.01]		[6.85]			[6.23]
g_t^{IND}			-0.06***		-0.05**			-0.05***		-0.03
			[-3.85]		[-2.44]			[-3.21]		[-1.38]
Gap_t				-3.91***	-4.40***				5.13***	3.57**
				[-2.66]	[-2.69]				[3.53]	[2.12]
Constant	0.92***	0.73***	0.89***	0.85***	0.76***	0.58***	0.12**	0.56***	0.52***	0.20***
	[25.94]	[17.38]	[31.31]	[33.31]	[16.28]	[12.12]	[2.43]	[16.91]	[18.09]	[3.72]
N	280	258	280	280	258	280	258	280	280	258
R^2	0.057	0.099	0.081	0.021	0.204	0.030	0.352	0.044	0.029	0.394

Table E.1: The dependent variable is either the long or the short term spread. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). The macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. The quarterly sample is from Q4–1951 to Q4–2021. Robust standard errors are in brackets.

			$\mathcal{S}_t(\ell)$					$\mathcal{S}_t(s)$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\ln P_t^{\mathrm{OIL}}$	0.14***				0.02	-0.08***				-0.00
	[7.55]				[0.54]	[-4.04]				[-0.15]
i_t^{FFR}		0.02***			-0.06***		0.09***			0.03***
		[3.10]			[-2.95]		[10.39]			[2.75]
i_t^{TED}			-0.02		0.12			0.66***		0.46***
			[-0.24]		[1.35]			[6.35]		[4.09]
VIX_t				0.02***	0.02***				0.01**	0.00
				[6.41]	[4.31]				[2.58]	[0.98]
Constant	0.48***	0.79***	0.91***	0.53***	0.61**	0.74***	0.09***	-0.03	0.09	-0.06
	[7.87]	[19.40]	[21.05]	[7.98]	[2.49]	[12.28]	[2.75]	[-0.48]	[1.32]	[-0.53]
N	280	269	144	128	128	280	269	144	128	128
R^2	0.150	0.026	0.001	0.225	0.404	0.039	0.461	0.775	0.091	0.789

Table E.2: The dependent variable is either the long or the short term spread. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). The financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. The quarterly sample is from Q4–1951 to Q4–2021. Robust standard errors are in brackets.

	$\mathcal{S}_t(\ell)$				$\mathcal{S}_t(s)$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dealers $\text{TCR}_t(s)$	-0.08				-0.13***			-0.14
	[-1.66]				[-3.12]			[-1.55]
Dealers $\text{TCR}_t(\ell)$	-0.08**			-0.08**	-0.07**			
	[-2.11]			[-2.18]	[-2.47]			
$\text{TCR}_t(s)$		0.06				0.00		-0.03
		[0.59]				[0.04]		[-0.39]
$\text{TCR}_t(\ell)$		-0.21		-0.09		-0.34		
		[-0.63]		[-0.63]		[-1.31]		
$\sum_{k\in t} \text{repo}_k(s)$			0.18**				-0.19***	-0.19**
			[2.25]				[-2.74]	[-2.24]
$\sum_{k\in t} \text{repo}_k(\ell)$			-0.34***	-0.24			0.01	
			[-2.88]	[-0.66]			[0.05]	
Constant	1.94***	1.43**	3.88**	5.49	1.24***	1.04**	2.79**	3.66***
	[4.81]	[2.56]	[2.50]	[0.98]	[3.44]	[2.14]	[2.15]	[2.73]
N	55	55	96	55	55	55	96	55
R^2	0.169	0.011	0.094	0.137	0.342	0.172	0.123	0.272

Table E.3: The dependent variable is either the long or the short term spread. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). The intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. .The quarterly sample is from Q4–1951 to Q4–2021. Robust standard errors are in brackets.

E.2 Military Expenditure Shocks

	Long spread $-\ \mathcal{S}_t(\ell)$			**Short spread** $-\ \mathcal{S}_t(s)$		
	(1)	(2)	(3)	(4)	(5)	(6)
Z_t^{ξ}	1.30**	0.72	0.09	0.13	0.63	-0.02
	[2.37]	[1.59]	[0.11]	[0.20]	[1.37]	[-0.08]
$\Delta y_t(\tau)$	-0.16***	-0.10**	-0.11**	-0.08	-0.12**	-0.07**
	[-3.10]	[-1.98]	[-2.01]	[-1.35]	[-2.24]	[-2.32]
Constant	0.86***	1.16***	0.36	0.40***	-0.02	0.11
	[18.42]	[12.18]	[0.76]	[7.38]	[-0.25]	[0.55]
Macro	No	Yes	No	No	Yes	No
Fin.	No	No	Yes	No	No	Yes
N	120	120	104	120	120	104
R^2	0.17	0.42	0.47	0.01	0.38	0.81
F-Stat	7.49	7.12	7.06	0.91	6.02	40.18

Table E.4: The dependent variable is the long term spread or the long term spread. Z_t^{ξ} denotes the cumulative military expenditure shock from Ramey (2011). The sample is Q1–1986 to Q4–2015.

E.3 Evidence from Portfolio Weights

	Log Treasury shares – $\log \omega_{it}^T$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\mathcal{S}_t(\ell)$	-0.46***	-0.48***	-0.44***	-0.12	0.07					
	[-8.15]	[-11.96]	[-9.77]	[-1.30]	[1.01]					
$\mathcal{S}_t(s)$						0.09***	0.09***	0.11***	0.17	-0.21***
						[2.91]	[2.91]	[3.42]	[1.48]	[-3.16]
Sector FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Macro	No	No	Yes	No	No	No	No	No	No	No
Fin	No	No	No	Yes	No	No	No	Yes	Yes	No
Int.	No	No	No	No	Yes	No	No	No	No	Yes
N	5658	5658	5284	2840	1349	5658	5658	5284	2840	1349
R^2	0.04	0.51	0.52	0.52	0.78	0.47	0.47	0.49	0.52	0.76

Table E.5: The dependent variable is the log Treasury share ω_{it}^T. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. Financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q4–1951 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

	Log Treasury shares – $\log \omega_{it}^T$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\mathcal{S}_t(\ell)$	-0.48***	-0.49***	-0.44***	-0.25**	-0.14*					
	[-8.36]	[-12.17]	[-9.58]	[-2.55]	[-1.69]					
$y_t^T(\ell)$	0.02*	0.01*	0.01	-0.08***	-0.14***					
	[1.75]	[1.77]	[1.11]	[-3.33]	[-4.06]					
$\mathcal{S}_t(s)$						0.03	0.03	0.02	0.36***	-0.14**
						[0.98]	[0.98]	[0.69]	[3.11]	[-2.13]
$y_t^T(s)$						0.02**	0.02**	0.05***	0.34***	0.08**
						[2.46]	[2.46]	[6.29]	[3.21]	[2.48]
Sector FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Macro	No	No	Yes	No	No	No	No	No	No	No
Fin	No	No	No	Yes	No	No	No	Yes	Yes	No
Int.	No	No	No	No	Yes	No	No	No	No	Yes
N	5658	5658	5284	2840	1349	5658	5658	5284	2840	1349
R^2	0.04	0.51	0.52	0.53	0.78	0.47	0.47	0.50	0.52	0.76

Table E.6: The dependent variable is the log Treasury share $\log \omega_{it}^T$. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. Financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q4–1951 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

E.4 Other Results with Portfolio Weigths

	Log relative weights $\log \omega_{it}^T - \log \omega_{it}^C$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\mathcal{S}_t(\ell)$	-0.70***	-0.74***	-0.68***	-0.37**	-0.34**					
	[-6.44]	[-10.37]	[-8.45]	[-2.44]	[-1.98]					
$y_t^T(\ell)$	0.01	0.02	0.02	-0.16***	-0.25***					
	[0.66]	[1.49]	[1.33]	[-4.09]	[-3.37]					
$\mathcal{S}_t(s)$						-0.15	-0.07	-0.07	0.65***	-0.21
						[-1.62]	[-1.13]	[-1.19]	[3.60]	[-1.64]
$y_t^T(s)$						0.02	0.03***	0.08***	0.83***	0.26***
						[1.47]	[2.81]	[5.76]	[4.98]	[3.88]
Sector FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Macro	No	No	Yes	No	No	No	No	No	No	No
Fin	No	No	No	Yes	No	No	No	Yes	Yes	No
Int.	No	No	No	No	Yes	No	No	No	No	Yes
N	4286	4286	4034	2363	1129	4286	4286	4034	2363	1129
R^2	0.03	0.58	0.58	0.56	0.70	0.00	0.55	0.57	0.55	0.70

Table E.7: The dependent variable is the log Treasury share relative to the corporate share ω_{it}^R. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). The acroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. The financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q4–1951 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

	Change in Treasury Share – $\Delta\omega_{it}^T$									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\Delta\mathcal{S}_t(\ell)$	-0.01	-0.01	-0.01	-0.04	-0.02					
	[-0.71]	[-0.68]	[-0.32]	[-1.49]	[-0.65]					
$\Delta y_t^T(\ell)$	-0.00	-0.00	0.00	0.00	-0.01					
	[-0.43]	[-0.36]	[0.17]	[0.21]	[-0.34]					
$\Delta\mathcal{S}_t(s)$						-0.02**	-0.02**	-0.01**	0.00	0.00
						[-2.51]	[-2.51]	[-2.11]	[0.03]	[0.00]
$\Delta y_t^T(s)$						-0.00	-0.00	-0.00	0.01	-0.02
						[-0.72]	[-0.72]	[-0.29]	[0.91]	[-0.68]
Sector FE	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Macro	No	No	Yes	No	No	No	No	No	No	No
Fin	No	No	No	Yes	No	No	No	Yes	Yes	No
Int.	No	No	No	No	Yes	No	No	No	No	Yes
N	5605	5605	5248	2822	1345	5605	5605	5248	2822	1345
R^2	0.00	0.01	0.01	0.02	0.03	0.01	0.01	0.01	0.02	0.03

t statistics in brackets
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table E.8: The dependent variable is the change in the Treasury share $\Delta\omega_{it}^T$. The long and the short term yield spreads $\Delta\mathcal{S}_t(\tau)$ between corporate and Treasuries are measured in percentage units (Krishnamurthy & Vissing-Jorgensen, 2012). Macroeconomic variables are real GDP growth, industrial production growth, CPI inflation and the output gap. Financial indicators are oil prices, the federal funds rate, the TED spread, and the VIX. Intermediaries measures include primary dealer tender-to-cover ratio (Klingler & Sundaresan, 2022) and the quarterly volume of repo transactions. Intermediaries measures are maturity-specific and are computed with respect to either bills or bonds. The quarterly sample is from Q4–1951 to Q4–2021. Newey and West (1987) t-statistics (4 lags) are reported in brackets.

E.5 Evidence from Treasury Auctions

	Federal Reserve		PDIs		Individuals		Brokers & Dealers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Maturity	-0.343***	-0.438***	0.0183	0.0197	-0.122***	-0.106***	-0.759***	-0.688***
	(-4.40)	(-5.14)	(1.47)	(1.26)	(-9.51)	(-7.02)	(-4.51)	(-3.72)
T-Bond	10.32***	13.36***	-0.119	-0.134	2.331***	1.939***	-3.370	-6.158
	(4.55)	(5.43)	(-0.30)	(-0.27)	(6.28)	(4.39)	(-0.66)	(-1.11)
FRN	-2.790***	-1.873**	-0.0852	-0.168	-0.978***	-0.903***	-10.80***	-10.01***
	(-4.70)	(-2.66)	(-0.86)	(-1.80)	(-25.1)	(-23.0)	(-7.82)	(-6.11)
T-Note	2.279***	3.118***	0.117	0.0823	0.118	0.0413	-14.06***	-15.48***
	(4.68)	(5.62)	(1.60)	(1.00)	(1.16)	(0.33)	(-16.1)	(-15.4)
TIPS Bond	7.702**	11.31***	-0.590	-0.644	2.574***	2.221***	-10.07*	-10.92
	(3.21)	(3.95)	(-1.73)	(-1.39)	(6.28)	(5.00)	(-2.09)	(-1.95)
TIPS Note	-0.589	1.239	-0.205	-0.164	0.655***	0.635**	-18.78***	-19.89***
	(-0.71)	(1.37)	(-1.56)	(-0.89)	(4.23)	(3.27)	(-8.87)	(-8.08)
GDP growth	-22.30***	46.76***	-1.180	-2.116*	1.646*	0.563	17.70	13.99
	(-4.95)	(8.98)	(-1.47)	(-2.43)	(2.35)	(0.75)	(1.89)	(1.42)
BOP	-2.877*	2.858	0.299	0.587*	-0.614**	-1.089***	-8.276***	-8.924**
	(-2.32)	(1.89)	(1.68)	(2.57)	(-2.84)	(-4.15)	(-3.57)	(-3.10)
Long spread	-14.32***		0.0845		0.870***		4.315***	
	(-27.6)		(1.28)		(12.5)		(5.86)	
Short spread		4.648***		-0.209***		0.274*		0.642
		(6.67)		(-3.31)		(2.12)		(0.62)
constant	22.10***	5.141***	0.204**	0.360***	0.342***	1.180***	58.51***	63.22***
	(38.0)	(24.8)	(2.87)	(11.7)	(4.95)	(38.0)	(71.2)	(184.7)
N	5679	4251	5679	4251	5679	4251	5679	4251
R^2	0.177	0.032	0.008	0.009	0.089	0.066	0.264	0.286

Table E.9: OLS estimates of regression equation $\nu^T_{i,j,t} = \beta_0 + \beta_1 cy_t + \gamma \boldsymbol{z}_t + \phi \boldsymbol{x}_{j,t} + \delta_j + \varepsilon_{i,j,t}$. The table reports coefficient estimates for the Federal Reserve, private depository institutions, individual investors, and security brokers and dealers. Robust standard errors are reported in parenthesis. The sample is from 2001 to 2022 and it covers all auctions carried out by the U.S. Department of Treasury.

	Pension Funds		**Investment Funds**		**Foreign Sector**	
	(1)	(2)	(3)	(4)	(5)	(6)
Maturity	-0.00853	-0.00163	0.702***	0.724***	0.473***	0.474***
	(-1.30)	(-0.32)	(4.59)	(4.23)	(7.22)	(6.39)
T-Bond	0.350	0.165	4.757	4.361	-11.79***	-11.83***
	(1.85)	(1.15)	(1.03)	(0.86)	(-6.09)	(-5.42)
FRN	0.0458	0.0355	3.277	-1.040	3.677***	5.872***
	(0.97)	(0.71)	(1.68)	(-0.54)	(3.31)	(4.26)
T-Note	-0.0295	-0.0793**	6.134***	6.787***	6.969***	6.778***
	(-0.88)	(-2.88)	(6.67)	(6.44)	(17.1)	(14.1)
TIPS Bond	1.243***	1.139*	12.07**	9.521	-10.59***	-11.04***
	(3.39)	(2.40)	(2.71)	(1.79)	(-5.46)	(-4.80)
TIPS Note	0.587***	0.483*	20.44***	19.52***	-0.362	-0.449
	(3.61)	(2.50)	(10.1)	(8.71)	(-0.48)	(-0.52)
GDP growth	0.669***	-0.299	7.564	-58.19***	2.342	-5.801
	(3.32)	(-1.39)	(0.61)	(-4.81)	(0.52)	(-1.26)
BOP	0.00782	-0.0636	12.33***	8.008**	-0.152	-1.932
	(0.069)	(-0.48)	(5.27)	(2.76)	(-0.097)	(-1.03)
Long spread	0.161***		9.330***		1.683***	
	(4.33)		(14.0)		(4.61)	
Short spread		-0.0879***		-3.873***		-2.312***
		(-3.70)		(-3.82)		(-5.64)
constant	-0.0280	0.179***	8.418***	19.98***	6.645***	8.757***
	(-0.75)	(12.6)	(11.3)	(58.1)	(17.8)	(42.3)
N	5679	4251	5679	4251	5678	4251
R^2	0.038	0.027	0.222	0.200	0.155	0.151

Table E.10: OLS estimates of regression equation $\nu^T_{i,j,t} = \beta_0 + \beta_1 cy_t + \gamma \boldsymbol{z}_t + \phi \boldsymbol{x}_{j,t} + \delta_j + \varepsilon_{i,j,t}$. The table reports coefficient estimates for pension funds, investment funds, and the foreign sector, and security brokers and dealers. Robust standard errors are reported in parenthesis. The sample is from 2001 to 2022 and it covers all auctions carried out by the U.S. Department of Treasury.