Historical US Funding Cost Advantage: 1860-2024*

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Abstract

We estimate a historical funding cost advantage of the US government, as measured by the spread between yields on high-grade corporate bonds and treasuries. We construct a new dataset with monthly price, cash-flow, and rating information for US corporate bonds over the period 1860-2024. We deploy a Kernel Ridge regression to estimate US high-grade corporate and treasury yield curves making adjustments for tax treatment and time-varying embedded option values. A high-grade corporate to treasury spread emerged well before Bretton Woods with the introduction of the 1862-65 National Banking Acts. Previous estimates have mismeasured and exaggerated US funding advantage in the post-WWII period. In particular, funding advantage is negatively correlated with inflation and goes to zero during the Great Inflation in the 1970s-80s. We find little evidence that the US strategically exploits its monopoly power.

JEL classification: E31, E43, G12, N21, N41

Key words: Corporate Yields, Treasury Yields, Convenience Yields, Government Debt Capacity, Flower Bonds.

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1 Introduction

Many researchers have argued that the US government enjoys a funding advantage in the sense that it can issue bonds at lower interest rates than the private sector, even when the private sector issues bonds that promise the after-tax cash flow sequence. In macroeconomic modeling this allows the government to sell debt that is not necessarily backed by future fiscal surpluses (a "convenience" benefit source of financing). The magnitude of the government's funding cost advantage is often measured by the spread between yields on high-grade US corporate bonds and the yields on US treasuries (e.g. Krishnamurthy and Vissing-Jorgensen (2012)). In this paper, we revisit and expand the historical evidence on US high-grade corporate to treasury spreads. This involves the compilation of new bond datasets, the estimation of corporate and government yield curves for the period 1860-2024, and corrections to make corporate and government debt comparable (e.g. adjustments for taxes and callability). In doing so, we uncover the statistical properties of US funding advantage and show how it has evolved with major changes in monetary, financial, and fiscal policies.

We construct zero-coupon yield curves for high-grade corporate and government bonds that promise consistent pecuniary payouts. This involves resolving three main difficulties: (i) detailed bond-level price data for high-grade corporate bonds prior to the 1970s has not previously been collected, (ii) public and private sector discount functions q_t and $\tilde{\mathsf{q}}_t$ must be inferred from the prices of *coupon-bearing bonds*, and (iii) the outstanding public and private sector coupon-bearing bonds differ in "technical characteristics" which contribute to observed price differentials but do not necessarily reflect the government's funding advantage. To overcome the first difficulty, we construct a new micro-level dataset with historical bond price, coupon, and maturity information from 1860-2024 that matches our existing datasets for Treasuries. To address the second challenge, we estimate zero-coupon yield curves using the "Kernel Ridge" estimator from Filipović et al. (2022). This approach is attractive because it uses out of sample forecasting to choose the appropriate yield curve shape from a large class of functional forms.

Finally, to address the third challenge, we adjust the estimated bond pricing formulas to ensure like-for-like comparison between private and public sector bonds. One set of adjustments relate to differential tax treatment. From 1913-1941 the treasuries were exempt from Federal taxation while corporate bonds were not. After

1941, all treasuries were subject to Federal income tax but sometimes ended up with a capital gains tax advantage. We resolve these issues by imposing historical tax rates in our asset pricing formulas. Another set of adjustments relate to differential option values. Between 1918 and 1971, the Treasury issued a subclass of government bonds, known as "flower bonds", which could be used to pay the bondholder's federal estate taxes upon their death *at par value* rather than market value. This meant that flower bonds essentially provided a tax concession that became more valuable during periods of high inflation when bond prices fell well below par value. That is, they provided a hedge against inflation risk. In addition, some treasuries and most corporate bonds included call options. We resolve these issues by pricing the various options embedded in the different bonds.

Our new estimates allow us to infer a collection of stylized facts about relative government debt prices and funding cost advantage. First, we identify low frequency movements in average funding cost spreads that coincide with large changes to financial sector regulation and the Federal Reserve's large scale bond purchase programs. The funding cost spread on US Treasuries emerged well before Bretton Woods and global dollar dominance with the introduction of the 1862-65 National Banking Acts. It generally stayed high during the gold standard but then dropped sharply after World War I and followed a trend decline after the Great Depression. Quantitative easing during World War II led to an increase in the funding cost spread at the short maturities while quantitative easing after the 2007-09 financial crisis led to an increase at long maturities.

Second, we find that heightened inflation risk during the 1970s coincided with an erosion of the funding cost spread on nominal government debt. This is in contrast to conclusions drawn from the series commonly used in the literature (e.g. the spread between the long-term treasury yield and Aaa corporate yield indices used by Krishnamurthy and Vissing-Jorgensen (2012) and other papers), which document the Aaa Corporate-Treasury spread reaching its highest level during the Great Inflation. The reason for the discrepancy is that the commonly used indices do not take into account the differential tax treatments of a certain subclass of government bonds, the so called "flower bonds". Holders of flower bonds could use the par value of their debt to off-set estate taxes, which meant that the bonds acted as a good inflation hedge. As a result, flower bonds traded like "real-bonds" and saw low yields during the Great Inflation in the 1970-80s. Ultimately, this (and other issues in the series) mean that the commonly used index-based spread in the literature is for many periods effectively a comparison between a nominal, callable corporate bond and a "real" treasury with a put option against inflation risk. We conclude that a large portion of the 1970's variation in existing AAA Corporate-Treasury series is attributable to the (negative) inflation risk premia on flower bonds instead of a heightened funding advantage on regular US Treasuries.

Related literature: Our work extends existing studies on the convenience yield (e.g. Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016), Choi et al. (2022), Cieslak et al. (2024)) back to the mid nineteenth century. This makes us part of a literature attempting to connect historical time series for asset prices to government financing costs (e.g. Payne et al. (2025), Jiang et al. (2022a), Chen et al. (2022), Jiang et al. (2022b), Jiang et al. (2021b), Jiang et al. (2021a), Jiang et al. (2020)).

Technically, our work is related to Nelson and Siegel (1987), Cecchetti (1988), Svensson (1995), Gürkaynak et al. (2007), Liu and Wu (2021), and Filipović et al. (2022) who estimate zero-coupon yield curves using combinations of the law of one price and some restrictions on the shape of the yield curve. We adopt and extend the Ridge regression approach proposed by Filipović et al. (2022). Our paper is related to the literature attempting to explain (at least) part of the corporate-treasury spread with technical characteristics such as tax advantages and time-varying option values: Cook and Hendershott (1978), Duffee (1996), Duffee (1998), Elton et al. (2001).

The paper is structured as follows. Section 2 explains our conceptual framework. Section 3 examines our dataset, traces the evolution of US bond markets, and outlines the institutional details regarding the distinctions between corporate and government bonds. Section 4 briefly summarizes our statistical methodology. Section 5 presents our estimate of the high-grade corporate yield curve and the term structure of AAA Corporate-Treasury spreads. Section 6 revisits key relationships studied in the macro finance literature using our new measure of the funding cost spread. Section 7 concludes.

2 Conceptual Framework

In this section, we introduce the notion of a government funding cost advantage using a stylized model. Consider a discrete time, infinite horizon economy with time indexed by $t \in \{0, 1, \ldots\}$. The economy contains a representative private sector investor and a government.

The government issue bonds with different cash-flow profiles none of which are subject to default risk. Let $\mathcal{N}_t$ denote the set of government bonds outstanding at time t. Each bond $i \in \mathcal{N}_t$ promises a sequence of coupons $\{cp_{t,i}^{(j)}\}_{j=1}^{\infty}$ and principal payments $\{pr_{t,i}^{(j)}\}_{j=1}^{\infty}$, combined into the cash-flow stream $\mathsf{c}_{t,i} := \{c_{t,i}^{(j)}\}_{j=1}^{\infty}$ with $c_{t,i}^{(j)} := cp_{t,i}^{(j)} + pr_{t,i}^{(j)}$ denoting period-t promises of j-period-ahead dollars. These coupon-bearing bonds trade in a competitive market at prices $p_{t,i}$ and are in positive net supply $B_{t,i}$, where $B_{t,i}$ is the total amount (face value) of newly issued and outstanding bond i in period t. In equilibrium, the law of one price holds implying that

$$p_{t,i} = \sum_{j=1}^{\infty} q_t^{(j)} c_{t,i}^{(j)}, \qquad \forall i \in \mathcal{N}_t, \forall t \geq 0, \tag{2.1}$$

where $q_t^{(j)}$ denotes the price of a government promise to one dollar at time $t + j$ with $q_t^{(0)} = 1$. We call the sequence $\mathsf{q}_t := \{q_t^{(j)}\}_{j=0}^{\infty}$ the government's *discount function*. Using condition (2.1), we can express the period-t market value of the government debt portfolio using the following (equivalent) forms:

$$\sum_{i \in \mathcal{N}_t} p_{t,i} B_{t,i} = \sum_{i \in \mathcal{N}_t} \sum_{j=1}^{\infty} q_t^{(j)} c_{t,i}^{(j)} B_{t,i} = \sum_{j=1}^{\infty} q_t^{(j)} \sum_{i \in \mathcal{N}_t} c_{t,i}^{(j)} B_{t,i} =: \sum_{j=1}^{\infty} q_t^{(j)} b_t^{(j)},$$

where the last expression defines $b_t^{(j)} := \sum_{i \in \mathcal{N}_t} c_{t,i}^{(j)} B_{t,i}$ as the number of $t + j$ dollars that the government has at time t promised to deliver. We call the sequence $\mathsf{b}_t := \{b_t^{(j)}\}_{j \geq 1}$ the *zero-coupon equivalent* government debt portfolio and construct the panel $\{\mathsf{b}_t\}_{t \geq 0}$ from historical data by adding up all of the dollar principal-plus-coupon payments promised by the government at time t.

Each period t, the government enters with a stock of promised payments b_{t-1}, spends g_t, raises taxes τ_t and finances the resulting deficit/surplus by "restructuring" its debt portfolio in the form of new issues of zero-coupon bonds b_t. The period t government budget constraint can be written as

$$b_{t-1}^{(1)} + g_t - \tau_t = \sum_{j=1}^{\infty} q_t^{(j)} \left(b_t^{(j)} - b_{t-1}^{(j+1)} \right)$$

that is, period-t interest payments, $b_{t-1}^{(1)}$, and primary deficit, $(g_t - \tau_t)$, must be financed by refinancing the government debt portfolio at market prices $\{q_t^{(j)}\}_{j\geq 1}$. In other words, the government's borrowing costs can be fully characterized by the discount function q_t.

The basic premise of this paper is that when a private corporation issues high-grade debt that matches the cash-flow profile of government bonds, they may face a different discount function $\tilde{\mathsf{q}}_t$ with $\tilde{\mathsf{q}}_t \leq \mathsf{q}_t$. This means that the government can potentially sell a bond at a higher price than the private sector, $q_t^{(j)} \geq \tilde{q}_t^{(j)}$, even when the bond promises the same cash flow stream $\mathsf{c}_{t,i} := \{c_{t,i}^{(j)}\}_{j=1}^{\infty}$ and the same (zero) default risk. A common explanation for such a difference is because the representative investor receives a non-pecuniary benefit from holding government debt due to higher liquidity, differential regulation, market segmentation, or other reasons unrelated to the bond's cash-flow stream. Following the literature, we characterize this non-pecuniary benefit by imposing that the elements of q_t and $\tilde{\mathsf{q}}_t$ solve the investor Euler equations $\forall j \geq 1$:

$$q_t^{(j)} = \mathbb{E}\Big[\xi_{t,t+1}\Omega_{t,t+1}q_{t+1}^{(j-1)}\Big], \qquad \tilde{q}_t^{(j)} = \mathbb{E}\Big[\xi_{t,t+1}\tilde{q}_{t+1}^{(j-1)}\Big] \qquad \text{with} \;\; q_t^{(0)} = \tilde{q}_t^{(0)} = 1,$$

where $\xi_{t,t+1}$ is the investor's stochastic discount factor (SDF) and $\Omega_{t,t+1}$ is a government debt specific wedge capturing the non-pecuniary benefit of government debt.

Iterating the government budget constraint forward gives the lifetime budget constraint under the private sector's stochastic discount factor (see Appendix A):[1]

$$\sum_{j=1}^{\infty} q_t^{(j-1)} b_{t-1}^{(j)} = \underbrace{\mathbb{E}_t\left[\sum_{s=0}^{\infty}\xi_{t,t+s}\Big(\tau_{t+s} - g_{t+s}\Big)\right]}_{(i)} + \underbrace{\sum_{j=1}^{\infty}\Big(q_t^{(j)} - \tilde{q}_t^{(j)}\Big)b_{t-1}^{(j+1)}}_{(ii)}$$
$$+ \underbrace{\mathbb{E}_t\left[\sum_{s=0}^{\infty}\xi_{t,t+s}\left\{\sum_{j=1}^{\infty}\Big(q_{t+s}^{(j)} - \tilde{q}_{t+s}^{(j)}\Big)\Big(b_{t+s}^{(j)} - b_{t-1+s}^{(j+1)}\Big)\right\}\right]}_{(iii)}. \tag{2.2}$$

This equation implies that the market value of outstanding debt (including interest payments) can be written as a sum of three components: (i) the present discounted value of future primary surpluses, (ii) a term associated with the revaluation of the

[1] Why use the private sector's SDF? To project the future cost of debt issuance—and the associated funding advantage—we must consider the SDF of the prospective buyer, which, in this case, corresponds to the private sector.

stock of existing long-term government debt, and (iii) the present discounted value of the "convenience revenue" the government earns from being able to issue *new* debt more cheaply than the private sector. The second term would disappear if the government only issued one-period debt.

We characterize the government's funding advantage through the term structure of the high-grade corporate to treasury yield spreads:

$$\chi_t^{(j)} := \frac{1}{j}\log\left(q_t^{(j)}\right) - \frac{1}{j}\log\left(\widetilde{q}_t^{(j)}\right), \qquad \forall j \geq 1, \text{ with } \chi_t^{(0)} = 0. \tag{2.3}$$

Evidently, the portion of the market value of government debt which is unbacked by future surpluses, i.e., the last two terms on the right-hand-side of (2.2), is an increasing function of $\{\chi_t^{(j)}\}_{j\geq 1}$. In the special case of $\mathsf{q}_t = \widetilde{\mathsf{q}}_t$, we obtain the result that current debt must be fully backed by future primary surpluses.

The goal of this paper is to provide an empirical counterpart for the term structure of the high-grade corporate to treasury yield spread, $\{\chi_t^{(j)}\}_{j\geq 1}$. As we discuss in the subsequent sections, this is a non-trivial task that requires both original data collection and statistical work.

3 Challenges With Measuring Funding Advantage

In this section, we discuss the available data and technical challenges with measuring government funding advantage. As defined by equation (2.3), we are trying calculate the premium that private investors are willing to pay for the government's promise to "pay \$1 j-periods ahead", relative to the same commitment made by high-grade private corporations. Ideally, such premiums would be measured by directly comparing the prices of commensurate private and public sector j-period zero-coupon bonds for different values of j. However, unfortunately, such assets do not exist in sufficiently large numbers, which necessitates a more complicated approach.

There are three key difficulties: (i) detailed bond-level price data for high-grade corporate bonds prior to the 1970s has not previously been collected, (ii) public and private sector discount functions q_t and $\widetilde{\mathsf{q}}_t$ must be inferred from the prices of *coupon-bearing bonds*, and (iii) the outstanding public and private sector coupon-bearing bonds differ in "technical characteristics" which contribute to observed price differentials but do not necessarily reflect the government's funding advantage. To overcome the first difficulty, we construct a new historical dataset with comprehensive coverage of corporate bonds going back to the 1840s. To address the second challenge, we estimate zero-coupon yield curves adopting the flexible non-parametric approach proposed by Filipović et al. (2022). To deal with the third challenge, we adjust the corresponding pricing formulas to ensure like-for-like comparison between private and public sector bonds.

Many of these technical characteristics originate from the US government's long-standing desire to minimize the cost of servicing federal debt. Key strategies to achieve this have included designing government debt instruments with appealing contractual features (e.g., extended call deferment periods, exchange options) and granting preferential treatment to government IOUs, such as through tax exemptions and substantial financial regulatory advantages. While these provisions have been effective in temporarily reducing the interest cost of federal debt, most were not "budget neutral", as they resulted in future government losses primarily through reduced tax revenues. This distinction is important because the defining feature of government funding advantage is that the government does not need to directly back it with tax revenues. Therefore, measuring the government's funding cost advantage requires removing the influence of these factors from observed high-grade corporate to treasury yield spreads.

We describe our data set in Section 3.2 and in Appendix C. The most important technical characteristics that need to be accounted for are discussed in Section 5.2.1. We present our proposed corrections in Section 4. However, before turning to our estimation strategy, in Section 3.1 we explain why we need a new historical convenience spread measure by pointing out some key issues with the commonly used index-based measure.

3.1 Index-based yield spreads

The most widely used measure of historical government funding advantage (or "convenience yield") on long-maturity bonds—likely favored for its relatively long time series—is computed by comparing two yield indices:

- Moody's Seasoned Aaa-rated long-maturity corporate bond index (FRED code: AAA)—constructed from a sample of industrial and utility bonds (industrial only after 2002) with more than 20 years to maturity.

- The Federal Reserve Board's long-term US government bond yield index (FRED code: LTGOVTBD)—constructed as the average yield on *all* outstanding government bonds neither due nor callable in less than 10 years.[2]

For brevity, we will call this the *index-based* Aaa Corporate-Treasury spread. This measure was proposed by Krishnamurthy and Vissing-Jorgensen (2012) and used by many subsequent papers.

The index-based Aaa Corporate-Treasury spread is derived from *before-tax yields-to-maturity*, calculated under the assumption that the future cash flows are default-free and repayment dates (or call dates) are known with certainty. Within this framework, the bond's "yield" is defined as the discount rate, $\overline{y}_t$, which equates the observed bond price to the present value of future cash flows. This calculation employs formula (2.1), assuming $q_t^{(j)} = (1 + \overline{y}_t)^{-j}$ and that $\mathsf{c}_{t,i}$ represents before-tax promised cash flows. The underlying assumption is that the *composition* of corporate and government bonds included in the indexes is similar and remains constant over time. Specifically, it is implicitly assumed that (i) both subsets of bonds share a comparable, time-invariant average maturity, (ii) all bonds are subject to the same federal income tax treatments and are traded close to par,[3] and (iii) even if some bonds have peculiar characteristics (like call or put options) the implied price effect is time-invariant.

In this paper, we show that, throughout the 20th century, the index-based Aaa Corporate-Treasury spread frequently violated these assumptions. First, the average maturity of long-term government bonds did not stay constant. During the 1960s, the average maturity of government bonds in the government yield index declined by almost 7 years due to a Congressionally-mandated interest rate ceiling. Second, the tax treatment of government bonds experienced significant changes prior to the 1980s. Notably, before World War II and during the 1970s government bonds benefited from substantial tax advantages over high-grade corporate bonds. Third, embedded call and put options were unevenly distributed between government and high-grade corporate bonds, with their values fluctuating significantly over time in response to

[2]More precisely, the Treasury bonds included are due or callable after 12 years for 1926–1941, 15 years for 1941–1951, 12 years for 1952, and 10 years for 1953–1999. The series was discontinued in 2000, after which point papers in the literature use the "market yield on US Treasury Securities at 20-year constant maturity" (FRED code: GS20).

[3]Robichek and Niebuhr (1970) and McCulloch (1975) demonstrate that tax-induced biases can distort the shape of the yield curve when it is derived from below-par price quotations. We will come back to this point in section 3.3.1.

changing market conditions.

Consequently, the index-based Aaa Corporate-Treasury spread is a very unreliable measure of government funding advantage. As we will show, this issue is especially pronounced during the high inflation of the 1970s and 1980s, when the index-based spread essentially contrasted a nominal, callable corporate bond with a "real" Treasury bond that included a put option against inflation risk. A key objective of this paper is to provide a measure of funding advantage that is immune to such distortions.

3.2 Data

High-grade Corporate Bonds: For US corporate bonds, we construct a new historical dataset for the period 1850-2024 with monthly data on trading prices, cash-flows, credit ratings, and bond characteristics such as maturity, denomination, and callability. Our dataset integrates existing databases with hand-collected prices and bond characteristics from historical newspapers, business magazines, and financial releases by companies.[4] Appendix C provides further details on our high-grade corporate bond data set.

For this project, we focus on the period from 1860-2024 where there are sufficiently many price observations to estimate a yield curve. We limit our sample to high-grade corporate bonds to minimize default risk. To classify bonds as high-grade, we primarily rely on Moody's credit ratings, which became available in 1909, and restrict our sample to Aaa-rated bonds. For bonds maturing before 1909, we follow Macaulay (1938) in identifying high-quality issuers, relying on the selection of railroad companies included in his high-grade railroad bond yield index. Specifically, we include companies from which Macaulay selected at least one bond for his index.[5]

US Government Bonds: For US Treasury debt we use the CRSP Treasury Securities database (containing month-end bond prices) in conjunction with the comprehensive bond panel assembled by Hall et al. (2018) and utilized in Payne et al. (2025). We

[4]In particular, from 1974 onward we rely on the Lehman Brothers Fixed Income Database (1974-1997) and the Merrill Lynch Bond Index Database (1998-2024).

[5]Macaulay carefully selected companies based on their financial strength and excluded them before they encountered financial trouble, to ensure that his index reflected only the most creditworthy issuers. However, as pointed out in Homer and Sylla (2004), constructing an index equivalent to a modern Aaa bond index prior to 1900 presents challenges due to the limited number of true high-grade issuers and even Macaulay's "high-grade" sample exhibits some variation in credit quality.

exclude the Treasury Inflation-Protected Securities (TIPS) from our sample, but we keep bonds with varying tax exemptions and bonds with embedded call and put options. Figure 1 depicts the number of outstanding marketable Treasury bonds and notes classified by tax-treatment for the sub-period 1926-2024. While the figure does not include T-Bills and Certificates of Indebtedness, we utilize these securities in our estimation.

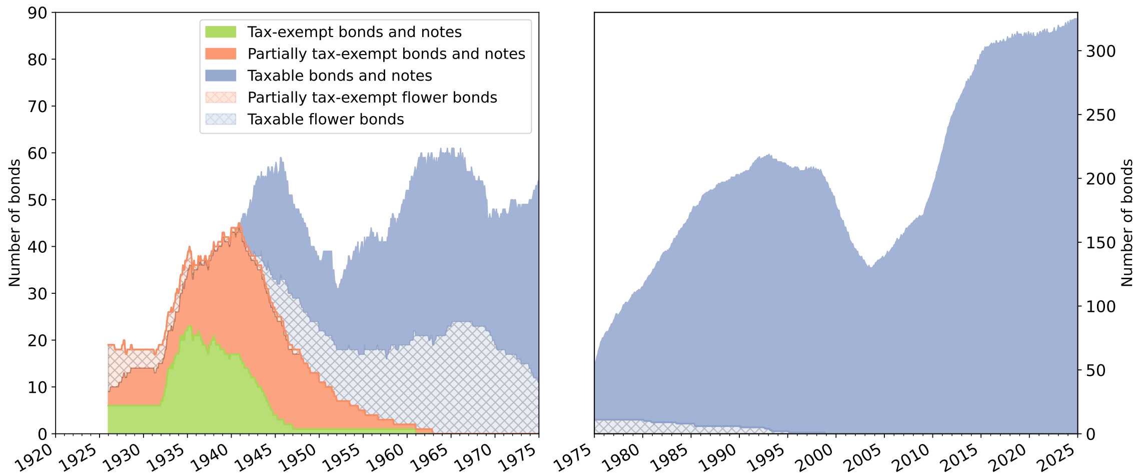

Figure 1: Number of Outstanding Marketable Treasury Bonds and Notes.

Notes: Excluding T-Bills and Certificates of Indebtedness. Different colors represent the tax treatment of each issue.

3.3 Technical Characteristics and Institutional Details

In this section we examine some institutional details that are crucial for understanding why and how specific technical characteristics resulted in pricing differences between otherwise "equivalent" corporate and government bonds. We focus on two themes: (i) price implications of the federal income tax code and (ii) price implications of options (implicit or explicit) embedded in corporate and government bonds.

3.3.1 Price Effects of Federal Income Taxation

Before the introduction of US federal income taxation in 1913, neither corporate nor government bonds were subject to any taxes.[6] Since then, income earned by both corporations and individuals from long-term securities holdings has been subject to two types of taxes.[7] Interest payments are taxed at the relevant (holder-specific) marginal income tax rate τ^{inc}, while the difference between the purchase price and the redemption value is taxed at the long-term capital gains tax rate τ^{cg}. Historically, long-term capital gains tax rates have consistently been lower than marginal income tax rates.[8]

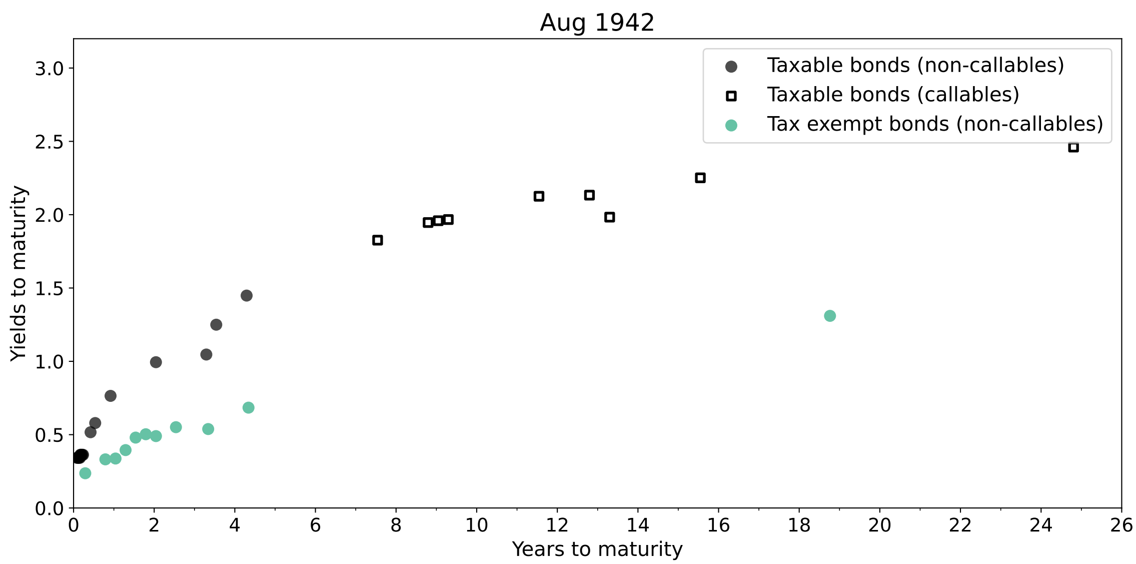

Figure 2: Price Implications of Tax Advantage.

Notes: Panels depict yields-to-maturity (y-axes) against years-to-maturity (x-axes) for different dates (panel title). Each circle/square corresponds to a separate bond outstanding in the given month. Dots show non-callable bonds, squares represent callable bonds. Green color represents tax-exempt bonds, black color represents regular taxable bonds.

Income Tax Rates: As we can see in Figure 1, from 1913 to 1941, an unusual situation

[6] The Sixteenth Amendment to the Constitution was announced on February 25, 1913 and the new Federal income-tax law in pursuance of this amendment was enacted on October 3, 1913.

[7] In addition, since 1916, all bonds were subject to estate taxes except for the so called flower bonds, represented by the light marked areas in Figure 1.

[8] A useful rule of thumb is that τ^{cg} is one half τ^{inc}.

existed where proceeds from corporate bonds were taxed while US federal government bonds were (either partially or wholly) exempt from federal income taxes, creating an obvious tax advantage for US treasuries. We can gauge the approximate price impact of this exemption by analyzing the early 1940s, a period during which taxable and fully tax-exempt bonds were traded concurrently. The left panel of Figure 2 illustrates the yields-to-maturity across various maturity horizons for taxable and fully tax-exempt government bonds outstanding in August 1942. The plot highlights that the price impact of federal income tax exemptions was substantial. Notably, at the five-year horizon, tax-exempt bonds earned yields approximately 80 basis points lower than those of taxable bonds with comparable coupon rates and maturities. For longer maturities, the effect was even bigger.

Capital Gains Tax Rates: As a result of the disparity in tax rates between ordinary income and long-term capital gains, bonds with income predominantly derived from the latter source—–such as low-coupon bonds traded well below par (the so called seasoned discount bonds)—–tended to benefit from a relative tax advantage compared to bonds whose income primarily came from interest payments, such as newly issued bonds.[9] When interpreting the high-grade corporate-to-treasury yield spread, it is essential to consider the compositional differences between corporate and government bonds, especially regarding the relative prevalence of seasoned discount bonds versus newly issued bonds within the bond samples.

In this context, a key legislation that unexpectedly gained prominence in the late 1960s and early 1970s was the Congressional mandate, established in 1917, which imposed a 4-1/4 percent interest rate ceiling on new long-term Treasury bonds.[10] Consequently, when interest rates surpassed the 4-1/4 percent ceiling in the 1960s, the US Treasury was unable to issue new bonds with maturities exceeding 5 years (extended to 7 years in 1967) and so the average maturity of outstanding US debt de-

[9]In practice, for newly issued securities, the coupon rate typically adjusts to ensure that bonds are sold at par, making newly issued bonds largely unaffected by the capital gains tax. Conversely, for seasoned securities with fixed coupon rates, it is the price that adjusts to ensure that, in equilibrium, comparable securities offer similar returns. During periods when market yields rise above the bond's coupon rate, this adjustment can lead to a pronounced "capital gains tax advantage".

[10]As explained in Department of the Treasury (1976), the primary rationale for setting a ceiling rate of 4-1/4 percent on long-term government bonds was to minimize borrowing costs tied to the United States' involvement in WWI. This ceiling was intentionally set 25 basis points below prevailing market yields, reflecting the belief that the American public would buy Liberty Bonds for reasons beyond comparative yield considerations.

clined significantly, and the government bond portfolio became heavily concentrated in seasoned discount bonds—benefiting from substantial "capital gains tax advantage". The ceiling on long-term U.S. Treasury bonds was effectively lifted in 1971.

3.3.2 Price Effects of Embedded Options

Estate tax provisions: A notable policy between 1918 and 1971 was the issuance of a subclass of government bonds, known as "flower bonds", which could be used to pay the bondholder's federal estate taxes upon their death *at par value* (instead of market value) plus accrued interest. Moreover, prior to the Tax Reform Act of 1976, flower bonds were valued as inherited property *at their par value* on the date of the decedent's death, effectively exempting them from long-term capital gains taxes. This meant that flower bonds effectively acted as an inflation hedge: rising inflation expectations drove up interest rates, which reduced the bond's market price relative to its par value. This decline, in turn, enhanced the bond's capital gains tax advantage, helping to maintain its *after-tax* return and offering protection against inflation risk. In this way, flower bonds functioned in a manner akin to inflation-protected bonds.

According to Figure 1 flower bonds were an important subset of Treasury securities during the early decades of the post-WWII period.[11] Importantly, from 1955-1971, (almost) all outstanding treasuries with maturity greater that 10 years were flower bonds. Effective March 1971, Congress eliminated flower bond privileges on new US bond issues, ensuring a gradual reduction in their overall supply as outstanding issues used for estate tax purposes were progressively retired over time. The passage of the Tax Reform Act of 1976 in October terminated the flower bonds' exemption from capital gains taxes, which significantly reduced their appeal. To illustrate the importance of the flower bonds, on the top left panel of Figure 3, we show yields-to-maturity for flower bonds (in red) and non-flower bonds (in black) for the month of August 1976. Evidently the flower bonds had a significant price impact. For longer maturities, the flower bond yields-to-maturity are 1-3 percentage points below yields-to-maturity of comparable non-flower bonds (the black dots) and appear to fit a downward sloping yield curve.

Call provisions: Call provisions, which grant the issuer the right to repurchase its

[11] McCulloch (1975), Cook (1977), Cook and Hendershott (1978), and Mayers and Clifford (1987).

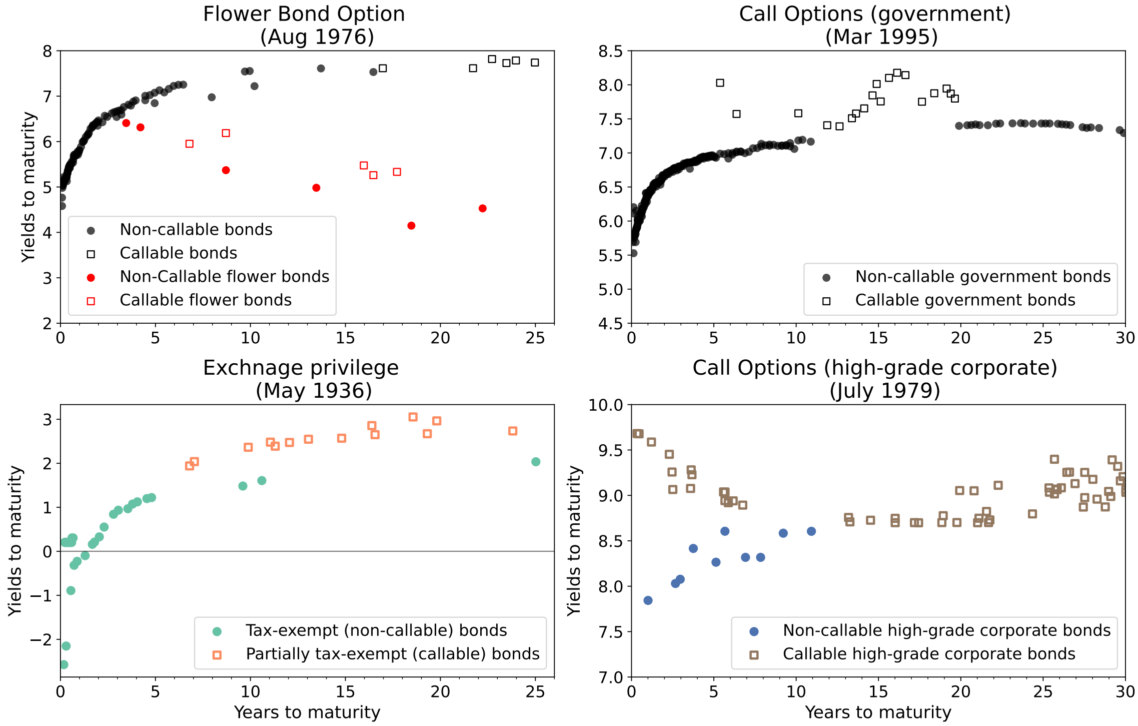

Figure 3: Price Implications of Embedded Options.

Notes: Panels depict yields-to-maturity (y-axes) against years-to-maturity (x-axes) for different dates (panel title). Each circle/square corresponds to a separate bond outstanding in the given month. Red color represents "flower bonds", black color is for regular taxable bonds. Dots show non-callable bonds, squares represent callable bonds. Green color represents tax-exempt bonds, orange color represents partially tax-exempt bonds.

bond before its maturity at a prespecified "call price", introduce uncertainty to the underlying cash flows from the bondholder's perspective. Because issuers are expected to call bonds when their market price sufficiently exceeds the call price, such bonds tend to trade at a discount compared to otherwise identical non-callable bonds.[12] Call provisions are accompanied by a *call-deferment period*—a predetermined timeframe after issuance (but before maturity) during which the issuer cannot call the bond.[13] Intuitively, the size of the discount investors demand for holding callable bonds is inversely related to the length of the call-deferment period.

[12]The greater the probability of a call, and consequently the higher the value of the call option for the issuer, the larger the bondholder's required discount compared to non-callable bonds.

[13]Non-callable bonds, by comparison, can be regarded as having a call-deferment period that extends to their maturity.

Prior to the early 1990's, virtually all high-grade corporate bonds had some kind of call provision with very brief call-deferment periods. In particular, these bonds were usually callable on any interest payment dates, with notice periods typically ranging from 30 to 60 days. The call price usually started at a premium (reflecting a refinancing penalty) and gradually declined to par over time following a structured schedule. Bonds with non-zero call-deferment periods provided only limited protection, typically around five years. In contrast, most US government bonds were non-callable. Those with call provisions typically featured long call-deferment periods, often only a few years shorter than the bonds' maturity.

This pronounced disparity in typical call-deferment periods between corporate and government bonds led, all else being equal, to relatively higher embedded option values in the prices of callable corporate bonds compared to the prices of callable government bonds. During periods of elevated call probability this contributed to a widening of the high-grade corporate-to-treasury spread. However, this spread does not reflect government funding advantage, as the losses stemming from the government's decision not to hedge interest rate risk must ultimately be offset by future revenues. To illustrate the price implications of call options, the top right and bottom right panels in Figure 3 show yields-to-maturity for callable bonds (squares) and non-callable bonds (dots) across government bonds (top right) and high-grade corporate bonds (bottom right). Evidently, the value of call options were relatively large in the two months under consideration resulting in a visible decoupling of the term structures of yields-to-maturity of callable and non-callable bonds.

Exchange Privilege: During the 1930s, interest-bearing US debt nearly doubled, placing substantial pressure on the US Treasury to allocate newly issued securities to the private sector. This challenge was further exacerbated by legal constraints that prohibited the issuance of new government debt securities below par value.[14] In response, as explained by Cecchetti (1988), the US Treasury began issuing new bonds with coupon rates implying market prices above par value, yet these bonds were sold at par. Holders of maturing government bonds and notes received preferential treatment in the allocation of these new issues, creating a valuable "exchange privilege": upon maturity, coupon-bearing Treasury securities could be exchanged for new bonds

[14] The Second Liberty Bond Act required that new Treasury bonds and certificates of indebtedness be issued at par and new notes issued at not less than par.

at par, which subsequently traded above par.

The value of this exchange option exerted significant downward pressure on the yields of coupon-bearing government bonds. In fact, throughout the 1930s, the yields of bonds nearing maturity often turned negative. The bottom left panel in Figure 3, depicting yields-to-maturity for outstanding government bonds in August 1936, is a representative example. Except for the zero-coupon T-bills (that did not have exchange option), all bonds less than 18 months to maturity offered a negative yield-to-maturity![15] According to Cecchetti (1988), the value of the exchange privilege was non-trivial throughout the early 1940s. While the practice of exchange continued beyond 1944, the terms were no longer as favorable and the value of the exchange option disappeared.

4 Constructing Yield Curves and Spreads

In this section, we outline our methodology for estimating yield curves adjusted for the various technical characteristics discussed in Section 3. While studying the term structure of yields-to-maturity provided insights into how these technical characteristics might influence the pricing of debt securities, the notion of yield-to-maturity is inappropriate for approximating the prices of non-traded assets based on law-of-one-price arguments which is the essence of yield curve estimation. This is because arbitrage arguments hold with zero-coupon yields, not with yields-to-maturity.[16] In addition, when proceeds from bonds are taxable, what matters for arbitrage arguments is the after-tax zero-coupon yield curve.

4.1 Tax-Adjusted Zero-Coupon Yield Curves

A prominent branch of the yield curve estimation literature builds on the assumption of the law of one price—by imposing a formula akin to (2.1)—combined with some regularizing (parametric or non-parametric) restrictions on the shapes of the term structure of interest rates. Fama and Bliss (1987), Nelson and Siegel (1987), Svensson

[15] A comparison between the callable bonds (squares) and non-callable bonds (dots) in the bottom-left panel of Figure 3 also suggests that the value of call options was relatively high during the 1930s.

[16] For instance, differences in yields-to-maturity between two coupon-bearing bonds with identical maturity dates do not indicate an arbitrage opportunity. However, differences in zero-coupon yields between two zero-coupon bonds with the same maturity date signify a violation of the law of one price and the presence of profitable arbitrage opportunities. See also Elton et al. (2001).

(1995), Gürkaynak et al. (2007), Liu and Wu (2021), and Filipović et al. (2022) all follow a version of this approach. Importantly, the price formula (2.1) determines the before-tax discount function q_t. However, when bond proceeds are taxable, the relevant concept for no arbitrage arguments becomes the *after-tax* discount function $\underline{\mathsf{q}}_t$. There should be a common after-tax zero-coupon yield curve capable of pricing all outstanding government bonds at a given point in time, and another after-tax zero-coupon yield curve for pricing all high-grade corporate bonds.

Nonetheless, formula (2.1) does not account for differences in tax treatments. Specifically, it cannot distinguish between securities providing interest income that is subject to federal income taxes—like corporate bonds—or exempt from them, as was the case with US government bonds before the 1940s. Nor does it differentiate between securities yielding returns in the form of capital gains, which are taxed at lower rates compared to interest income. To address these variations in the bond data, we adjust the pricing formula as follows:

Assumption 1 (Tax-adjustment)**.** The price of bond i with maturity M_i and promised payments $\mathsf{c}_{t,i}$ is given by:

$$p_{t,i} = \sum_{j=1}^{M_i} \underline{q}_t^{(j)}(1 - \tau_t^{inc})c_{t,i}^{(j)} + \underline{q}_t^{(M_i)}\Big(100 - \tau_t^{cg}[100 - p_{t,i}]^+ - \tau_t^{inc}[100 - p_{t,i}]^-\Big), \quad (4.1)$$

where $\{\underline{q}_t^{(j)}\}_{j\geq 1}$ is the after-tax discount function (government or high-grade corporate depending on the issuer of the bond), τ_t^{inc} is the representative investor's marginal tax rate on ordinary income, while τ_t^{cg} is her tax rate on long-term capital gains.

Pricing formula (4.1) implicitly assumes that the hypothetical representative investor holds the bond until maturity and that she expects her tax rates $(\tau_t^{inc}, \tau_t^{cg})$ to remain constant over the lifetime of the bond. A similar formula to adjust yields for tax effects was applied by Robichek and Niebuhr (1970), McCulloch (1975), and Cook and Hendershott (1978). We assume that the tax rates are equal to the prevailing highest marginal income and capital gains tax rates faced by large corporations.

4.2 Option-Adjusted Zero-Coupon Yield Curves

The prices of bonds with embedded options can be modeled as the sum of the value of a straight bond—having the same coupon and maturity—and the value of the embedded option. More precisely, we generalize our bond price formula as follows:

$$p'_{t,i} := p_{t,i} + v_{t,i}$$

where $p_{t,i}$ denotes the "fundamental value" of the bond, derived from its (after-tax) cash-flow stream $\mathsf{c}_{t,i}$, as defined in (4.1), and $v_{t,i}$ represents the value of the option embedded in bond i. For bonds that do not have embedded options, we simply set $v_{t,i} = 0$, $\forall t$. Adjustments for the three types of options discussed in Section 3.3.2 ultimately requires specifying functional forms for $v_{t,i}$.

Assumption 2 (Option-adjustment)**.** The values of the flower bond option, $v^f_{t,i}$, and call option $v^c_{t,i}$ can be written as

- Value of call option:

$$v^c_{t,i} = \Big(\theta^c_0 + \theta^c_1 p_{t,i} + \theta^c_2 p^c_i\Big) f(M_i)$$

  where p^c_i is the call price of bond i, and $f(\cdot)$ is an exogenous function such that $f(0) = 0$ and $\lim_{m\to\infty} f(m) = \infty$.

- Value of flower bond option:

$$v^f_{t,i} = \Big(\theta^f_0 + \theta^f_1 (100 - p_{t,i})\Big) f(M_i)$$

  where $f(\cdot)$ is an exogenous function such that $f(0) = 0$ and $\lim_{m\to\infty} f(m) = \infty$.

The function $f(\cdot)$ ensures that the value of the options approaches zero for bonds nearing maturity. Additionally, the value of the options increases with M_i, as the prices of longer-term bonds are more sensitive to interest rate fluctuations compared to those of shorter-term bonds. To correct for the exchange privilege we apply formula (1) in Cecchetti (1988).

4.3 Estimating Yield Curves

We estimate zero-coupon yield curves using the Kernel Ridge estimator of Filipović et al. (2022) (henceforth FPY). They propose a flexible, globally non-parametric approach that uniformly improves upon the out-of-sample performance of other popular estimators such as Fama and Bliss (1987), Nelson and Siegel (1987)-Svensson (1995), Gürkaynak et al. (2007), and Liu and Wu (2021) while imposing only weak assumptions about the features of the yield curve. The shape of the yield curve is chosen so that its out-of-sample predictive power is maximized. The estimator is governed by three tuning parameters: $(\lambda, \alpha, \delta)$ that control the smoothness of the yield curve. We summarize the estimation process in Appendix D.

5 Corporate Bond Yields and Convenience Spreads

In this section, we describe the key outputs from our estimation: the high-grade corporate bond yield curve, the treasury yield curve, and the Aaa Corporate-Treasury spread curve for the period 1860-2024. We show that our spread estimate differs significantly from existing series, especially during the Great Inflation period (1965-1980) where the implicit inflation protection embedded in the "flower-bonds" was very valuable.

5.1 High-Grade Corporate Bond Yield Curves

The top panel of Figure 4 depicts selected long term nominal yields on high-grade US corporate bonds. The solid black line represents the median of our 20-year zero coupon yield estimates. Bands around the posterior median depict the 90% interquantile range. Between 1860-1900, long term high-grade corporate yields trended downward from around 8% to around 4% (the "great bond bull market"), then climbed slowly back to 5% by World War I. During the war and the subsequent 1920 recession long term corporate yields reached more than 7% before they began their renewed downward decline (interrupted briefly by the Great Depression). During World War II and the 1950s, the 20-year high-grade corporate yield exhibited surprising stability up until the late 1960s when, in tandem with increasing inflation, it reached its peak of 18% during the 1981-1982 recession.

The blue dashed line in the top panel of Figure 4 depicts the high-grade railroad bond index from Macaulay (1938) computed as the average yield-to-maturity on selected long term bonds issued by reputable railroad companies between 1857-1937. The red solid line is Moody's Seasoned Aaa Corporate Bond Yield index computed as the average yield-to-maturity on bonds with maturity 20 years and above. This

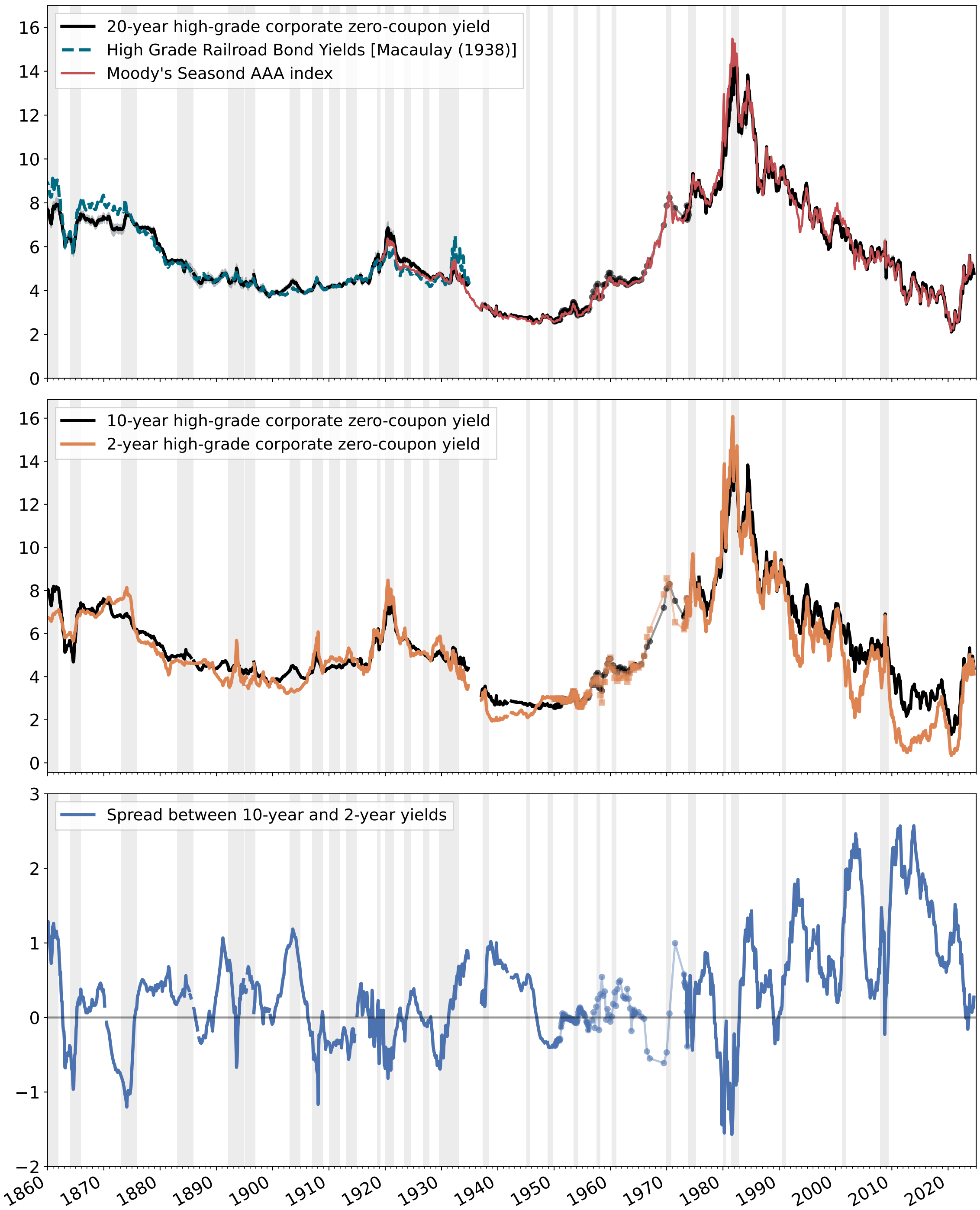

Figure 4: High-grade Nominal Corporate Zero-Coupon Yields 1860-2024

Top panel depicts our posterior median estimate of the 20-year high-grade corporate zero-coupon yield (black). The blue dashed line depicts the High Grade Railroad Bond Index from Macaulay (1938). The red solid line is Moody's Seasoned Aaa bond index. Middle panel depicts posterior median estimates of the 10- (black) and 2-year (orange) high-grade corporate yields. Bottom panel depicts the spread between the 10-year and 2-year yields. The light gray intervals depict NBER recessions.

index is available from 1919 onward. While yields-to-maturity are different from the notion of a zero-coupon yield, we find it reassuring that our estimates broadly align with Macaulay's high-grade railroad and Moody's Aaa indexes.[17]

One of the main advantages of estimating the whole yield curve is to observe shorter maturity private borrowing costs. The middle panel of Figure 4 depicts our posterior median estimates of the 10-year and 2-year zero-coupon yields on high-grade corporate bonds. The bottom panel shows the corresponding spread. Evidently, short- and medium-term yields follow the same trend as the 20-year yield, but they are more volatile, especially in the post WWII period. Before the 1980s, the spread between the 10-year and 2-year zero-coupon yields is close to zero, suggesting that for about 100 years, the average yield curve on high-grade corporate bonds was flat on average.

5.2 Treasury Yield Curves

In previous work, we estimated historical zero-coupon yield curves on US Treasuries from 1790-1933 (see Payne et al. (2025)). For this paper, we extend our estimation to 1934-2024 and make the adjustments for taxes and embedded options described in Section 4 to provide a consistent comparison to the corporate yield curve. Here we explore these estimates. In subsection 5.2.1, we highlight importance of adjusting for the flower bonds. In subsection 5.2.2 we then discuss the overall time series for the Treasury yield curve.

5.2.1 Treasury Yields in the 1960-80 Inflation Episode

As discussed in Subsection , before 1971, the US Federal government issued "flower bonds" which bondholders could use to pay federal estate taxes upon their death *at par value* plus accrued interest (see Cook (1977), Mayers and Clifford (1987)). In addition, before 1976, flower bonds were *valued as inherited property at their par value* on the date of the decedent's death, effectively exempting them from capital gains tax and acting as an effective inflation hedge.

Figure 5 depicts the number of treasuries outstanding over the period 1960-1990

[17] Yield-to-maturity is computed under the assumption of a flat yield curve. In this sense, yield-to-maturity of a particular bond can be considered as the weighted average of zero-coupon yields with the bond's cash-flows acting as weights.

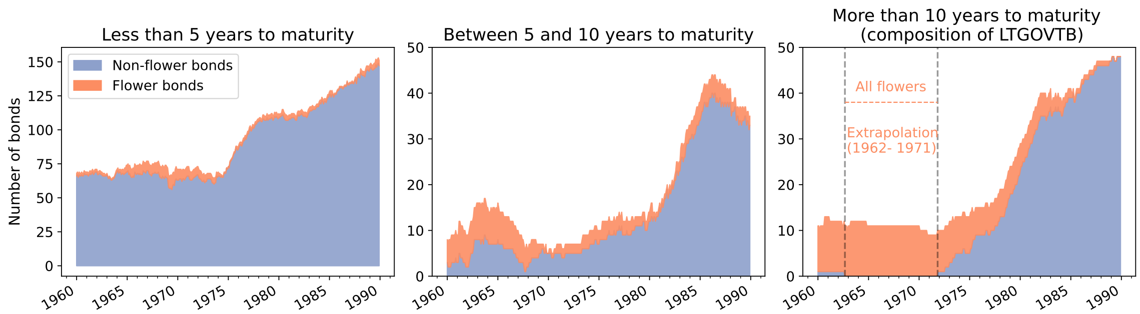

Figure 5: Composition Treasuries: 1960-1990. The left subplot shows the number of bonds with less than 5 years to maturity. The middle subplot shows the number of bonds with 5-10 years to maturity. The right subplot shows the number of bonds with more than 10 years to maturity.

for different maturity categories and broken down into flower and non-flower bonds. Evidently, the flower bonds made up a significant fraction of the long-maturity treasuries until the 1980s. In particular, for the period from 1962-1971 all bonds with maturity greater than 10 years were flower bonds.

To get a sense of the magnitude of the "flower bond effect", we undertake two illustrative exercises. First, in Figure 6, we reconstruct the LTGOVTBD index using the same methodology as the Federal Reserve but without the flower bonds. That is, we compute the average yield-to-maturity for the non-flower bonds with maturity greater than 10 years. We can see that throughout the 1970s the index becomes 0.5 to 1.0 percentage points higher once the flower bonds are excluded.

Second, we estimate our yield curve model from Section 4 using a sample that includes only flower bonds and a sample that excludes all flower bonds. The results are depicted in Figure 7. The black line shows the posterior median estimate of the 10-year zero-coupon yield without flower bonds. The green line shows the posterior median estimate of the 10-year zero-coupon yield using only flower bonds. Evidently, before the end of 1965, the two yields are indistinguishable. This implies that the average long-term government yield index, represented by the red line in Figure 7, is a good approximation of long-term treasury yields.

However, from 1966 onward, a gap opens up between the black and green lines due to the slow increase in the flower bond premium which affected mainly the lowest-

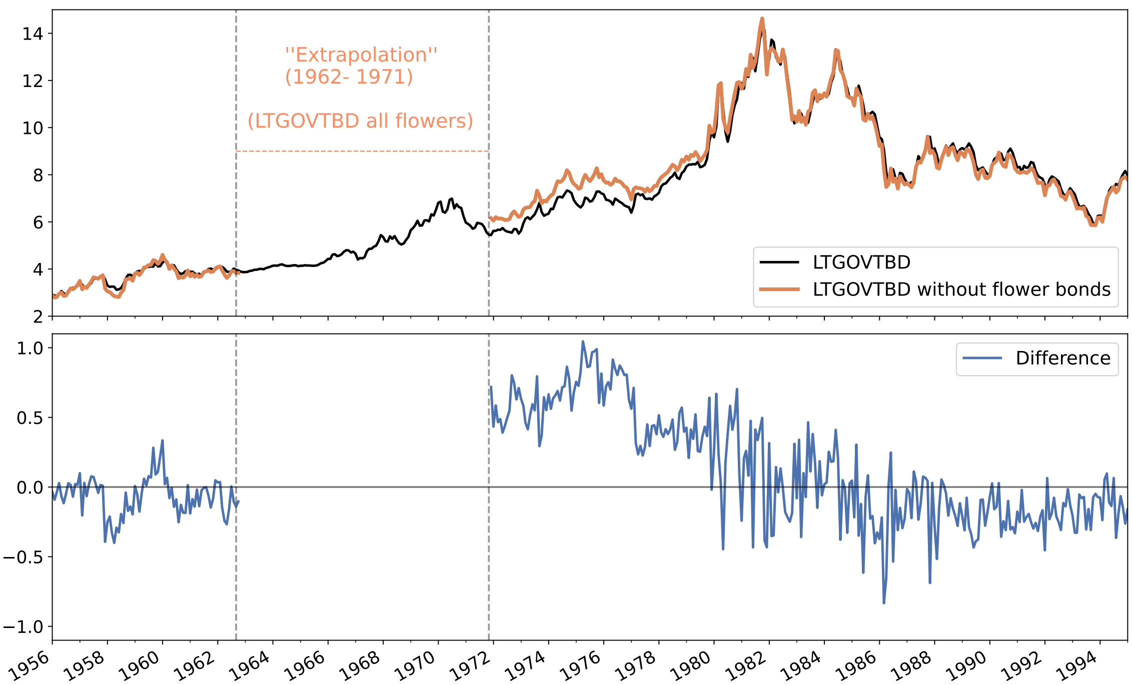

Figure 6: Reconstruction of the LTGOVTBD index. The black line in the top plot original LTGOVTBD index. The orange line is the index reconstructed without the flower bonds. The bottom plot is the difference between the lines.

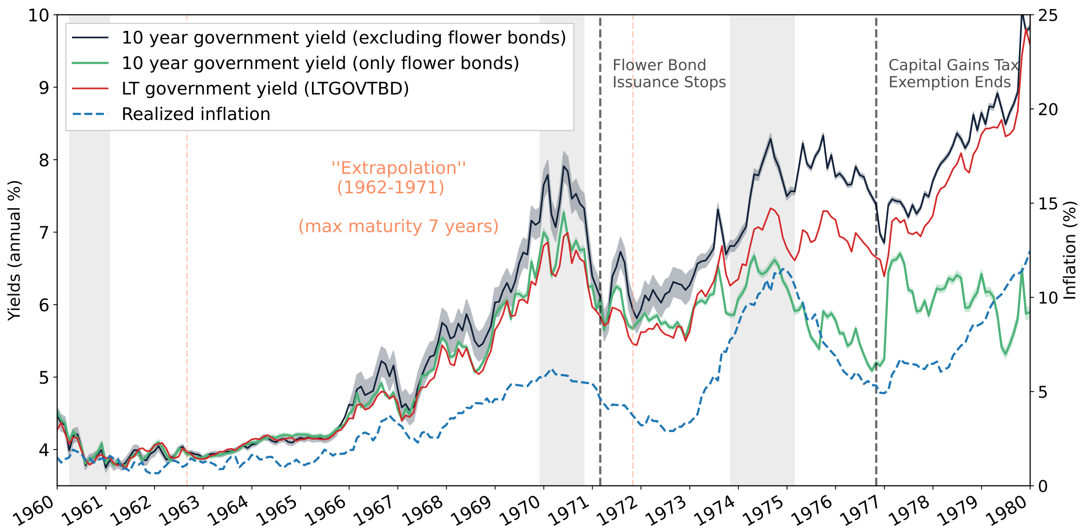

Figure 7: Long Term Government Yields With and Without Flower Bonds

Black solid line is the posterior median estimate of the 20-year zero-coupon yield on US Treasuries excluding all flower bonds from the sample. Green solid line is the posterior median estimate of the 20-year zero-coupon yield on flower bonds only. Bands denote 90% posterior interquantile ranges. Red solid line is the average long-term government yield index (LTGOVBD).

coupon issues.[18] 1971 brought two important changes in the US treasury market. First, the 4-1/4% ceiling on new US bond issues was lifted and so long-term bonds without flower bond provisions started to reappear (with higher coupons). Second, effective March 1971, Congress eliminated flower bond privileges on new US bond issues, thereby ensuring a steadily declining stock as outstanding issues purchased for estate tax purposes were retired over time. The flower bond premium started to increase sharply on all flower bonds, which can be attributed to the combination of (1) the steady decline in the supply of flower bonds and (2) increased demand for flower bonds as rapid inflation drove up the value of estates, but tax laws were not adjusted in a timely manner to correct for the impact on the level of estate taxes. We can see these effects reflected in the decrease in the green line between 1973-1976 in Figure 7. The next big regulatory change was the Tax Reform Act of 1976, passed in

[18] Among the outstanding flower bonds, the ones actually purchased because of the estate-tax feature tended to be the lowest coupon bonds, such as the 3's of 1995 and the 3-1/2 of 1998, which were selling at the largest discounts. Evidence of this can be seen in the amount outstanding, with the net decline from year to year measuring the amount redeemed for estate tax purposes. See Cook (1977).

October, which effectively terminated the flower bonds' exemption from capital gains taxes. Figure 7 demonstrates that the Tax Reform Act of 1976 had a major impact on the pricing of flower bonds. The 20-year zero-coupon yield on flower bonds jumped from around 5% to almost 7% in the two months following the passage of the Act.

Ultimately, because the value of flower bond provisions was inversely related to market prices of bonds, flower bonds implicitly hedged inflation and/or interest rate risk. As a result, these bonds were not priced as regular nominal bonds but instead like real bonds. In fact, to a first approximation, the spread between the black and green lines in Figure 7 can be interpreted as a compensation for inflation risk, which is highest between 1971-1976. In this sense, the yield on flower bonds is not comparable to the yield on corporate bonds: one uses tax revenue to provide an inflation protected return while the other does not. This reinforces why we take the flower bonds out of our baseline estimate for the Treasury yield curve.

5.2.2 Treasury Yields

Before we turn to the construction of high-grade corporate-Treasury yield spreads, it is instructive to see the extent to which the Treasury and Corporate yield curves co-move with each other. The top panel of Figure 8 depicts the 10-year high-grade corporate yield against the 10-year zero-coupon Treasury yields from Payne et al. (2025) combined with our estimates for the modern period. Evidently, the two yields follow similar trend dynamics, but long term treasury yields are persistently lower than high-grade corporate yields throughout our sample. In addition, despite the similar trend, short- and medium-term fluctuations of the two yield curves around their respective trends are very different in the early part of the sample. We can see this reflected in the middle and bottom panels of Figure 8. The middle panel depicts yield curve slopes defined as the spreads between the 10 year and 2 year zero-coupon yields on high-grade corporate bonds (blue) and on US treasuries (orange). The bottom panel shows the 10 year centered rolling correlation between the long end of the yield curves (blue) and the 2-year yields (orange). The corporate and treasury yield curves are only weakly correlated between 1860-1950 and then became highly synchronized after the late 1950s. Despite this convergence, the two yield curves seemed to decouple during the yield curve control period (1942-1951), the Great Inflation, and the post 2008 period.

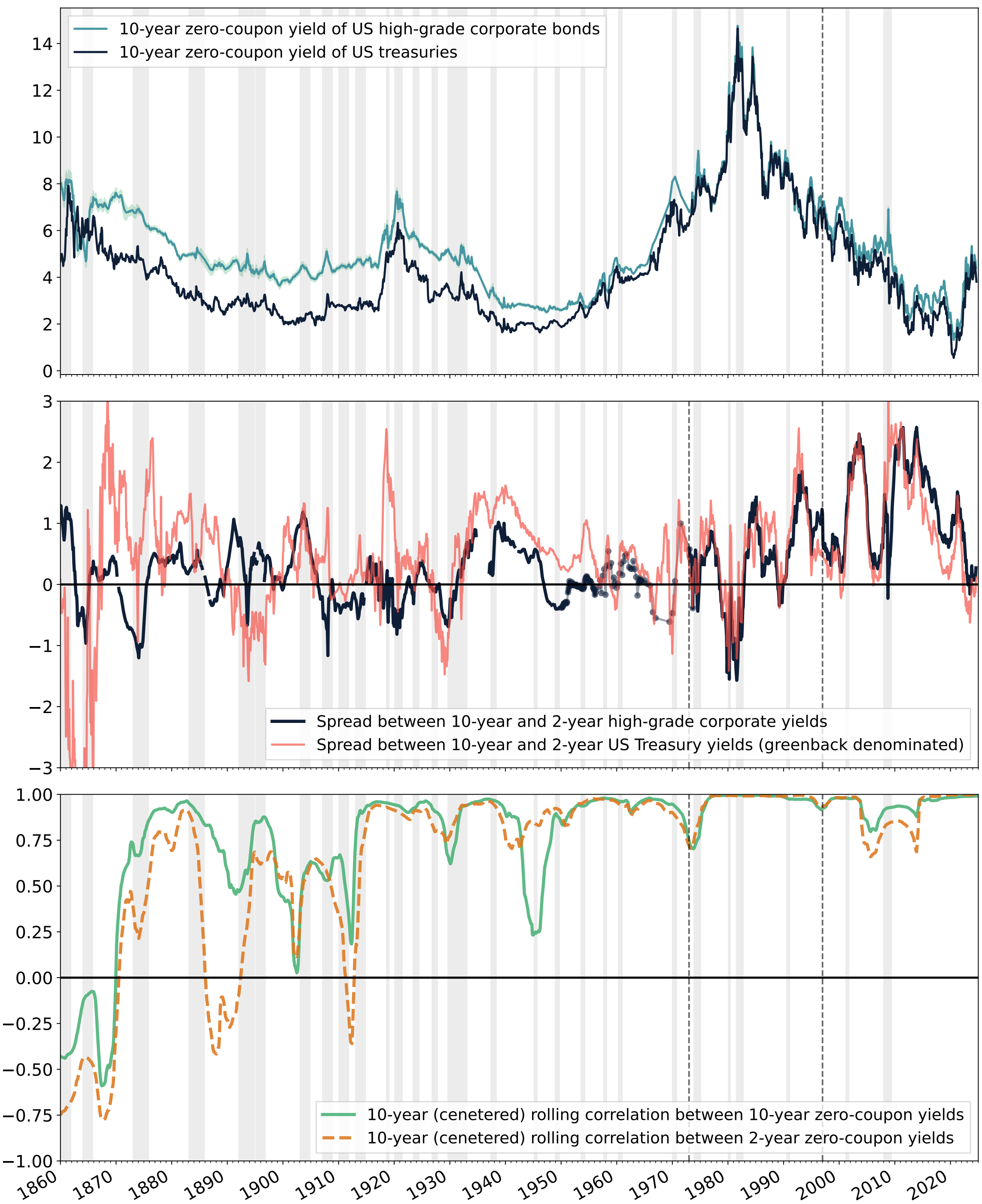

Figure 8: Difference Between Private and Public Borrowing Costs

Top panel depicts posterior median estimates of the 10-year zero-coupon yields on high-grade corporate debt (blue) and US Treasuries (black). Middle panel depicts spreads between 10-year and 2-year yields for high-grade corporate debt (black) and US Treasuries (red). Bottom panel depicts 10-year (centered) rolling correlations computed from the monthly series of posterior median estimates of 10-year (green solid) and 2-year (orange dashed) zero-coupon yields.

5.3 Properties of the AAA Corporate-Treasury Spread

Figure 9 shows our estimates of the 10-year (top) and 20-year (bottom) AAA Corporate-Treasury spread, as measured by our estimate for the high-grade corporate zero-coupon yield minus our estimate for the treasury zero-coupon yield. Evidently, both measures of the spread exhibit large low frequency variations with their long-run mean value ranging between 0-2 % over the last 160 years. On average, the spread peaked during the National Banking Era (1862-1913) and generally stayed high during the gold standard. Its long-run mean dropped sharply after World War I and reached its lowest levels during the high inflation of the 1970's and 1980's.

The red line in Figure 9 depicts the index-based high-grade corporate-treasury spread introduced by Krishnamurthy and Vissing-Jorgensen (2012). Our 20-year spread estimate follows this measure fairly closely except during the high inflation of the 1970's and 1980's. While the index-based measure (the red line) reaches its highest values during this period, our estimate shows the opposite: the high-grade corporate to treasury spread is close to zero. The difference occurs because we exclude the flower bonds from our sample, suggesting that a large portion of the variation in the index-based measure is attributable to an "inflation risk premium" instead of a "specialness premium" on US treasuries.[19]

We find more discrepancies relative to index-based measure (the red line) at shorter maturities, which are arguably more relevant for US government borrowing costs. In particular, at the 10-year horizon, which approximates the average debt maturity of US federal debt between 1860-2024 well, our estimates indicate relatively high spreads during the yield curve control period, and relatively low spreads during the decade after the Global Financial Crisis (GFC). Details of the Fed's Treasury buying programs during these two episodes provide a potential explanation for these patters in the term structure of funding cost spreads. While during the 1940s and 1950s the Fed purchased predominantly short-term government debt, the post-2008 quantitative easings (QE) focused on the purchase of long-term Treasuries.

[19] This is consistent with Figure 1 in Cook and Hendershott (1978), which suggests that after adjusting for "tax effects" yield spreads between high grade corporate and government bonds stayed below 1% before 1975.

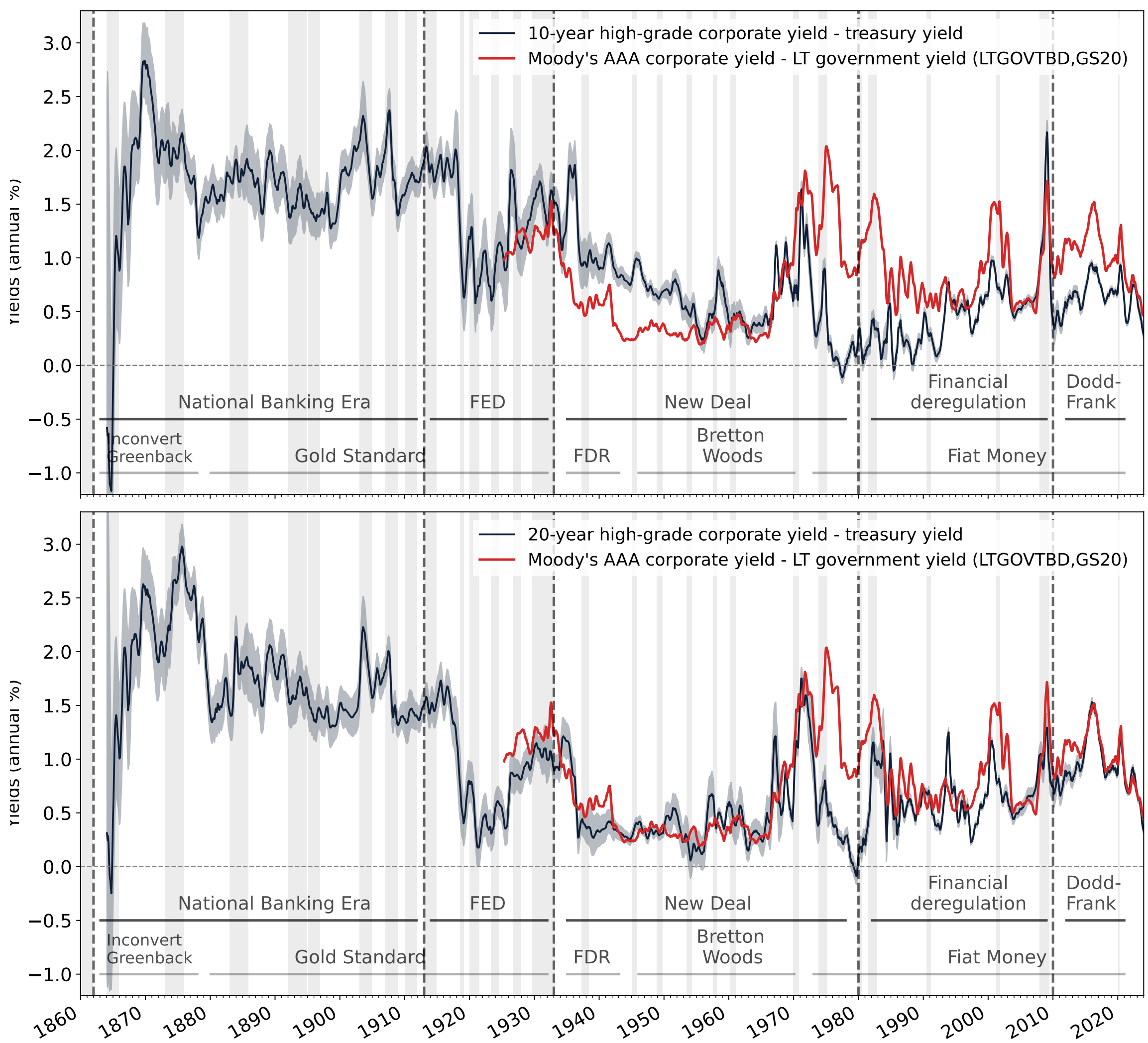

Figure 9: High-Grade Corporate to Treasury Spread Estimates: 1860-2024

Top panel depicts the 12-month centered moving average of the posterior median estimate of the 10-year convenience spread (black solid line) defined as the difference between 10-year zero-coupon yields on high-grade corporate debt and US Treasuries. The gray bands depict 90% posterior interquantile ranges. The red solid line shows the 12-month centered moving average of the index-based AAA Corporate-Treasury spread proposed by Krishnamurthy and Vissing-Jorgensen (2012). Bottom panel depicts the 20-year convenience spread against the index-based measure. Dashed vertical lines denote financial regulatory eras. Bottom labeling shows monetary standards. The light gray intervals depict NBER recessions.

6 Implications for the Macro-Finance Literature

We conclude the paper by discussing how our estimate of the high-grade corporate to treasury spread relates to some recent narratives in the literature. In particular, we argue that many of the relationships identified in the current research rely on the behavior of the index-based measure during the high-inflation period of 1965–1985 and lose identification using our series.

6.1 Comovement With Inflation

Our estimate of the AAA Corporate-Treasury spread helps to resolve a "puzzle" with the existing index-based estimate: the correlation between inflation and the AAA Corporate-Treasury spread appears to become positive during the Great Inflation.

To study how the use of our high-grade corporate to treasury spread measure affects the relationship between inflation and the Aaa Corporate-Treasury spread on US treasuries, Figure 10 depicts (annual) CPI inflation from Officer and Williamson (2021) along with our 10-year spread estimate[20] between 1870-2024. The dashed vertical lines divide the sample into 5 sub-periods. These sub-periods are the: (i) National Banking Era (1868-1919), (ii) Interwar years (1920-1941), (iii) Yield Curve Control (1942-1951), (iv) Post Treasury-Fed Accord (1952-1999), (v) Post 2000 (2000-2024). The numbers at the bottom of Figure 10 show the correlations between the two time series over the respective sub-periods. Evidently, the co-movement between inflation and the convenience spread was remarkably stable over the period of 1870-2024. Except for the yield curve control years, when the correlation is close to zero, the relationship is negative with a correlation coefficient ranging from -0.4 to -0.15. In particular, unlike for the existing index-based measure, we do not find that the correlation became positive during the Post Treasury-Fed Accord (1952-1999) period.

Our results are in contrast to a recent paper Cieslak et al. (2024), which documents and attempts to rationalize a change in the correlation between inflation and the AAA Corporate-Treasury spread during the high inflation period. The difference between our findings and those of Cieslak et al. (2024) stems from our reassessment of how the Treasury yields behaved during the high inflation period. The positive correlation observed in the existing index-based series from 1952-1999 appears to be driven by the

[20] We annualize our monthly estimate by taking the mean convenience spread each year.

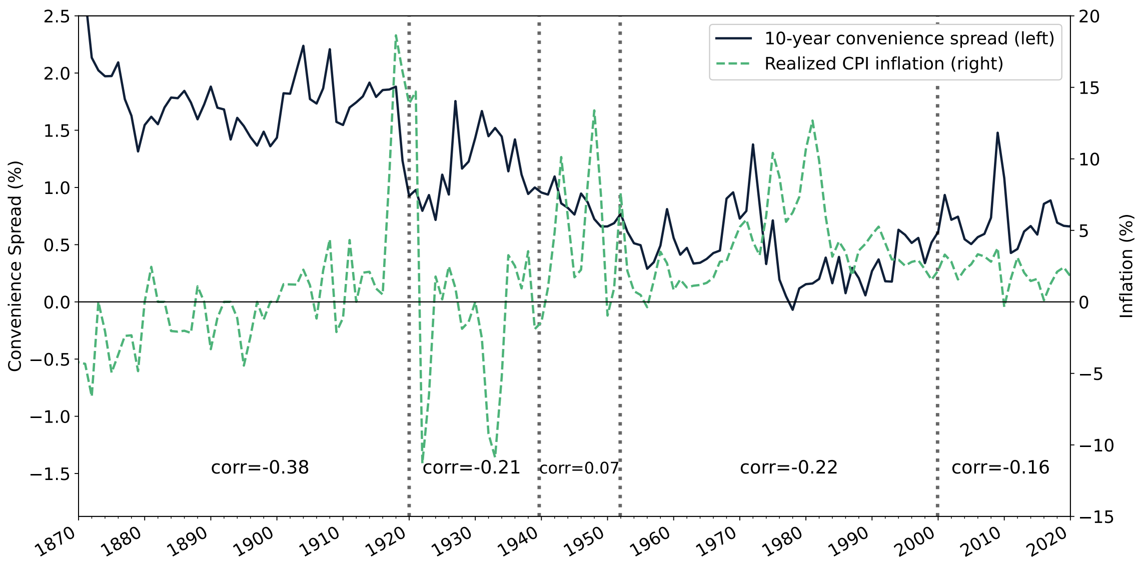

Figure 10: Convenience Spread vs Realized CPI Inflation: 1870-2024, Annual

Black line depicts our annualized 10-year convenience spread (left axis) defined as the yearly average of the monthly series. Green dashed line shows the realized annual CPI inflation between period $t-1$ and period t (right axis). Vertical dashed line divide the sample into five sub-periods. Numbers at the bottom show correlations between the two time series within the respective sub-samples.

inclusion of "real" flower bonds in the index that appreciated during the high-inflation period. This suggests that the pattern is not due to an increase in the non-pecuniary or "convenience" benefits of US Treasuries, as proposed by Cieslak et al. (2024). Instead, it appears because the government effectively used tax incentives to ensure that the real return on flower bonds remained high and this distorted the index-based measure of the high-grade corporate to treasury spread.

6.2 Treasury Demand and US Government Market Power

There has been recent interest in finding instruments for US Treasury demand and estimating the US government's market power. In this section, we investigate one such instrument that has been used in the literature: foreign volatility shocks as rotators for US debt demand.

Figure 11 depicts the relationship between the AAA Corporate-Treasury spread and debt issuance for maturities less than one year (the left panel) and for maturities greater than one year (the right panel). The red dots depict periods with high foreign volatility while the blue dots depict periods with low volatility in returns on UK equities. Changes to the shape of the equilibrium relationship in periods of high volatility have been interpreted as evidence of rotation in US debt demand (e.g. by Choi et al. (2022)). Contrary to the literature, we find little evidence that the foreign volatility acts as a rotator, except for very short term maturities.

Our findings have implications for estimation of US treasury market power. Following Choi et al. (2022), we impose a log linearized government issuance policy rule:

$$\lambda \log(q_t^b B_t / Y_t) = \log(\chi_t) + \log(1 - \xi \epsilon_t^{-1}(\sigma_t)) - \omega_t$$

where $q_t^b B_t / Y_t$ is the market value of debt-to-GDP ratio, χ_t is the AAA Corporate-Treasury spread, ξ is an indicator function whether debt issuance reacts systematically to elasticity, $\epsilon_t^{-1}(\sigma_t)$ is the inverse elasticity, $\sigma_t \in \{\sigma_L, \sigma_H\}$ is foreign volatility, and ω_t is an iid policy shock. We then estimate the price elasticity ϵ_t in high and low foreign volatility periods $\sigma \in \{\sigma_L, \sigma_H\}$. Finally, we test if $\xi = 1$ (debt issuance reacts systematically to elasticity) or $\xi = 0$ (debt issuance does not react systematically to elasticity) is a better fit. The results are shown in Table 1. Contrary to Choi et al. (2022), we find little evidence that US government issuance reacts systematically to elasticity shocks at maturities greater than 1 year. In other words, using the

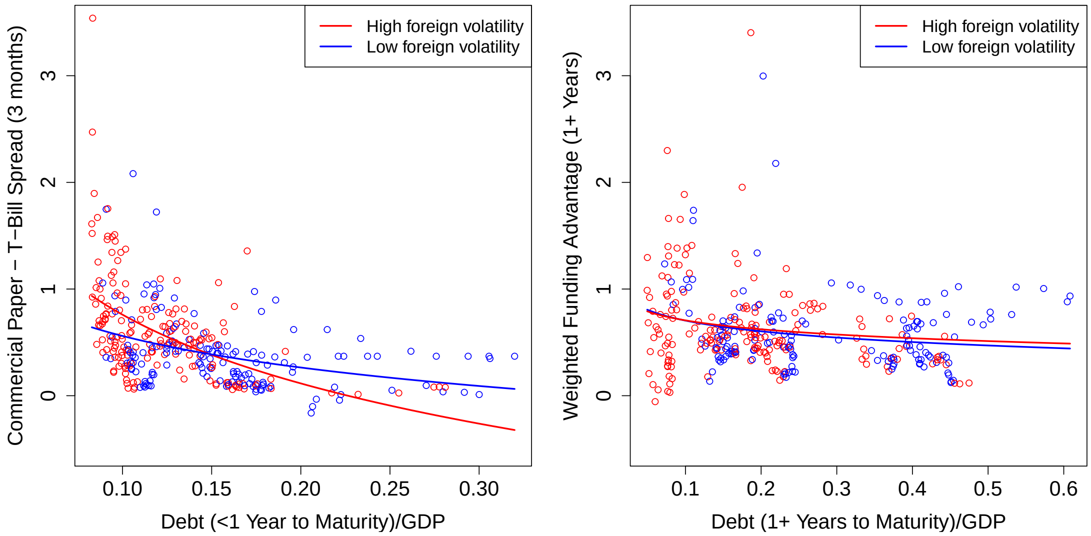

Figure 11: Convenience Spread vs Debt/GDP: 1919-2008, Annual, High and Low Foreign Volatility

framework of Choi et al. (2022), our results suggest that the US hasn't been exploiting its market power in the bond market for maturities above 1 year. However, we do find evidence for systematic reaction at maturities < 1 year. Since inflation and volatility are correlated, this may reflect monetary policy adjustments rather than exploitation of safe-asset monopoly power.

Cost elasticity	$\lambda = 0$	$\lambda = 1$	$\lambda = 2$
<1 Year to Maturity	-2.630^{***}	-2.712^{***}	-2.281^{**}
1+ Year to Maturity	0.575	-1.439	-1.585

Table 1: Null hypothesis: US debt issuance does not react to elasticity ($\xi = 0$)

6.3 Convenience Spread and Debt Supply

A much studied historical relationship in the literature is the negative correlation between the convenience spread and the supply of US government debt. Figure 12 revisits this relationship by depicting our estimate of the 10-year convenience spread along with the market value of debt-to-GDP ratio since 1865. The top panel represents the co-movement between these variables as time series, the bottom panel reports the same information as a scatter plot replicating Figure 1 in Krishnamurthy and Vissing-Jorgensen (2012) (we include the maturity specific scatter plots in Figure 16 Appendix E, which show the downward sloping relationship is primarily at the short end of the yield curve.). Evidently, there seems to be a negative co-movement between the stochastic trend components of these series. The long-run mean of the high-grade corporate-treasury spread is highest during the National Banking Era when the mean debt-to-GDP ratio is at its lowest level in our sample. Moreover, as the long run mean of the debt-to-GDP ratio started to shift upward after WWI and WWII, the spread started to trend down. The shape of the scatter plot in Figure 12 is a reflection of this negative correlation between the low-frequency components of the convenience spread and the debt-to-GDP ratio. Notice, however, that the "slope" of this equilibrium relationship is flatter than what Krishnamurthy and Vissing-Jorgensen (2012) found, suggesting that the co-variation attributable to the year-to-year fluctuations in the government debt supply is more muted.

To show that the equilibrium relationship between government debt supply and the convenience spread has different properties under different monetary, fiscal, and financial regulation regimes, we divide our 160-year sample into the following sub-periods (represented by different colors in the bottom panel of Figure 12): (a) National Banking Era (1865-1919); (b) Interwar period (1920-1940); (c) Yield Curve Control (1941-1951); (d) Post WWII low inflation (1952-1964, 1990-2007); (e) Post WWII high inflation (1965-1989); (f) Post Global Financial Crisis and Quantitative Easing (2010-2024). To study the relationship between government debt supply and the convenience spread more systematically, in Table 2 we rerun the regression from Krishnamurthy and Vissing-Jorgensen (2012) using our sub-samples from our extended dataset.

The regressions confirm what can be seen visually in Figure 12:

1. For 1868-1919 (National Banking Era) the debt/GDP ratio is insignificant and has a small positive coefficient. We run the regression with and without the average corporate default rate during the period but find it makes little difference, which suggests it is not changes in the likelihood of corporate default that is driving the result.

2. Similarly, for 1942-1951 (Yield Curve Control) and for 2010-2024 (QE period)

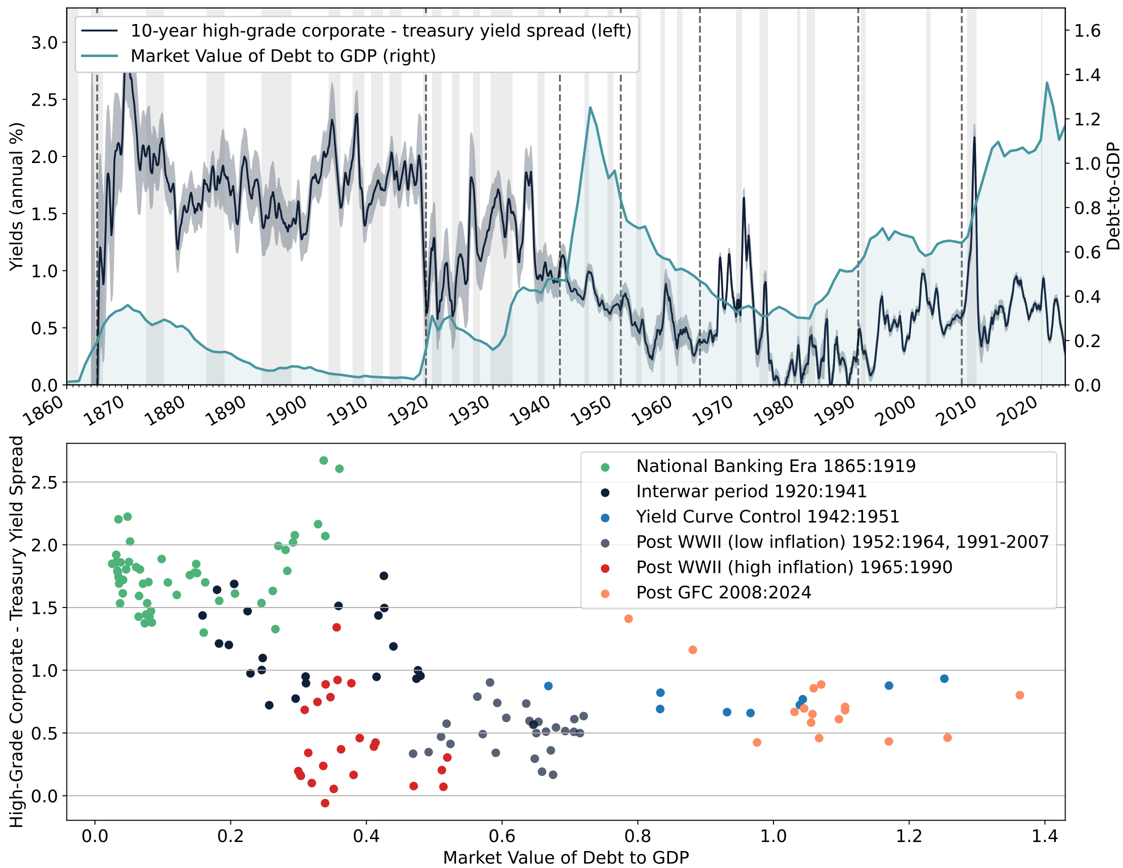

Figure 12: High-grade corporate-Treasury spread vs Debt/GDP: 1860-2024

Top panel depicts the 12-month centered moving average of our 10-year high-grade corporate-treasury spread estimate (left axis) along with the market value of government debt to GDP ratio (right axis). Bottom panel is the scatter plot of the annualized spread and debt-to-GDP from the top panel. The vertical dashed lines in the top panel and the color coding in the bottom panel divide the sample into six sub-periods specified in the text (and in the bottom panel's legend).

	1868-1919 (NBE)		1920-2007 (FED, Macroprudential Regulation)						Dodd-Frank
	no EDF	with EDF	1920-41	1942-1951	1952-1964 1991-2007	1965-1990	1952-2007	All 1920-2007	2010-2024
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$ln(debt/GDP)$	0.071 (0.065)	0.061 (0.073)	-0.774^{***} (0.206)	0.1148 (0.172)	-0.255^{***} (0.091)	-0.366^{**} (0.168)	-0.0461 (0.070)	-0.184^{*} (0.099)	0.064 (0.306)
$Volatility$	-0.237 (0.434)	-0.327 (0.497)	0.1835 (0.559)	0.1871 (1.685)	2.064^{***} (1.784)	-1.335 (1.358)	-0.008 (0.781)	1.765^{***} (0.547)	2.213^{***} (0.611)
$Slope$	-0.039 (0.041)	-0.035 (0.043)	0.176^{**} (0.066)	0.1403 (0.085)	-0.0277^{*} (0.050)	-0.0124 (0.037)	-0.032 (0.020)	-0.031 (0.040)	-0.015 (0.029)
EDF		0.007 (0.019)							
$constant$	1.99^{***} (0.235)	1.970^{***} (0.247)	-0.0917 (0.341)	0.5092 (0.279)	0.1865^{**} (0.090)	-0.0187 (0.280)	0.448^{***} (0.098)	0.302^{***} (0.113)	0.536^{***} (0.130)
Adj R^2	-0.03	-0.05	0.35	0.082	0.19	0.052	0.05	2.1e-4	0.193
F-test	0.666	0.425	0.013	0.367	8.39e-06	0.0428	0.262	5.91e-13	0.003
AIC	36.60	38.44	3.038	-14.89	-78.06	99.88	109.1	74.75	-33.43
N	51 (A)	51 (A)	22 (A)	10 (A)	114 (Q)	97 (Q)	221 (Q)	88 (A)	56 (Q)

Nota: $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 2: Relationship Between Treasury Supply and the 10-year High-grade Corporate-Treasury Spread

the debt/GDP ratio is insignificant and has a small positive coefficient.

3. For the Interwar period (1920-1941) we find a significant downward sloping relationship between the high-grade corporate-treasury spread and government debt supply, with a value similar to Krishnamurthy and Vissing-Jorgensen (2012).[21]

4. For 1952-2007 (post Fed-Treasury Accord), we find a broadly negative relationship, but the coefficients are about half as large as the coefficient in the interwar period. In addition, while we find significantly negative coefficients within the low inflation (column 5) and high inflation (column 6) sub-periods, overall the coefficient on $\log(Debt/GDP)$ is close to zero and insignificant.

6.4 High Inflation Period

The 1970's High Inflation period provides a particularly interesting laboratory to test whether the scatter plot in Figure 12 can be viewed as a stable relationship. To illustrate this, the top panel of Figure 13 replicates the scatter plot between the index-based AAA corporate-Treasury spread and the market value of debt-to-GDP ratio over the period 1919-2008 which was the original sample studied by Krishnamurthy and Vissing-Jorgensen (2012). As before, the red dots denote the High Inflation period of 1965-1990 with the lines linking consecutive years to show the direction of time. Looking at this figure, one can easily get the impression that as inflation shocks started to devalue long-term government debt after 1965, the high-grade corporate-treasury spread started to increase (i.e. the economy was moving along a stable demand function for US treasuries). The bottom panel of Figure 13—showing the same scatter plot except for the index-based spread measure being replaced by our 10-year high-grade corporate-to-Treasury spread estimate—tells a very different story.[22] While for the first few years, between 1965-1971, the high-grade corporate-to-Treasury spread went up, the relationship eventually broke down and for most of the 1970's and early 1980's the spread remained close to zero. In other words, adjusting for the differential tax treatment and embedded options in corporate and government bonds leads to a substantial revision of what happened to the high-grade corporate-

[21] Krishnamurthy and Vissing-Jorgensen (2012) uses a different range and finds the coefficient to be in the range of -0.55 to -1.66 depending upon the exact time period and bond yield chosen.

[22] The light blue dots represent the yield curve control period. As we saw before, Fed QE pushed the medium term convenience yield up (relative to the 20-year).

to-Treasury spread during the Great Inflation period. Instead of reaching its highest levels since WWI, losing the nominal anchor during the 1970's coincided with an almost complete erosion of the premium on US treasuries.

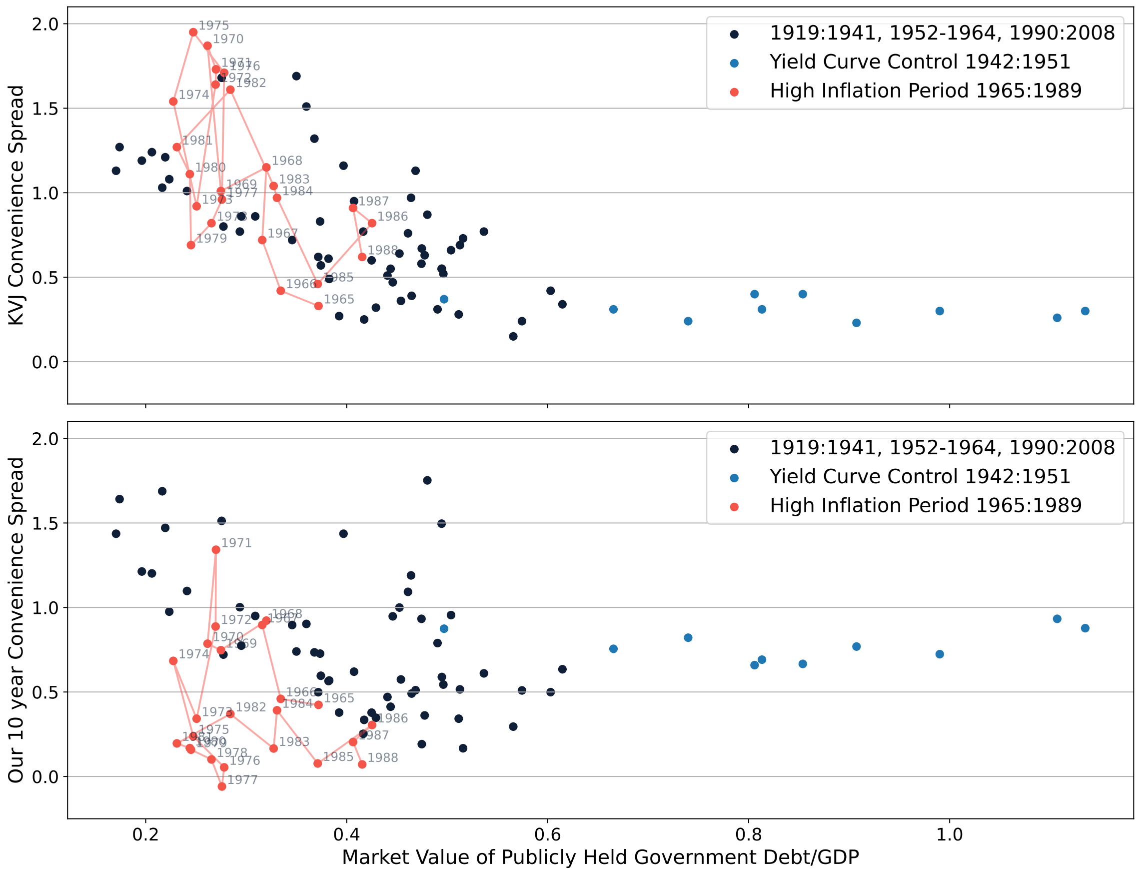

Figure 13: High-grade Corporate-Treasury Spread vs Debt/GDP: 1919-2008, Annual

Top panel depicts a scatter plot of the KVJ convenience spread proxy against the market value of publicly held government debt to GDP ratio. The bottom panel depicts a scatter plot of our 10-year convenience spread estimate against the time series of debt-to-GDP ratio used in the top panel. Red dots highlight the High Inflation period.

7 Conclusion

In this paper, we construct new estimates for historical high-grade corporate and nominal treasury yield curves and use them to compute a term structure of Aaa-rated corporate to US Treasury spreads. We use our estimates to document how the long-run mean of the US funding cost advantage, as measured by the AAA Corporate-Treasury spread, has fluctuated in response to financial sector regulation and monetary-fiscal policies, thereby challenging prevailing narratives about the existence of an exploitable demand function for US treasuries.

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A Government Budget Constraint Arithmetic

The market value of the portfolio of coupon-bearing government bonds in period t is:

$$\mathcal{B}_t := \sum_{i \in \mathcal{N}_t} q_{t,i} B_{t,i}$$

where $B_{t,i}$ is the face value of bond i at date t, $q_{t,i}$ is the market price of bond i at date t and $\mathcal{N}_t$ is the set of bonds outstanding at date t. Each bond i is characterized by a triple (c_i, p_i, T_i), where c_i is the coupon rate, p_i is the principal, and T_i is the maturity date. We can turn the maturity date into a time-to-maturity variable, $J_{t,i} = T_i - t$.

Suppose that the usual asset pricing equation holds for all bonds:

$$q_{t,i} = \sum_{n=1}^{\infty} q_t^{(n)} \mathsf{c}_{t,i}^{(n)} \qquad \forall i \in \mathcal{M}_t$$

where $q_t^{(n)}$ is a discount function which is independent of i and only depends on (t, n). By definition, $q_t^{(0)} = 1$.

That said, we can re-express the market value of the government debt portfolio (of coupon-bearing bonds) in terms of a portfolio of zero-coupon bonds:

$$\begin{aligned}\mathcal{B}_t := \sum_{i \in \mathcal{M}_t} q_{t,i} B_{t,i} &= \sum_{i \in \mathcal{M}_t} \sum_{n=1}^{\infty} q_t^{(n)} \mathsf{c}_{t,i}^{(n)} B_{t,i} \\ &= \sum_{n=1}^{\infty} q_t^{(n)} \sum_{i \in \mathcal{M}_t} \mathsf{c}_{t,i}^{(n)} B_{t,i} = \sum_{n=1}^{\infty} q_t^{(n)} b_t^{(n)}\end{aligned}$$

where $b_t^{(n)}$ denotes the number of $t+n$ dollars that the government has at time t promised to deliver. To construct the panel $\{\{b_t^{(n)}\}_{n=1}^{\infty}\}_{t \geq 1}$ from historical data, we add up all of the dollar principal-plus-coupon payments, $\mathsf{c}_{t,i}^{(n)}$, that the government has at time t promised to deliver at date $t+n$. Let the total (face value of) outstanding debt in period t be $b_t := \sum_{n=1}^{\infty} b_t^{(n)}$ and the "portfolio shares" are $b_t^{(n)}/b_t$.

A.1 Government Budget Constraint and Bond Returns

In any period t, the government enters with a stock of promised payments $\{b_{t-1}^{(n)}\}_{n \geq 1}$ and issues new (zero-coupon) bonds $\{b_t^{(n)}\}_{n \geq 1}$, where $b_t^{(n)}$ is the amount of bond of maturity n issued in period t.[23] The government budget constraint can be written as

$$\begin{aligned}\sum_{n=1}^{\infty} q_t^{(n)} b_t^{(n)} &= \sum_{n=1}^{\infty} q_t^{(n-1)} b_{t-1}^{(n)} + g_t - \tau_t \\ &= b_{t-1}^{(1)} + \sum_{n=1}^{\infty} q_t^{(n)} b_{t-1}^{(n+1)} + g_t - \tau_t\end{aligned}$$

where g_t is government spending and τ_t is tax revenues. Let Δ_t be the net amount of dollars that the government raises in period t from "refinancing" its debt:

$$\Delta_t := \sum_{n=1}^{\infty} q_t^{(n)} \left[b_t^{(n)} - b_{t-1}^{(n+1)} \right]$$

so that the budget constraint becomes

$$g_t + b_{t-1}^{(1)} = \tau_t + \Delta_t.$$

The role of the yield curve for government financing can be summarized by the Δ_t term. The government's total deficit (including interest payments) is $g_t + b_{t-1}^{(1)} - \tau_t$, while its primary deficit is $def_t := g_t - \tau_t$.

As a result, the difference between Δ_t and $\widetilde{\Delta}_t$ can be viewed as the contribution of the borrowing cost spread to period t surplus. Alternatively, we can also write the budget constraint in terms of holding period returns:

$$\begin{aligned}\mathcal{B}_t = \sum_{n=1}^{\infty} q_t^{(n)} b_t^{(n)} &= \sum_{n=1}^{\infty} q_t^{(n-1)} b_{t-1}^{(n)} + def_t \\ &= \sum_{n=1}^{\infty} \left(\frac{q_t^{(n-1)}}{q_{t-1}^{(n)}} \right) q_{t-1}^{(n)} b_{t-1}^{(n)} + def_t \\ &= \sum_{n=1}^{\infty} R_t^{(n)} q_{t-1}^{(n)} b_{t-1}^{(n)} + def_t = \underbrace{\frac{\sum_{n=1}^{\infty} R_t^{(n)} q_{t-1}^{(n)} b_{t-1}^{(n)}}{\sum_{n=1}^{\infty} q_{t-1}^{(n)} b_{t-1}^{(n)}}}_{=\mathcal{R}_t} \sum_{n=1}^{\infty} q_{t-1}^{(n)} b_{t-1}^{(n)} + def_t \\ &= \mathcal{R}_t \mathcal{B}_{t-1} + def_t\end{aligned}$$

where $\mathcal{R}_t$ denotes the holding period return on the government debt portfolio which defined by the weighted average of the one-period holding period returns (of n-period

[23] For instance, one period bond issued in period t and maturing in $t+1$ is $b_t^{(1)}$. Similarly, $b_{t-1}^{(n)}$ is the amount of n-period bond issued in period $t-1$ coming due in period $t-1+n$.

zero coupon bonds): $r_{t+1}^{(n)} := \log R_{t+1}^{(n)} = \log q_{t+1}^{(n-1)} - \log q_t^{(n)}$. The log holding period returns $\{r_{t+1}^{(n)}\}_{n\geq 1}$ can be easily computed as

$$r_{t+1}^{(n)} = -(n-1)y_{t+1}^{(n-1)} + ny_t^{(n)}$$

from the time-series of zero-coupon yield curves $\{y_t^{(n)}\}_{n\geq 1}$. Yet another way to write the budget constraint is

$$\begin{aligned} \sum_{n=1}^{\infty}(q_t^{(n)} - \tilde{q}_t^{(n)})b_t^{(n)} + \sum_{n=1}^{\infty} \tilde{q}_t^{(n)} b_t^{(n)} &= \sum_{n=1}^{\infty}(q_t^{(n-1)} - \tilde{q}_t^{(n-1)})b_{t-1}^{(n)} + \sum_{n=1}^{\infty} \tilde{q}_t^{(n-1)} b_{t-1}^{(n)} + def_t \\ \widetilde{\mathcal{B}}_t &= \widetilde{\Delta}_t - \Delta_t + \widetilde{R}_t \widetilde{\mathcal{B}}_{t-1} + def_t \end{aligned}$$

where $\widetilde{R}_t$ denotes the holding period return on the government debt portfolio under the high-grade corporate yield curve.

With these notations, the two versions of the budget constraint can be expressed as

$$\begin{aligned} \mathcal{B}_{t-1} &= \mathcal{R}_t^{-1}\Big(- def_t + \mathcal{B}_t\Big) \\ &= \sum_{s=0} \left(\prod_{h=0}^{s} \mathcal{R}_{t+h}^{-1}\right) (-def_{t+s}) \end{aligned}$$

and

$$\begin{aligned} \widetilde{\mathcal{B}}_{t-1} &= \widetilde{\mathcal{R}}_t^{-1}\Big(- def_t + \Delta_t - \widetilde{\Delta}_t + \widetilde{\mathcal{B}}_t\Big) \\ &= \sum_{s=0} \left(\prod_{h=0}^{s} \widetilde{\mathcal{R}}_{t+h}^{-1}\right) \Big(- def_{t+s} + \widetilde{\Delta}_{t+s} - \Delta_{t+s}\Big) \\ \Leftrightarrow \quad \widetilde{\mathcal{R}}_t \widetilde{\mathcal{B}}_{t-1} &= -def_t + \Delta_t - \widetilde{\Delta}_t + \sum_{s=1} \left(\prod_{h=1}^{s} \widetilde{\mathcal{R}}_{t+h}^{-1}\right) \Big(- def_{t+s} + \Delta_{t+s} - \widetilde{\Delta}_{t+s}\Big) \end{aligned}$$

A.2 Models with representative long-term debt

The *admissible set of portfolios* is restricted to follow an exponential rule, i.e. $\forall t,\ \exists\, (b_t, \omega_t)$ s.t.

$$b_t^{(n)} = b_t \omega_t \left(1 - \omega_t\right)^{n-1}$$

In other words, the assumption is that we can summarize/proxy the $\{b_t^{(n)}\}_{n=1}^{\infty}$ with a pair of scalars (b_t, ω_t). The variable Δ_t can be written as:

$$\Delta(b_t, \omega_t; b_{t-1}, \omega_{t-1}) := \sum_{n=1}^{\infty} q_t^{(n)} \Big[\underbrace{(1-\omega_t)^{n-1}\,\omega_t b_t}_{=b_t^{(n)}} - \underbrace{(1-\omega_{t-1})^{n}\,\omega_{t-1} b_{t-1}}_{=b_{t-1}^{(n+1)}} \Big]$$

In the above expression, if the government enters the period with a portfolio (b_{t-1}, ω_{t-1}) and wants to exit it with a portfolio (b_t, ω_t), then for each maturity $n \geq 1$ it must issue/buy back $b_t^{(n)} - b_{t-1}^{(n+1)}$ many bonds at price $q_t^{(n)}$.

Suppose for now that ω_t is not a choice variable and it's fixed over time, i.e. $\omega_t = \omega$. We can then write

$$\Delta_t := \underbrace{\left(\sum_{n=1}^{\infty} q_t^{(n)}\,(1-\omega)^{n-1}\,\omega \right)}_{=:q_t^b(\omega)} \Big(b_t - (1-\omega)\,b_{t-1} \Big) = q_t^b \Big(b_t - (1-\omega) b_{t-1} \Big)$$

where q_t^b denotes the market price of a "unit" of government debt portfolio (at face value) with average maturity $1/\omega$. From the definition of Δ_t we can write the law of motion of (the face value of) debt as

$$b_t = (1-\omega) b_{t-1} + \frac{\Delta_t}{q_t^b}$$

so if $\omega < 1$ and q_t^b depends on (b_t, b_{t-1}), q_t^b will behave as an (endogenous) debt adjustment cost. In this case, the government budget constraint is

$$g_t + \omega b_{t-1} = \tau_t + q_t^b \Big(b_t - (1-\omega) b_{t-1} \Big).$$

B Details on Historical Context

To help interpret the historical data, this Appendix provides further details on some key institutional details impacting the corporate and government bond markets that present challenges for measuring the funding advantage of the US government.

Brief History of the US Bond Market: The US corporate bond market traces its origins to the early 19th century, driven by the need to finance large infrastructure projects. The first corporate bonds were issued by banks and canal companies, but the market truly expanded with the rise of the railroad industry. By the 1850s, railroad companies were expanding into the "wild west" at a scale and level of uncertainty that they could no longer raise sufficient capital from the local and fragmented banks of the time. The solution was to issue bonded debt to a broader pool of investors, which created what is considered the world's first corporate bond market (Sylla et al., 2006). Essentially a railroad bond market in its early decades, by the early 1900s, the corporate bond market was several times larger than that of the UK or US sovereign debt markets.[24] By the late 19th and early 20th centuries, the market matured, with securities becoming more standardized, and industrial corporations and utilities also began issuing bonds.

Concurrently, the federal government initially issued bonds infrequently, as Congress was responsible for debt management, leading to long-maturity issuances with significant variations in maturities, coupon rates, denominations, and units of account (Payne et al., 2025). The expansion and standardization of federal debt issuance occurred gradually over time, with Congress delegating more autonomy in designing and issuing securities to the Treasury Department between 1917 and 1939. Both markets continued to expand throughout the 20th century and by the mid-20th century, US Treasury securities had become the world's largest and most liquid debt market, with a standardized set of securities at various maturities.

Treasuries dominated in scale but both corporate and Treasury bonds traded actively on major exchanges like the New York Stock Exchange (NYSE) and were held by similar investors, including banks, insurers, and wealthy individuals. Both corporate and government bonds shared similar features, such as fixed coupon payments and typically long maturities and exhibited relatively high liquidity compared

[24]The US actually paid off its entire national debt in 1836.

to other asset classes. On the corporate side, railroad bonds declined in importance as industrials and utilities became the dominant issuers in the 20th century, increasingly offering high-grade bonds.

Denomination: The denomination of both Treasury and corporate bonds has evolved similarly throughout American financial history. From 1800 to 1933, the US adhered to a gold standard except from 1861 to 1878 when it temporarily suspended gold convertibility and issued a paper currency known as "greenbacks". During this period, both federal and corporate bonds were typically denominated in gold (or greenbacks during the suspension). Following the Gold Reserve Act of 1933, which prohibited private US citizens from holding gold coins, both markets transitioned to nominal dollar denomination. The Bretton Woods Agreement (1944-1971) reintroduced a type of gold standard by establishing an international system of fixed exchange rates with the US dollar convertible to gold until its collapse in 1971 when the dollar was floated. Since then, both Treasury and corporate bonds have been issued exclusively in nominal terms until the introduction of Treasury Inflation-Protected Securities (TIPS) in 1997, which provide explicit inflation protection.

Credit ratings: The rise of corporate bonds was accompanied by the development of credit ratings. Beginning in 1832, the "American Railroad Journal" published detailed assessments of railroad companies, covering physical descriptions of the railroads, their assets, liabilities, and earnings. In 1868, its former editor Henry V. Poor published the first volume of "Poor's Manual of the Railroads of the United States", a comprehensive resource detailing financial statements, operational statistics, and the capital structure of their securities. In 1909, John Moody in his "Moody's Manual of Railroads and Corporation Securities" first introduced a structured rating system for these securities that established the foundation for modern credit ratings.

Default Risk: In the early 1900s, Moody's Investors Service began assigning credit ratings to bonds and other financial assets, with "Aaa" denoting the highest level of creditworthiness. This rating was based on factors such as physical capital, debt levels relative to assets and revenue, profitability, and liquidity. To qualify for an "Aaa" rating, bonds needed a long-term track record of exceptionally strong interest coverage and substantial physical assets backing the issue, ensuring minimal investment risk. Most bonds were either first mortgages or well protected underlying mortgages. Moody's argued that even in changing economic conditions, the fundamental strength of these securities would remain intact. As Hickman (1958) found, credit ratings offered investors valuable insights into bond quality and default probabilities. However, their performance was not significantly better than the bond market's own assessment, as reflected in interest rate spreads.

Callability: Call provisions, which grant the issuer the right to repay the bond's principal ("call" the security) before its maturity, introduce uncertainty to the underlying cash flows from the bondholder's perspective. Because issuers are likely to call bonds when their market price sufficiently exceeds the call price to offset the costs of refinancing and administering the call, such bonds are typically expected to trade at a discount compared to otherwise identical non-callable bonds. Call provisions are accompanied by a *call-deferment period*—a predetermined timeframe after issuance (but before maturity) during which the issuer cannot call the bond. Non-callable bonds, by comparison, can be regarded as having a call-deferment period that extends to their maturity. Intuitively, the size of the discount investors demand for holding callable bonds is inversely related to the length of the call-deferment period.

Prior to the late 1980's, virtually all corporate bonds had some kind of call provision with very brief call-deferment periods. In particular, these bonds were usually callable on any interest payment dates, with notice periods typically ranging from 30 to 60 days. The call price usually started at a premium (reflecting a refinancing penalty) and gradually declined to par over time, often following a structured schedule. Some bonds allowed partial redemptions, while others required full redemption, and only a small number included a non-zero (typically 5 year) call-deferment period.

In contrast, most US government bonds were non-callable. Those with call provisions typically featured long call-deferment periods, often only a few years shorter than the bonds' maturity. This pronounced difference in typical call-deferment periods between corporate and government bonds likely contributed to the observed corporate–treasury yield spreads. However, this does not reflect the government's funding advantage. This is because the losses resulting from the government's need to always refinance its debt at prevailing market rates, rather than a lower preset call price (often at par), ultimately must be offset by future revenues.

Policy Interventions: Corporate and government bond markets have historically been subject to different regulatory frameworks, evolving in response to financial and economic pressures. In the decades before the Civil War, only state-chartered banks existed, which were not incentivized to hold Treasuries.[25] This changed with the National Banking Acts of 1863–1866, which established a system of nationally chartered single-branch banks. These banks were permitted to issue banknotes up to 90% of the lower of the par or market value of qualifying US federal bonds, effectively tying their balance sheets to government debt. However, national banks were prohibited from using railroad bonds as backing for their notes and faced strict limitations on the types of loans they could issue.

World War II brought further regulatory intervention, as concerns over war financing led to the government "fixing" the yield curve from 1942 to 1951, with the T-bill rate set to 3/8% and the long-term bond yield capped at 2.5% (see Garbade (2020) and Rose (2021)). This policy was implemented through coordination between the Treasury and the Federal Reserve, with the Fed agreeing to absorb excess bond supply at the fixed price, and implicit coordination with the banking system, which ended up predominantly holding government debt. The arrangement ended with the 1951 Treasury-Fed Accord, establishing official Fed independence from the Treasury.

The 2007–2009 financial crisis triggered extensive regulatory reforms, including the Dodd-Frank Wall Street Reform and Consumer Protection Act, which introduced new oversight for financial institutions. Additionally, the Basel III regulations imposed stricter capital requirements and portfolio constraints on banks, penalizing excessive leverage and encouraging the holding of government debt over assets like corporate bonds. In response to the crisis, the Federal Reserve also launched a quantitative easing (QE) program, purchasing long-term government bonds to lower interest rates and stabilize financial markets.

[25] These banks, chartered by state legislatures, could issue their own banknotes and were subject to diverse balance sheet regulations, often requiring them to hold gold and state bonds. However, no state banks could operate nationally.

C The High-Grade Corporate Bond Dataset

We construct a new historical dataset of high-grade US corporate bonds, providing monthly data on trading prices and cash-flows as well as bond characteristics and credit ratings from 1860-2024. Monthly prices and cash-flows date back to 1860, along with detailed bond characteristics such as maturity, denomination and callability. Annual Moody's credit ratings date back to their earliest availability: 1909 for railroads and 1914 for public utilities and industrials. Our dataset integrates existing databases with hand-collected prices and bond characteristics from historical newspapers, business magazines, and financial releases by companies.

C.1 Bond Prices

To compile end-of-month trading prices from 1860-2024 we rely on five main data sources: *Global Financial Data (GFD)*, the *Commercial & Financial Chronicle (CFC)*, *Barron's Magazine*, the *Lehman Brothers Fixed Income Database*, and the *Merrill Lynch Bond Index Database*. From 1860-1884 we take bond price data from *Global Financial Data (GFD)*. The GFD dataset covers nearly 800 corporate bonds from 1791 to 1884, almost all of which are railroad bonds, reflecting their dominance in the bond market during that period. The price data is particularly rich between 1870-1884, featuring both daily time series of trading prices and bond characteristics such as the bonds name, coupon, and company information. The data does not include further bond characteristics such as maturity date or denomination. From 1884 to 1963, we collect end-of-month trading prices from the *Commercial & Financial Chronicle*. The *Commercial & Financial Chronicle* was a weekly business newspaper published from 1865 to 1987.[26] We use bond quotations from the New York Stock Exchange, focusing on actual sale prices, as reported in the "Stock Exchange Quotation / Bond Record" section. From 1884 to 1918, we collect only railroad bond prices. Beginning in January 1918, we expand the collection to include all corporate bonds, reflecting the growing importance of utility and industrial securities in the corporate bond market during the early 20th century. From 1964 to 1972, we collect bond closing prices from *Barron's Magazine*. *Barron's* is a weekly financial newspaper founded in 1921, providing coverage of closing prices for actively traded

[26]Scanned digital copies of the Chronicle are available from the Federal Reserve Archival System for Economic Research (FRASER) from July 1865 to December 1963.

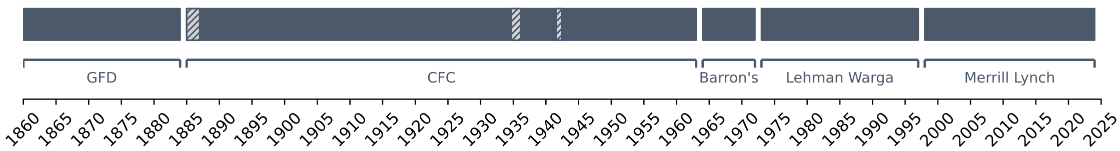

Figure 14: Corporate Bond Price Data Sources

Data sources for bond prices from 1860-2024. GFD, Lehman Warga, and Merrill Lynch are existing datasets, while bond price data from the CFC and Barron's was manually collected using scans from digital archives. Light gray areas indicate gaps in the current sample.

corporate bonds in their "Listed Bond Quotations" section. From 1973 to 1997 we rely on the *Lehman Brothers Fixed Income Database* distributed by Hong and Warga (2000) which provides comprehensive monthly bond-specific information from January 1973 to December 1997, including bond price, ratings and coupons. After 1997 we use the *Merrill Lynch Bond Index Database* which provides a similar level of detail. We use daily closing prices from the New York Stock Exchange as reported in *The New York Times (NYT)* to fill in any gaps in our sample between 1884 and 1972.

C.2 Bond Characteristics

A major challenge with computing yield curves is that we need accurate information about bond maturity and coupon payments. For the period after 1972, we are able to rely on detailed bond information from the *Lehman Brothers Fixed Income Database* and the *Merrill Lynch Bond Index Database.* For bonds maturing between 1900 to 1972, we extract the maturity, coupon and coupon schedule from various *Moody's Manuals* which were first published in 1900. Initially titled *Moody's Manual of Industrial and Miscellaneous Securities*, it was later replaced by *Moody's Manual of Railroads and Corporation Securities*, and subsequently by *Moody's Analyses of Investments.* These manuals provide comprehensive information on outstanding bonds, including the issue and maturity dates, coupon rates and schedules. For the pre-1900 period, we draw maturity and coupon information from a variety of sources. These include the *Investors' Supplement of the Commercial and Financial Chronicle*, the *American Railroad Journal*, *Poor's Manual of Railroads*, the *Catalogue of Railroad Mortgages*, various publications by Joseph G. Martins on the Boston stock market, and annual reports to stockholders of various railroad companies.

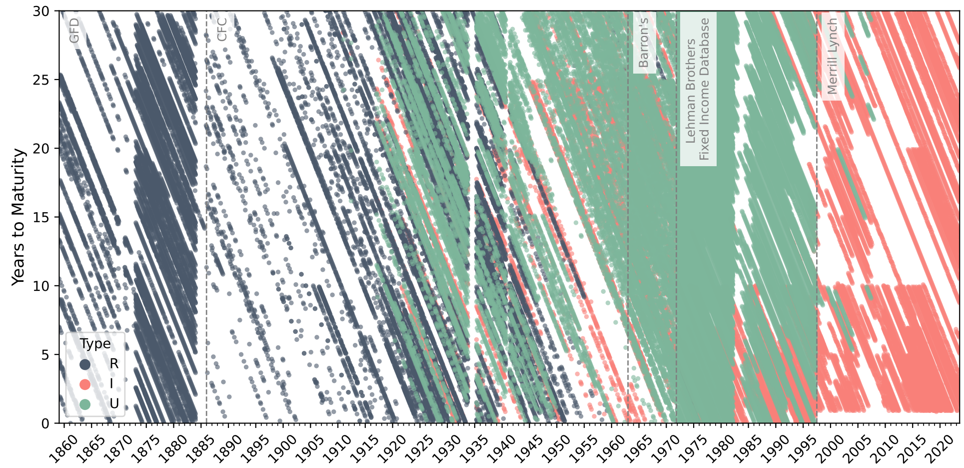

Figure 15: Maturities of observed high-grade corporate bonds

Years-to-maturity of high-grade corporate bonds, defined as those rated at least A by Moody's. R (gray) stands for "railroad companies", I (red) stands for "industrials", U (green) stands for "utilities".

C.3 Credit Ratings

To classify high-grade bonds, we mainly rely on Moody's credit ratings which are readily available from the *Lehman Brothers Fixed Income Database* and the *Merrill Lynch Bond Index Database*. Prior to the availability of these datasets, we collect annual bond ratings from the *Moody's Manuals*. Moody's first issued credit ratings in 1909 for railroads, expanding to public utilities and industrial companies in 1914.[27] Further details on how we identify high-grade bonds prior to 1909 are provided in Section **??**.

[27] We focus on Moody's ratings since they are the earliest available, whereas Poor's ratings began in 1922 and Fitch's in 1924.

D Additional Details on Yield Curve Estimation

We observe prices $P_1, \ldots, P_N$ of N coupon bonds with cash flows summarized in the $N \times M$ matrix C, where M spans the observed maturity spectrum. Entries $C_{i,j}$ correspond to the cash flow of bond $1 \leq i \leq N$ occurring at time $1 \leq j \leq M$ in the future. We seek to estimate the vectorized discount function $q(\mathbf{x})$, where $\mathbf{x}$ is the vector spanning the maturity spectrum M periods in the future. The law of one price dictates that the fitted price of the bond be:

$$P_i(q) = \sum_{j=1}^{N} C_{i,j} q(x_j)$$

In order to impose structure on the estimates and penalize overfitting, we follow FPY and define a measure of smoothness as a weighted average of the first and second derivatives of the discount function:

$$||q||_{\alpha,\delta} = \left(\int_0^\infty \left(\delta q'(x)^2 + (1-\delta) q''(x)^2 \right) e^{\alpha x} dx \right)^{\frac{1}{2}}$$

for maturity weight parameter $\alpha \geq 0$ and shape parameter $\delta \in [0, 1]$. δ closer to 0 forces the curve to be tense, avoiding oscillations, while δ closer to 1 forces the curve to be straight, avoiding kinks. The term $e^{\alpha x}$ allows the smoothness term to be maturity dependent, which gives way to more flexibility at the shorter end while enforcing the longer end of the curve to be smooth.

Define $\mathcal{Q}_{\alpha,\delta}$ to be the set of discount curves q satisfying weak regulatory conditions discussed by FPY. Then the convex optimization problem to solve for q is:

$$\min_{q \in \mathcal{Q}_{\alpha,\delta}} \sum_{i=1}^{M} \omega_i (P_i - P_i(q))^2 + \lambda ||q||_{\alpha,\delta}^2 \tag{D.1}$$

for exogenous weights ω_i and smoothness parameter λ. FPY show that (D.1) has a unique solution for any tuple of $(\lambda, \alpha, \delta)$, except in the ill-defined case $\alpha = \delta = 0$, given in closed form. Toward a discussion on the distributional aspect of the estimator, we may define q to be made up of a prior curve p plus a deviation from prior h,

$q(\mathbf{x}) = p(\mathbf{x}) + h(\mathbf{x})$. The objective function decomposes into:

$$\min_{q \in \mathcal{Q}_{\alpha,\delta}} \sum_{i=1}^{M} \omega_i \Big(P_i - C_i(p(\mathbf{x}) + h(\mathbf{x}))\Big)^2 + \lambda ||h||^2_{\alpha,\delta} \tag{D.2}$$

where C_i is a row vector of cash flows over the maturity spectrum for bond i, or equivalently, the i-th row of C. Problem (D.2) can be decomposed in terms of β given an $M \times M$ kernel matrix $\mathbf{K}$. The entries of $\mathbf{K}$ are determined by the parameters α and δ in five cases. (See FPY for details). With this formulation, the optimization problem simplifies further to:

$$\min_{\beta} \sum_{i=1}^{M} \omega_i \left(P_i - C_i p(\mathbf{x}) - C_i \mathbf{K} \beta\right)^2 + \lambda \beta^T \mathbf{K} \beta$$

which emits a unique solution:

$$\hat{\beta} = C^T \left(C\mathbf{K}C^T + \Lambda\right)^{-1} (P - p(\mathbf{x}))$$

where P is the vector of observed prices and Λ is defined by:

$$\Lambda = \operatorname{diag}\Big(\frac{\lambda}{\omega_1}, \ldots, \frac{\lambda}{\omega_M}\Big)$$

The fitted discount function $\hat{q}(\mathbf{x})$ is therefore

$$\hat{g}(\mathbf{x}) = p(\mathbf{x}) + \mathbf{K}\hat{\beta}$$

We obtain a fitted zero-coupon yield curve, which we denote $\hat{y}(\mathbf{x})$, by taking;

$$\hat{y}(\mathbf{x}) = -\log\left(\hat{g}(\mathbf{x})\right)/\mathbf{x}$$

To summarize the estimation process, we obtain a flexible closed form estimator by assuming that the estimated discount function is twice differentiable and obeys some level of smoothness for given tuple $(\lambda, \alpha, \delta)$. To choose an optimal tuple, we adopt the same cross-validation strategy as FPY, discussed in section 3.2. This ensures that the parameters we choose best minimize out of sample error for a given parameter.

D.1 Distributional Aspects

An important feature of the FPY Kernel Ridge estimator is that assuming a normally distributed prior curve, we obtain a normally distributed posterior distribution for the estimated curve $\hat{q}$. Specifically, assuming a Gaussian distribution for q:

$$q(\mathbf{x}) \sim \mathcal{N}(p(\mathbf{x}), \mathbf{K})$$

emits a normal posterior distribution with mean function m and covariance function v for scalars y, z:

$$\begin{aligned} m^{post}(z) &= p(z) + k(z, \mathbf{x}^{\mathbf{T}})\hat{\beta} \\ v^{post}(y, z) &= k(y, z) - k(y, \mathbf{x}^{\mathbf{T}})C^T(C\mathbf{K}C^T + \Lambda)^{-1}Ck(\mathbf{x}, z) \end{aligned}$$

where $k(y, z) = \mathbf{K}_{yz}$ and we assume that the price errors have variance $\Sigma_\epsilon = \Lambda$. We can therefore easily obtain confidence bounds on the fitted discount function $\hat{q}$. The posterior distribution additionally provides information on extrapolated discount functions when we have periods with only short term bonds outstanding. As expected, the confidence intervals tend to expand dramatically as we extrapolate past the maximum observed maturity in a given period.

D.2 Cash Flow corrections

While we maintain the same approach to estimating the discount curve as FPY, we change the cash flow streams such that they are adjusted for income and capital gains taxes, if they are taxable bonds. In the above analysis we replace the cash flow matrix for a given observation date C, which catalogs streams of future cash flows for each bond in a corresponding row with a tax corrected matrix C^*.

To implement this, we break up the matrix C into components of future coupons Cp and future principal repayments Pr. That is:

$$C = Cp + Pr$$

where Cp_{ij} is the coupon payment of bond i at date j in the future, and set to 0 otherwise. Likewise, Pr_{ij} is set equal to 100 if bond i matures at date j in the future, and set to 0 otherwise.

We observe income and capital gains taxes on a given date, denoted τ^{inc} and τ^{cg}, respectively. Assuming that bond i is a taxable bond, we may construct after-tax matrices Cp^* and Pr^*. The after-tax coupon matrix can be easily defined with entries:

$$Cp^*_{ij} = (1 - \tau^{inc})Cp_{ij}$$

The principal matrix is now conditioned on the observed price because capital gains/losses depend on whether the bond was purchased above or below par. That is, the principal matrix is a function of the observed prices P at time 0. Assume that bond i matures at date j and pays a principal of \$100. Then Pr^* can be defined by:

$$Pr^*_{ij} = \begin{cases} 100 - \tau_{cg}(100 - P_i) & \text{if } P_i \leq 100 \\ 100 - \tau_{inc}(100 - P_i) & \text{if } P_i > 100 \end{cases}$$

With the after-tax cash flows defined, we sum up the two to get a total after-tax cash flow matrix:

$$C^* = Cp^* + Pr^*$$

which we use in place of C in our Kernel Ridge estimator. We find substantial improvement in the cross-validation step to select tuning parameters between the same tuples with and without the tax corrections. In the period 1960-99 for example, given a tuple $(\lambda, \alpha, \delta)$ we find that the tax corrections roughly halve the total out of sample mean squared error relative to the same tuple without the tax correction, for any tuple.

E Other Empirical Results

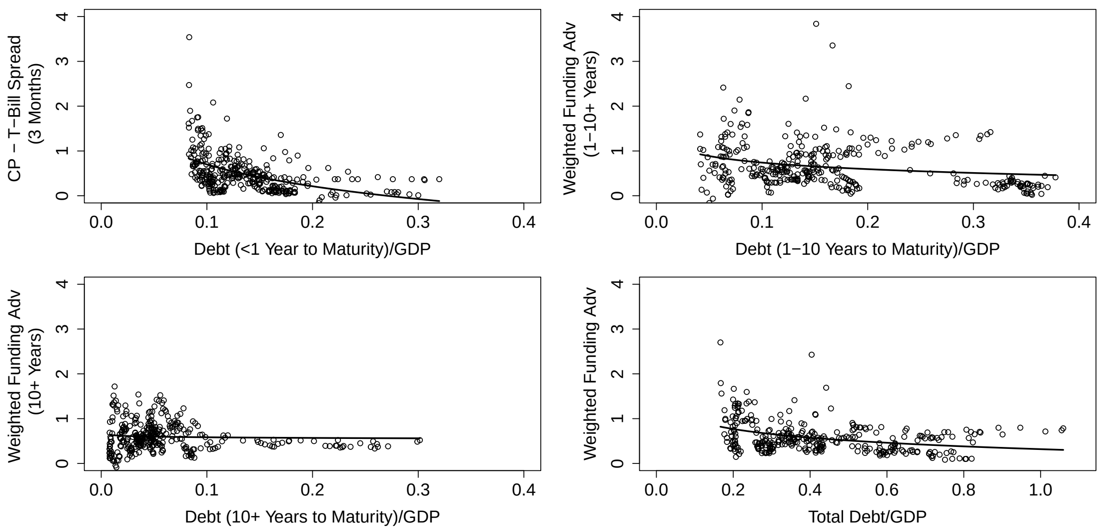

Figure 16: Post WWII: Downward sloping relationship between funding cost spread and debt-to-GDP ratio holds at short maturities