

Costs of Financing US Federal Debt Under a Gold Standard: 1791-1933*

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Abstract

From a new data set, we infer time series of term structures of yields on US federal bonds during the gold standard era from 1791-1933. Gold denominated yields trended downwards throughout the 19th century, falling below UK levels by the 1880s. Bonds nearing maturity carried a “liquidity premium” except during the height of the National Banking Era from 1880-1913. Despite the Union’s issues of inconvertible greenbacks, long term price expectations were anchored during 1862-1879.

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

KEY WORDS: Big data, default premium, yield curve, units of account, convenience yield, gold standard, government debt, pricing errors, specification analysis.

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1 INTRODUCTION

In 1790, Alexander Hamilton urged the US federal government to reduce its borrowing costs to UK levels by earning a reputation for timely debt service, minting gold and silver coins, and chartering a federal bank. But it was not until the late 19th century that most of Hamilton’s system was firmly in place. Throughout the 19th century, US Congresses adjusted monetary, fiscal, and financial arrangements in efforts either to implement or to unwind Hamilton’s project. Studying how the unfolding of those monetary-financial-fiscal policies influenced US borrowing costs requires data on prices and quantities of US government bonds and finding ways to infer yields from a long but thin panel of bond prices that spans periods that saw many institutional changes. This paper takes up these challenges as part of a quest to understand connections among monetary-fiscal policies and *default risk*, *denomination risk*, and *liquidity* premia on US federal debt.

For monthly data collected by [Hall et al. \(2018\)](#), we infer term structures of *yields* on US federal bonds with greater than one year to maturity throughout the gold standard period from 1791-1933¹. Sometimes several currencies circulated simultaneously, including gold and silver coins, greenback paper dollars, and notes issued by state and federally chartered banks. Because gold coins circulated throughout the entire period and were dominant for most of it, we start by estimating yield curves for gold coin denominated US federal debt contracts. We fit a dynamic [Nelson and Siegel \(1987\)](#) model with stochastic volatility and bond specific measurement errors to model our long, historical data set.

We detect several features of gold denominated bond yields during the “gold standard era.” First, yields trended downwards throughout the 19th century, with the 10-year gold yield dropping from around 8% in 1800 to around 2% in 1900, and stabilizing around that level until World War I.² Second, there were large spikes in yields during 19th century wars. We find substantially larger yields during the Civil War than has previously been understood. Third, yield curves typically sloped downward before the Civil War but then turned positive after the late 1870s.

We use our estimated yield curves to revisit historical narratives about US borrowing costs during the 19th century. In Section 5 we study default risk premia by comparing yields to maturity on gold denominated UK consols to yields-to-maturity on hypothetical gold denominated US consols that promise the same coupon flows as the UK consols. Since UK consols were widely considered to be “the” safe asset and since both countries were on a gold standard for most of the 19th century, we interpret the spread as a risk premium on US debt. We find that US debt typically carried a risk premium until 1905, when US yields became persistently lower than UK yields. This indicates that US debt started to have characteristics of a global “safe-asset” well

¹George Washington and Alexander Hamilton introduced a gold standard in 1791 that was theoretically maintained until 1933, at which point Franklin Roosevelt accepted Irving Fisher’s advice to abandon the gold standard.

²This is consistent with the global super-secular decline hypothesis put forward by [Schmelzing \(2020\)](#) but suggests that, from the turn of the 20th century, US debt started to play a different role than other debt securities.

before World War I.

In Section 6 we investigate denomination risk. In February 1862, Congress passed the Legal Tender Act, which authorized the Treasury to issue inconvertible greenback dollars. During and after the Civil War, the federal government issued bonds denominated in both gold and greenbacks dollars, a situation that enables us to estimate a greenback denominated yield curve and also investors' expectations about the volatile gold-greenback exchange rate. Despite a 60% depreciation in the greenback to gold exchange rate during the Civil War, we infer a strong nominal anchor: investors seemed to have anticipated that greenbacks would trade one-for-one with gold dollars after the war. An anticipated appreciation of the greenback kept greenback yields persistently lower than the gold yields. Having that firm nominal anchor helped the Union government raise wartime revenues by printing greenbacks.

Finally, in Section 7, we investigate short term bond premia. During 1862-66, Congress passed four National Bank Acts that constructed a system of federally chartered banks that could issue standardized bank notes backed by long-term U.S. government debt. Their goal was to increase the supply of short term assets and increase banks' demand for long term US federal debt and thereby lower long term yields. Our yield curves contain evidence about consequences of those reforms. We estimate differences between observed and model-implied yields to maturities for bonds with less than one year to maturity.³ Following others, we interpret this spread as a "short-rate-disconnect" or "liquidity premium" on short term bonds. We find that for most of the 19th century short-maturity government debt traded at a 0.25 to 0.5 percentage point premium, which indicates that money-like assets were scarce and so earned a "liquidity" premium. But premia on short term debt disappeared at the height of the National Banking Era from 1885 until 1917. This suggests the short rate disconnect varied with regulatory changes.

To parameterize and estimate a stochastic process for yield curves on US federal bonds, several challenges prompted us to deploy methods described in [Payne et al. \(2023\)](#). Our data set is sparse along the cross-section dimension. We acknowledge this by adopting a dynamic version of a tightly parameterized Nelson-Siegel yield curve model proposed by [Diebold and Li \(2006\)](#). Another challenge is that 19th century US federal bonds sometimes included call options and other features that gave lenders and/or the Treasury some discretion over maturity dates and conversions. Our inference procedure assumes that agents priced bonds under perfect foresight about those discretionary contract features. To prevent that assumption from unduly influencing our inferences, we introduce bond-specific idiosyncratic pricing errors.

We face additional challenges when estimating the greenback denominated yield curve during the period 1862-1878. Some bonds promised all payments in gold while other bonds promised all payments in greenbacks. In order to estimate the greenback yield curve, we extend the procedure in [Payne et al. \(2023\)](#) to incorporate a state-space model of the gold-to-greenback exchange rate. We then estimate the joint process of the greenback yield curve and anticipated

³Because our model was estimated using bonds with maturity greater than 1 year, this spread represents an "out-of-sample" fit at the short end of the yield curve.

gold-to-greenback exchange rates *conditional* on our baseline gold yield curve estimates. This approach could be applied in other settings where a government issues bonds denominated in a mixture of currencies.

RELATED WORK In the spirit of [Friedman and Schwartz \(1963\)](#), we present a narrative history supported by data and statistics. Other recent work has compiled international historical interest rate series and examined long-term trends (e.g., [Shiller \(2015\)](#), [Hamilton et al. \(2016\)](#), [Jordà et al. \(2019\)](#), [Schmelzing \(2020\)](#), [Officer and Williamson \(2021\)](#), [Chen et al. \(2022\)](#)). Data in those studies had limited coverage of US federal yields. Instead, they use a commercial paper rate as a “short interest rate” and a “long market rate” from [Homer and Sylla \(2004\)](#) that combines yields-to-maturity on US federal bonds pre-Civil War with yields-to-maturity on New England Municipal bonds and corporate bonds post-Civil War. By estimating the full yield curve on US federal bonds, this paper opens up exciting new questions about historical trends in government financing costs.

Technically, our work is related to [Svensson \(1995\)](#), [Dahlquist and Svensson \(1996\)](#), [Cecchetti \(1988\)](#), [Annaert et al. \(2013\)](#), [Andreasen et al. \(2019\)](#), [Diebold and Li \(2006\)](#), [Diebold et al. \(2006\)](#) and [Diebold et al. \(2008\)](#) who, like [Gürkaynak et al. \(2007\)](#) and ourselves, implement versions of the parametric yield curve model of [Nelson and Siegel \(1987\)](#). The so called “Dynamic Nelson-Siegel Approach”, studied in detail in [Diebold and Rudebusch \(2013\)](#), makes assumptions on the yield curve parameters’ time-variation in order to improve the model’s forecasting ability. We make assumptions on the yield curve parameters’ time-variation in order to pool information across time periods.

Our analysis of events during the 1862 to 1879 greenback period revisits issues presented in landmark studies of [Mitchell \(1903, 1908\)](#), [Friedman and Schwartz \(1963\)](#), [Roll \(1972\)](#), and [Calomiris \(1988\)](#). Our analysis of the national banknote issuance puzzle revisits work by [Cagan \(1965\)](#), [Cagan and Schwartz \(1991\)](#), [Champ et al. \(1994\)](#), [Champ and Wallace \(2003\)](#), [Champ \(2007\)](#), and [Calomiris and Mason \(2008\)](#).

OUTLINE Section 2 describes data and provides historical context. Section 3 outlines how we parameterise gold dollar yield curves and delineates our econometric strategy. Section 4 discusses some stylized facts about the “gold standard era” from 1791 to 1933 and compares our estimates to other available historical interest rate series. Section 5 compares historical US and UK yields. Section 6 discusses statistical inferences about greenback dollar yield curves and gold-greenback dollar exchange price expectations during and after the Civil War. Section 7 estimates the short-rate-disconnect and revisits the national bank note puzzle. Section 8 concludes.

2 DATA AND HISTORICAL CONTEXT

We have assembled prices, quantities, and descriptions of all securities issued by the US Treasury from 1776 to 1960.⁴ Our bond price data are monthly. When available, we use the closing price at the end of each month. When a closing price is not available, we use an average of high and low prices or an average of bid and ask prices. In Appendix A, we spotlight decisions about our data that we made to prepare the statistical inferences presented in this paper. In this section, we provide historical context.

Monetary Policy: US federal monetary policies varied over our sample. From April 1792 and February 1862, the US dollar was defined in terms of gold and silver (a “bimetallic” system). From 1862-1878, the US government also issued non-convertible greenback dollars that circulated alongside gold coins. The greenback depreciated substantially during the Civil War and did not attain parity with gold until January 1, 1879, when the US Treasury started converting greenbacks into gold dollars one-for-one. Convertibility between gold dollars and US notes at par prevailed until 1933 when President Franklin D. Roosevelt increased the paper price of gold and prohibited private US citizens from holding gold coins. For the purposes of this paper, we consider this the end of the US gold standard.

US Federal Debt Policy: Before World War I, the federal government issued bonds infrequently. New bond issues were often small. The US Congress, not the Treasury, designed each government security with the consequence that securities varied over time in terms of their coupon rates, denominations, lengths, units of account, tax exemptions, and call features. Before the 1920s, the federal government occasionally issued customized long term debts, mostly to finance wars, debt reschedulings, and specific infrastructure projects. As a result, between 1776 and World War I, the US Congress only authorized the Treasury to issue a total of approximately 200 distinct securities, with at most 8 distinct ones being authorized in any one year.

Between 1917 and 1939, Congress gradually delegated more and more decisions about designing US debt instruments to the Treasury and the Treasury gradually standardized security design. As a result, from 1920 to 1960 alone, the Treasury issued about 2500 securities with a wide range of maturities. Ultimately, this transformed the market for US Treasury securities into the world’s most liquid debt market with a collection of standardized securities at many maturities that allowed a large national debt to be issued and rolled over.

When gold and greenback dollars coexisted between 1862 and 1878, different US Treasury bonds promised payments in different currencies. Some bonds promised all payments in gold (we refer to these as “gold dollar” bonds), while others promised all payments in greenbacks

⁴The data set (excluding any data taken from non-publicly accessible data sets) is available at the Github repository <https://github.com/jepayne/US-Federal-Debt-Public> and construction methods are explained in Hall et al. (2018).

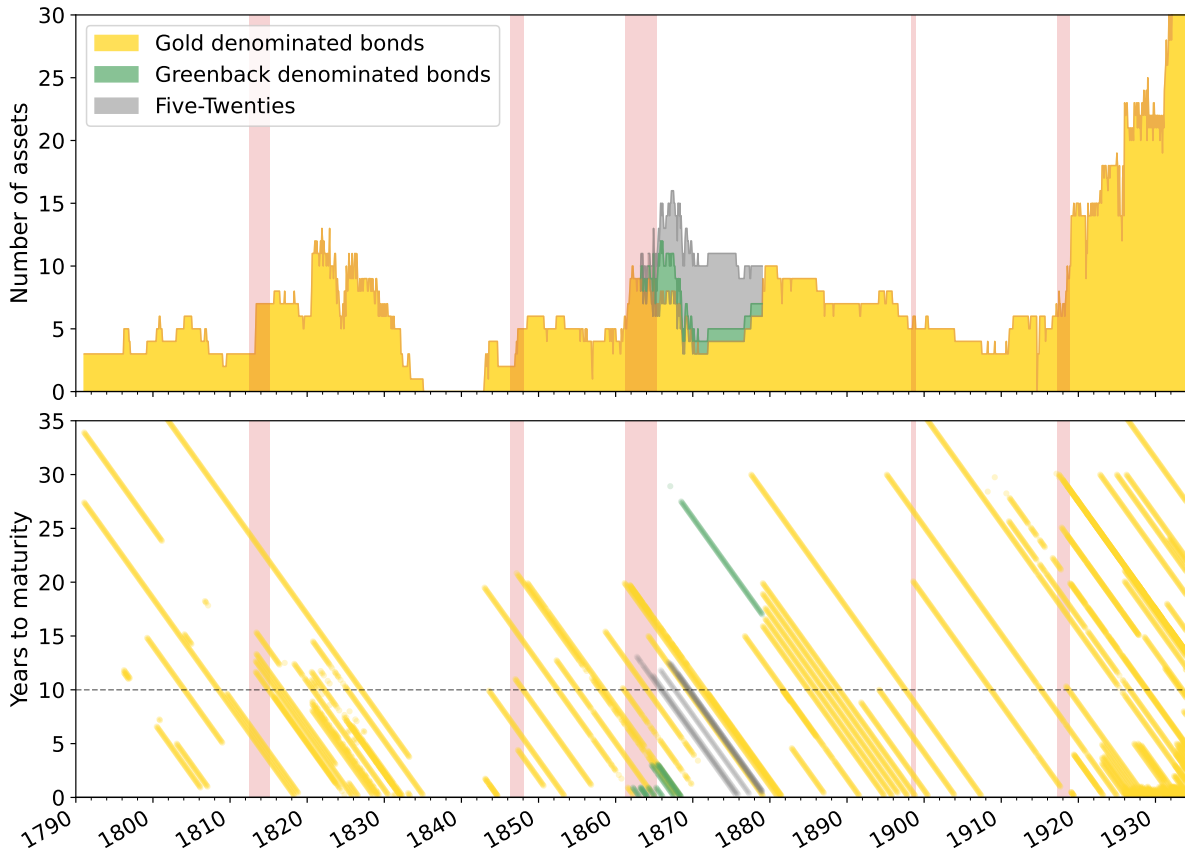


Figure I: Our Dataset

The top panel depicts the number of securities with observed prices each month. The bottom panel depicts maturities (in years) of observed securities. Darker lines indicate overlapping securities. Red bars correspond to wars.

(we refer to these as “greenback dollar” bonds).⁵ Figure I depicts the monthly time series for the number of securities with observed prices and times to maturity of all outstanding bonds. The presence of bonds denominated in different currencies allows us to estimate both gold dollar and greenback dollar nominal yield curves. Because we observe only 9 greenback dollar bonds, initially we focus on the gold dollar bonds to obtain our baseline yield curve estimate. We will build on this baseline gold dollar yield curve when we turn to estimating greenback dollar yield curves in Section 6.

⁵There was also a small collection of bonds that offered coupons in gold but left ambiguous whether the principal would be paid in gold or greenbacks (we refer to these as “ambiguously” denominated bonds). We exclude these bonds from the analysis in this paper.

3 ESTIMATING YIELD CURVES

In order to facilitate comparability of our historical estimates of gold denominated yield curves with modern counterparts we use the popular Dynamics Nelson-Siegel (DNS) model of [Diebold and Li \(2006\)](#) and [Diebold et al. \(2006\)](#) extended with stochastic volatility as in [Hautsch and Ou \(2008\)](#) and [Hautsch and Yang \(2012\)](#). Dynamic relationships among three factors that can be thought of as levels, slopes, and curvatures of yield curves allow us to use the model to learn about yields at all dates simultaneously by pooling information across time periods. This feature of the model is essential to address the cross-sectional sparsity of our data set. Stochastic volatility in the factor dynamics lets the amount of information pooling vary over time. That helps the model accommodate consequences for gold denominated yield curves of wars and important institutional changes.

In a departure from the literature, we add *bond-specific pricing errors* to the observation equation of our model. Throughout our sample, many US Treasury securities had custom features such as indefinite maturities associated with call and conversion options. To manage such issues, researchers of the post-WWII sample have usually homogenized their samples by carefully pre-selecting bonds with specific properties. For us, doing that would sacrifice too much information. Furthermore, to us it is a priori unclear which bond characteristics are important for bond pricing. We use bond-specific pricing errors as a diagnostic tool to decide which ones warrant special treatments.

NOTATION: Let $q_t^{(j)}$ denote the gold price of a government promise to one gold dollar at time $t + j$. We call the sequence $\mathbf{q}_t := \{q_t^{(j)}\}_{j=0}$ a *discount function* and denote the corresponding j -period zero-coupon yields as $y_t^{(j)} := -\log q_t^{(j)}/j$. Suppose that at time t bond i promises a sequence of gold dollar coupon and principal payments $\mathbf{m}_t^{(i)} := \{m_{t+j}^{(i)}\}_{j=1}$. We let $\rho_t^{(i)}$ denote the price of such a coupon-bearing gold dollar bond in terms of gold.

3.1 A DYNAMIC NELSON-SIEGEL MODEL

We parameterize zero-coupon yields—embedded in discount function \mathbf{q}_t —as follows:

Assumption 1. The j -period gold dollar zero-coupon yield takes the form

$$y_t^{(j)} = L_t + S_t \frac{1 - \exp(-j)}{j} + C_t \frac{1 - \exp(-j)}{j} - \exp(-j)$$

where L_t , S_t , and C_t are hidden factors that characterize the level, slope, and curvature of the yield curve at time t . The vector $\mathbf{z}_t := [L_t, S_t, C_t]$ follows a drift-less random walk:

$$\mathbf{z}_{t+1} = \mathbf{z}_t + \Sigma_t^{\frac{1}{2}} \boldsymbol{\varepsilon}_{t+1}$$

where Σ_t is a covariance matrix with $\Sigma_t = \Xi_t \Omega \Xi_t$. Here, Ω is the time-invariant correlation matrix and

Ξ_t is a diagonal matrix with marginal standard deviations $\sigma_{t,t+1}$ that follow:

$$\log r_{t+1} = \log r_t + \Xi_{t,t+1}$$

where Ξ is a positive definite diagonal matrix. Shocks $\{\epsilon_{t,t}, \epsilon_{t,t+1}\}_{t=1}^T$ are Standard Normal.

This is the yield curve model of [Diebold and Li \(2006\)](#) and [Diebold et al. \(2006\)](#) extended with stochastic volatility. The matrix Σ_t governs the degree of information pooling over time. The closer are two dates to each other, the more correlated are the associated yield curves, with Σ_t capturing what “close” means.⁶ In this context, “stochastic volatility” means that the amount of pooling varies over time.⁷

As is standard, we assume that the zero-coupon yield curves implied by this model can price coupon-bearing government gold bonds well.

Assumption 2. The law of one price holds for government bonds and for each $t = 0$

$$p_t^{(i)} = \sum_{j=1}^m q_t^{(j)} m_{t+j}^{(i)}.$$

Assumption 2 expresses our key identifying restriction: within each time period, a common discount function prices all bonds that we include in our sample, i.e., there is no cross-sectional variation in how government promises of bond repayment are priced. In principle, q_t implicitly includes compensations for default risks, convenience benefits, and inflation risk, so it should be thought of as the price of a *risky* government promise. Our specification allows these components to vary with maturity j and time t , but not by individual bond. However, as we noted in Section 2, 19th century US federal bonds had idiosyncratic contract features that could easily lead to violations of this common discount function assumption. Because we want our model to warn us when that is the case, we introduce *bond specific* pricing errors.

Assumption 3. Each bond i has an independent pricing error that has a time-invariant Gaussian distribution with mean 0 and standard deviation $\frac{\sigma^{(i)}}{m}$.

Introducing these errors enables our model to decrease the influence of peculiar bonds on our yield estimates while still informing us about situations when our collective assumptions prevent us from consistently pricing the *cross-section* of bonds. After starting by presuming that all bonds can be priced with a common discount function, we look for patterns in the estimated pricing errors, the idea being that misjudgments in our bond classification should

⁶The limit $\Sigma \rightarrow 0$ corresponds to *complete pooling*: here the yield curve is assumed to be fixed over time. Contrary situations in which $\Sigma \rightarrow \infty$ call for *no pooling*: there is no relationship between adjacent parameter estimates as in [Gürkaynak et al. \(2007\)](#).

⁷We gain additional pooling by letting shocks to different components of ϵ_t be correlated. Assuming that different parts of the yield curve follow correlated but time-invariant dynamics allows us to transmit what we learn about co-movements between short- and long-term yields from years when many maturities are outstanding to years when data are scarce.

show up as large, cluster-specific relative pricing errors.⁸ As a result, the observation equation becomes:

$$\tilde{p}_t^{(i)} = q(t, \cdot), m_t^{(i)} + d_t^{(i)} \frac{(i)}{m} \frac{(i)}{t}$$

where $\tilde{p}_t^{(i)}$ denotes the *observed* period- t price of bond i in terms of gold and $d_t^{(i)}$ is the Macaulay duration of bond i in period t . Using the technique in [Payne et al. \(2023\)](#), we estimate this model with Bayesian Markov Chain Monte Carlo methods assuming the weakly informative priors detailed in Table I.

Table I: Prior Distributions of the Dynamics Nelson-Siegel Model

Parameter	Description	Priors	Hyper parameters
L_0	initial level factor	$N(\mu, \sigma^2)$	$(\mu, \sigma) = (10, 5)$
S_0	initial slope factor	$N(\mu, \sigma^2)$	$(\mu, \sigma) = (0, 10)$
C_0	initial curvature factor	$N(\mu, \sigma^2)$	$(\mu, \sigma) = (0, 10)$
	location parameter	$\log N(\mu, \sigma^2)$	$(\mu, \sigma) = (5, 5)$
Ξ_0	initial shock volatilities	$\log N(\mu, \sigma^2)$	$(\mu, \sigma) = (0.05, 0.1)$
Ω	correlation of shocks	LKJ(ν)	$\nu = 5$
Ξ	volatilities of Ξ_t shocks	Exp(λ)	$\lambda = 20$
$\frac{(i)}{m}$	volatilities of pricing error	Exp(λ)	$\lambda = 0.1$

¹ The LKJ distribution is defined by $p(\Omega/\nu) \propto \det(\Omega)^{-\nu-1}$. See [Lewandowski et al. \(2009\)](#)

STATISTICAL APPROACH: We estimate parameters directly from bond prices adjusted by the bond’s duration as in [Gürkaynak et al. \(2007\)](#). An alternative approach in the literature is first to produce zero-coupon yield observations by an iterative extraction method—the so called “bootstrap” of [Fama and Bliss \(1987\)](#)—and fit a DNS model to the resulting yield series. With our sparse data set, properties of the Fama-Bliss “bootstrap” is tenuous, so we prefer instead to minimize duration-adjusted price errors. Nevertheless, in a companion paper, [Payne et al. \(2023\)](#), we verify that the two methods lead to very similar results.⁹ We also conduct an information-criterion-based model selection exercise and find that a model with stochastic volatility and correlated shocks is preferred to a model without these components because of how these features

⁸We identified two types of bonds that require special treatment: (i) greenback-denominated bonds, for which we devise custom pricing formulas in Subsection 6.2, and (ii) bonds that are close to maturity, in which case, we suspect the large relative pricing errors are due to a liquidity premium that emerges from the relative ease in which such bonds could be used for transactions. We drop prices of bonds that are less than one year to maturity from the sample and in Subsection 7.1 use the residual pricing errors on these bonds as a proxy for the liquidity premium on money-like federal liabilities.

⁹To a first order, the difference between actual and predicted prices of bond i equals its duration multiplied by the difference between actual and predicted yields. As a result, minimizing duration-adjusted pricing errors approximates minimizing unweighted yield errors.

help reduce pricing errors without overfitting. We also show that introducing mean-reversion in the factor process does not significantly improve the fit, so we omit mean reversion from our baseline model.

3.2 FIT

An important aspect of our approach is its use of bond-specific pricing errors. The black crosses in Panel A of Figure II depict *duration-weighted mean absolute pricing errors* for each bond included in the analysis.¹⁰ We note that our yield curves price the included bonds well with similar errors across different bonds. This is also reflected in estimated standard deviations of bond-specific pricing errors, $\hat{m}^{(j)}$, the posterior distributions of which are depicted by the boxplots in Panel A of Figure II. The relative magnitude of these estimates indicates the influences of certain bonds on the estimated yield curves. Our algorithm assigns relatively less weight to bonds with large estimated $\hat{m}^{(j)}$ values. The absence of obvious “clusters” in Panel A indicates that our common discount function assumption provides a reasonably good description of the gold dollar bonds with maturities larger than 1 year.

To obtain a measure of fit with a more interpretable scale, we take the posterior median of our zero-coupon yield estimates, compute the implied yields-to-maturity for each bond at each month, and compare them to the observed yields-to-maturity. The bottom panels of Figure II report different aspects of these *yield errors*. Panel B depicts distributions of yield errors for specific maturity bins. We see that on average our parametric yield curve specification fits observed yield-to-maturities well and without systematic differences across maturities larger than 1 year. Panel C depicts cross-sectional means and standard deviations (over bonds for each calendar year) of yield errors. The mean error stays close to zero within a similar range to [Diebold and Li \(2006\)](#).¹¹ The cross-sectional variation in the yield error is also typically small but becomes large relative to [Diebold and Li \(2006\)](#) during the early 19th century and the Civil War, indicating that we have the most difficulty pricing the cross section of bonds during those years. This means that our yield curve estimates should be regarded as more tenuous both during big wars, when yields are rapidly changing, and during the early 19th century, when we have limited data.

4 GOLD YIELD CURVES: 1791-1933

In this section, we use our estimates of gold denominated US federal yield curves to infer that: (i) yields trended downwards throughout the 19th century, (ii) there were larger spikes in yields

¹⁰[Bliss \(1996\)](#) used this measure of in-sample fit. It is computed as the time average of the absolute difference between observed prices and posterior median price forecasts weighted by the inverse of the respective Macaulay durations.

¹¹For comparison, in Table 2, they show time averages of yield errors across maturities in the range of -6 to +6 basis points. In view of our much more limited data, we find this encouraging.

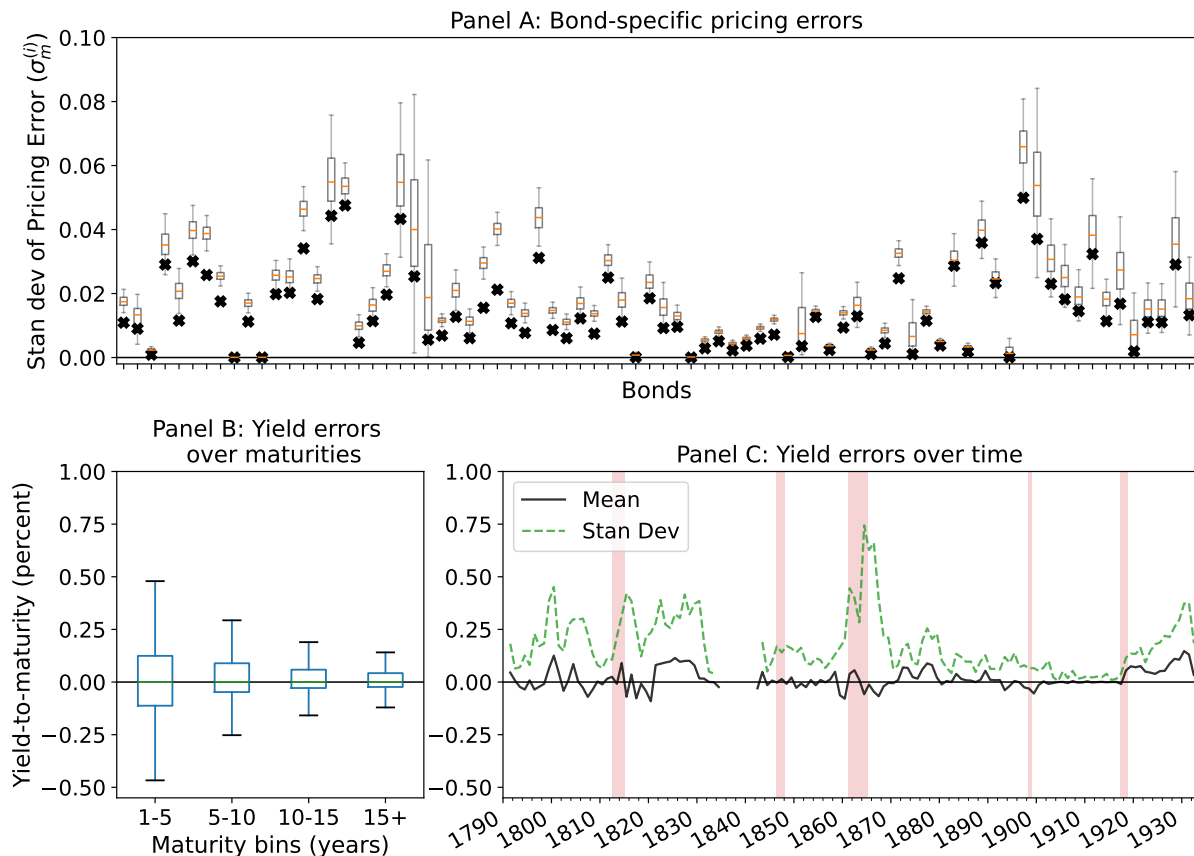


Figure II: Statistical Fit of the Model

Panel A: Each boxplot represents the interquartile range and median (orange line) of the posterior distribution of $\sigma_m^{(i)}$ —that is the standard deviation of the bond-specific pricing error—for each bond used in the estimation. Black crosses represent *duration-weighted mean absolute price errors* computed from the difference between observed and model-implied prices for each bond. *Panel B:* Each boxplot represents the interquartile range and median (green line) of yield errors (difference between model-implied and observed yield-to-maturities) for different maturity bins. *Panel C:* Cross-sectional mean (black solid line) and standard deviation (green dashed line) of yield errors over time. Sample statistics are computed over bonds for each calendar year. Red bars correspond to wars.

during 19th century wars than has previously been understood, and (iii) slopes of yield curves were typically negative before the Civil War, but positive afterwards.

4.1 LONG TERM US YIELDS FELL DURING THE 19TH CENTURY

Figure III depicts selected long term yield estimates. The solid black and grey lines depict the median of our posterior probability distributions for 10-year, gold denominated, zero coupon yields. The bands around the posterior median depict the 90% interquantile range. We show 25 year gold dollar zero-coupon yields for dates before 1800 because we only have price observations for very long term bonds during that period. Long yields trended downward throughout the 19th century interrupted by sharp (but temporary) increases during times of war and financial turmoil. The sharpest increases came during the War of 1812 and the Civil War.

Few estimates of 19th century US long yields exist. Most economic historians follow [Officer and Williamson \(2021\)](#) and use a ‘composite series’ that combines the [Homer and Sylla \(2004\)](#) estimates for 10-year US federal bond yield for the period from 1798-1861 with the yield-to-maturity on New England Municipal bonds for 1862-1899 and the yield-to-maturity on corporate bonds for 1900-1940.¹² Figure III also plots this composite series alongside our 10-year yields. Evidently, compared to the composite series, our estimates are similar before the Civil War, much higher during the Civil War, and consistently lower after greenback-gold convertibility in 1879. In particular, our ten-year gold yield estimate reaches a peak of 16% near the end of the Civil War, which is substantially higher than the [Homer and Sylla \(2004\)](#) series peak of 6% at the start of the war.

We find it reassuring that our estimates align with [Homer and Sylla \(2004\)](#) during “non-emergency” periods because there are good reasons to think that their estimates should be a good approximation to the 10 year yield.¹³ The following observations also suggest that during the Civil War our higher estimates are more plausible than those of [Homer and Sylla \(2004\)](#).¹⁴ Starting in 1862, all US Treasury bonds could be purchased with greenback dollars, including bonds with coupons and principal payments denominated in diverse units of account, some in greenbacks, others in gold dollars. The value of the greenback fluctuated with battlefield and political news, and all Treasury bond prices deviated substantially from par. For example, with the re-election of President Abraham Lincoln in doubt during the summer of 1864, 100 greenback

¹²Prominent examples of researchers who used this series include [Shiller \(2015\)](#), [Jordà et al. \(2019\)](#), and [Hamilton et al. \(2016\)](#), as well as the Macrohistory Database ([Jordà et al., 2016](#)).

¹³Their approach calculates an average yield to maturity for 10 year bonds trading close to par, which should be similar to the 10 year zero-coupon yield when the yield curve is relatively flat. Except during and after the Civil War, the average duration of outstanding bonds was close to 10 years and the average market trading price was close to par so [Homer and Sylla \(2004\)](#) have enough bonds for their methodology.

¹⁴[Homer and Sylla \(2004\)](#) warn against using their estimates for the Civil War period stating on page 303, “... the tables of bond yields for the years 1863 to 1870 do not provide a reliable picture of long-term interest rates.” This is because there were no federal bonds trading with a gold price of par, so they were forced to estimate the yield as the gold coupon rate for bonds trading with a greenback price of par. We capture greater variation in the yield curve because we use the universe of US Treasury bonds at monthly frequency whereas [Homer and Sylla \(2004\)](#) use the subset of these bonds that traded at par.

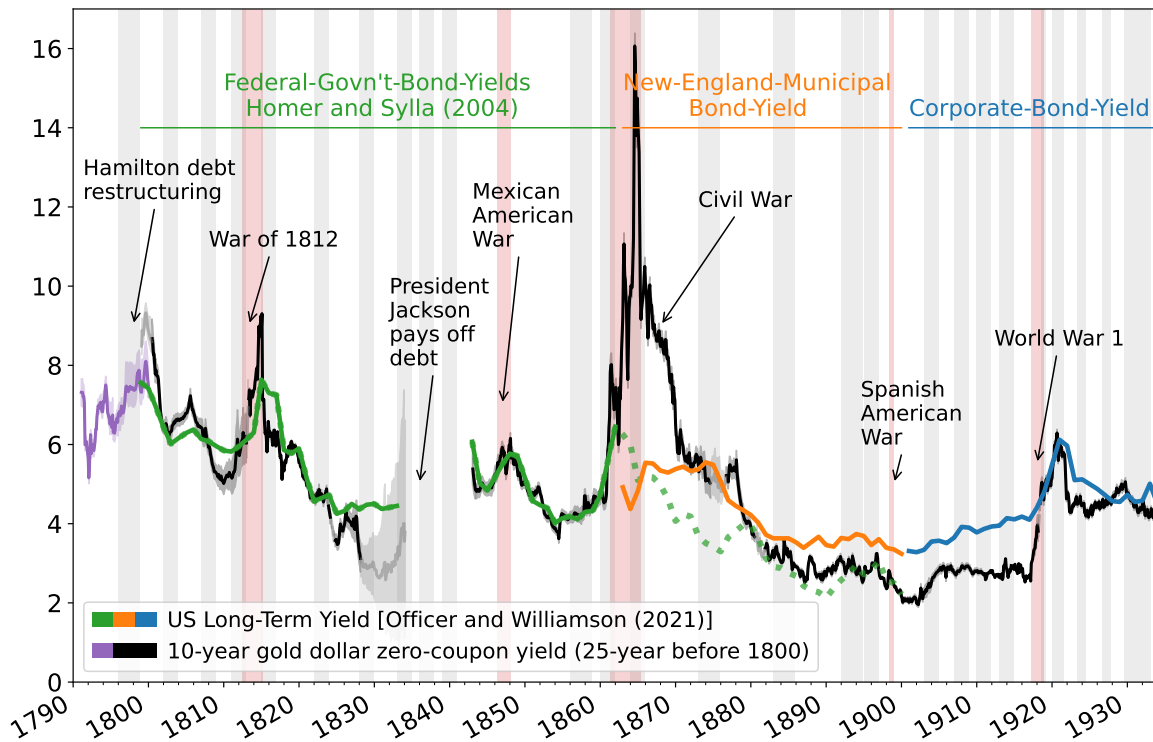


Figure III: Long-Term Yield Estimates

The solid black (purple) line depicts the median of our posterior estimate for the 10-year (25-year), gold denominated, zero coupon yield after (before) 1800. The bands around the posterior median depict the 90% interquantile range. We use a grey line for periods when the 10-year maturity was not covered by observed maturities and so the estimate should be thought of as an extrapolation. The green line (bold and dotted) depicts the 'US Government Bond Yield' series from [Homer and Sylla \(2004\)](#). The orange line depicts the New England Municipal Bond Yield reported by [Homer and Sylla \(2004\)](#). The blue line depicts the Corporate Bond Yield reported by [Homer and Sylla \(2004\)](#). The bold green-orange-blue line depicts the 'composite' bond series used by [Officer and Williamson \(2021\)](#). The light gray intervals depict recessions and the light red intervals depict wars.

dollars could be purchased for as few as 40 gold dollars. Consequently, during that time Treasury bonds that promised to pay 6 percent coupons in gold dollars could be purchased for 40 percent of par, implying long-term yields in excess of 15 percent.

Our estimates of lower long-term yields after 1880 reflect differences between US federal debt and other bonds during the late 19th century. Federal debt probably carried greater default risks during the Civil War. After the war, federal debt played a special role in the financial sector because National Banking Era protocols increased demands for federal bonds as reserves against National Bank Notes. In particular, we can see that a “convenience yield” spread opened up between US federal bonds and other low risk bonds during the 1880s that persists to this day. Because it mixes very different types of bonds, the commonly used composite long-term yield series inaccurately reflects variations in either US federal borrowing costs or private sector borrowing costs.¹⁵

4.2 SLOPES SWITCHED SIGNS

There are no existing estimates for 19th century yields on short term US federal debts. Instead, 19th century economic historians have typically presented the bank call rate as a short yield.¹⁶ Figure IV depicts our estimates for 2-year gold denominated zero-coupon yields alongside the bank call rate. Our short term yield series is substantially higher than the bank call rate during the Civil War and does not always co-move with it after the Civil War.¹⁷ This is not surprising because the bank call rate reflects distress in the financial sector whereas the 2-year zero coupon yield on US federal debt reflects short term federal government borrowing costs. We can see that the federal government had substantially more difficulty borrowing during the war but less difficulty borrowing during financial crises when the call rate spiked.

Having yield curves allows us to study their slopes. Figure V depicts the 10-year gold dollar yield minus the 2-year yield, which we refer to as the term spread. A positive term spread indicates an upward sloping yield curve (i.e., longer maturity bonds have higher rates), while a negative term spread indicates an inverted yield curve (i.e., shorter maturity bonds have higher rates). The term spread was typically negative before the Civil War and positive afterwards, with major decreases occurring during the War of 1812, the Mexican-American War, and the Civil War.

¹⁵Comparing our yield estimates to those of [Homer and Sylla \(2004\)](#) sheds new light on a literature that, starting with [Evans \(1985, 1987\)](#), found that during the 19th century there was no strong association between interest costs and deficits. To infer that, previous papers used the composite series in Figures III and IV. Our estimates indicate that those series substantially underestimated increases in yields on US federal debt during episodes of large 19th century government deficits.

¹⁶For example, [Officer and Williamson \(2021\)](#) and [Jordà et al. \(2016\)](#) use a series “Surplus Funds (Contemporary Series).” The Series is the interest rate on the short-term lending or borrowing of surplus funds by financial institutions, often referred to as the “call rate”.

¹⁷Anecdotal evidence indicates that Union short-term debt paid very high yields during the Civil War. For example, [Homer and Sylla \(2004, page 302\)](#) report that in 1860 the Treasury had issued one-year notes at rates of 10-12% and had rejected bids ranging from 15-36%.

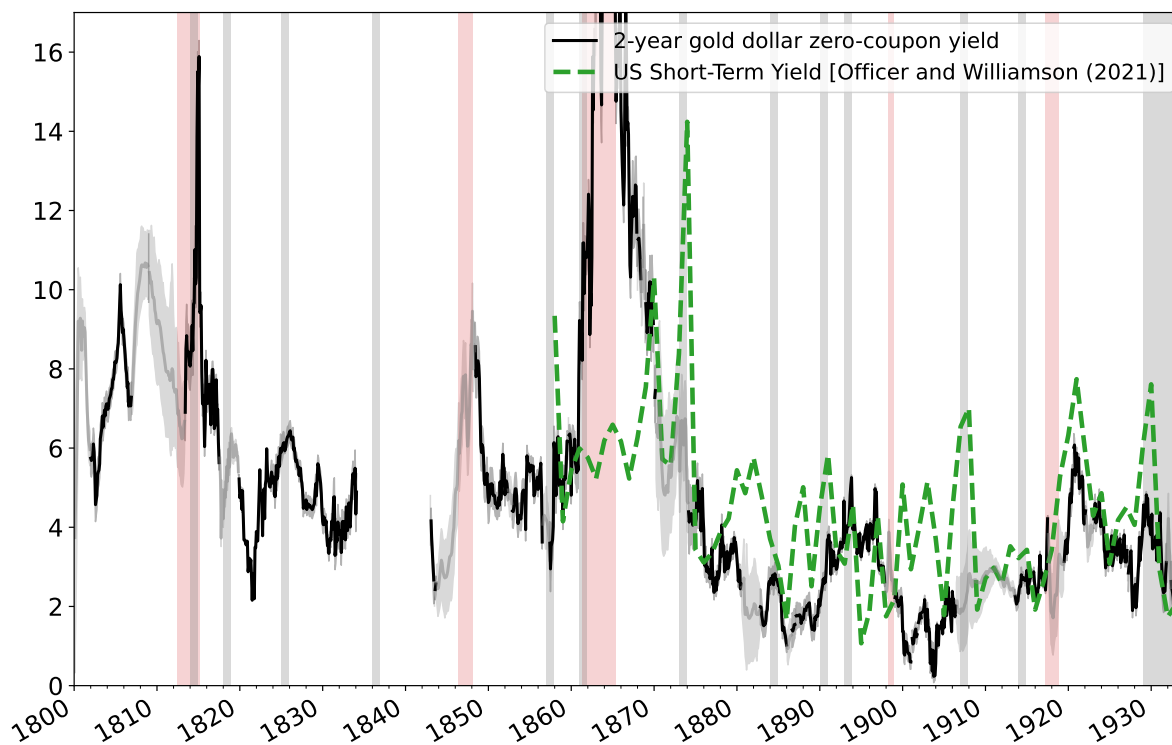


Figure IV: Short-Term Yields

The solid black line depicts the median of our posterior estimate for the 2-year, gold denominated, zero coupon yield. The grey bands around the posterior median depict the 90% interquantile range. We use a grey line for periods when the 2-year maturity was not covered by observed maturities and so the estimate should be thought of as an extrapolation. The green dashed line depicts the US short term yield series (surplus funds, contemporary) used by [Officer and Williamson \(2021\)](#) and [Jordà et al. \(2019\)](#). The gray intervals depict financial crises from [Reinhart and Rogoff \(2009\)](#). The light red intervals depict wars (from left to right: the War of 1812, the Mexican-American War, the Civil War, the Spanish-American War, and World War I).

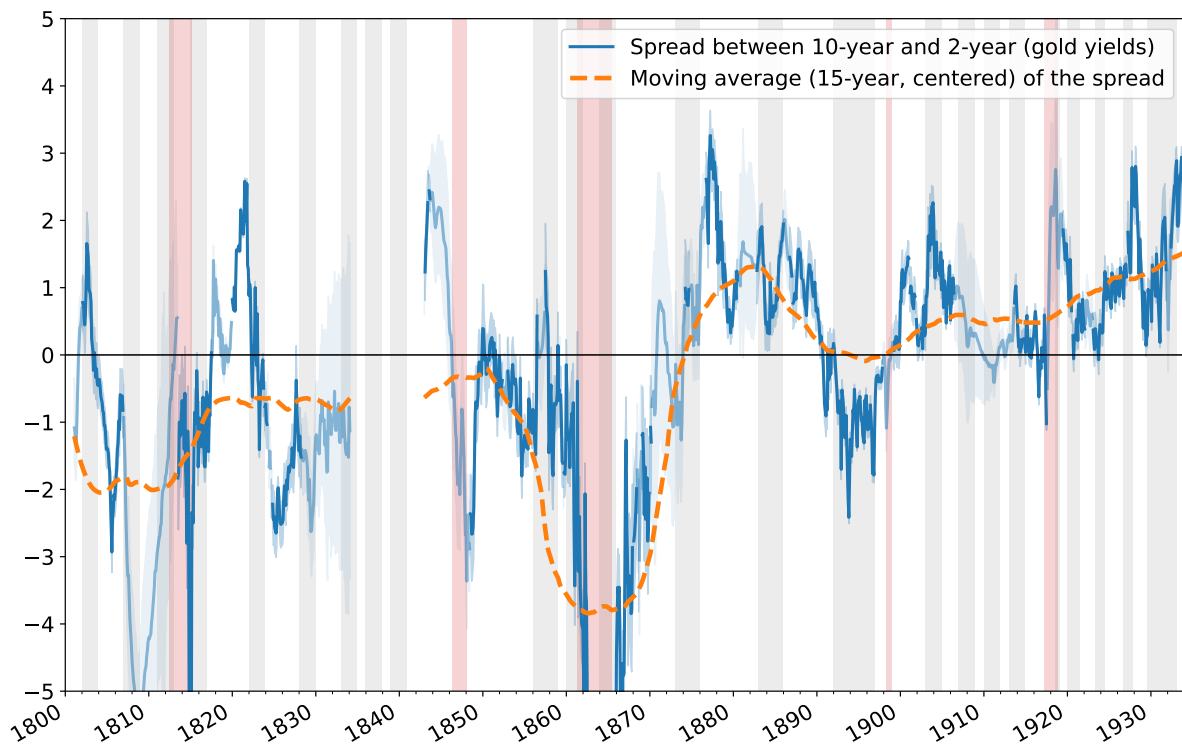


Figure V: Term Spread

The solid blue line depicts the posterior median for the spread between the yield on 10-year, gold denominated, zero coupon US government bonds and the yield on 2-year bonds. The grey bands around the posterior median depict the 90% interquartile range. We use a grey line for periods when either the 10 or the 2 year maturity was not covered by observed maturities and so the estimate should be thought of as an extrapolation. The orange dashed line depicts the 15-year centered moving average of the spread.

5 LONG TERM US YIELDS APPROACHED UK YIELDS

One possible explanation for the sustained decrease in long yields is a fall in the risk premium on US federal debt securities. After the American War for Independence, the Continental Congress owed approximately \$52 million in foreign loans to France, Spain, and Holland, loan office and debt certificates to the American public, and unpaid interest. The Congress confronted substantially higher long term yields than the UK even though the UK then had a high debt-to-GDP ratio. This situation sparked a lively debate in the US about whether and how to service wartime debts. In his *1790 Report on Public Credit*, Treasury Secretary Alexander Hamilton argued

For when the credit of a country is in any degree questionable, it never fails to give an extravagant premium, in one shape or another, upon all the loans it has occasion to make. Nor does the evil end here; the same disadvantage must be sustained upon whatever is to be bought on terms of future payment.

Hamilton convinced Congress to honor its foreign debts and to offer its domestic creditors a rescheduling deal that, except for owners of Continental and state-issued currencies, left them with 65 to 80 cents on the dollar. Even after those haircuts, US domestic creditors came away with much higher *ex post* returns than had been anticipated during much of the previous decade.¹⁸ Hamilton intended these steps to kick-start a process that would eventually give the US a reputation for servicing its debts that would help reduce future US borrowing costs to lower levels than being paid by the UK government.

We use our estimated yield curves on US federal debt to quantify whether and when Hamilton's hopes were fulfilled. Figure VI compares yields-to-maturity on gold denominated UK consols to yields-to-maturity on *hypothetical* gold denominated US consols that promise the same coupon flows as the UK consols.¹⁹ We plot yields to maturity on gold denominated UK consols because almost all UK government bonds were consols, so that is the only UK yield that can be reliably estimated. Our estimates of yield curves enables the construction of yields on comparable hypothetical US consols.

We make the following observations. First, notice that the hypothetical US consol yield exhibits a downward trend, falling from close to 8% at the beginning of the 19th century to around 2% at the end of the century. Second, notice that the US yield was typically higher than the UK yield until the 1880s, except for a temporary coincidence during the 1820s. Third, notice that the US yield was persistently lower than the UK yield after 1900. This suggests that the combination of the federal government's having serviced War of Independence IOUs,

¹⁸Hall and Sargent (2014) describe details of Hamilton's rescheduling operations, including estimates of haircuts to domestic federal creditors.

¹⁹The UK consol yield is the series "Spliced consol yield 1753-2015, corrected for Goschen's conversion issues" from Thomas and Dimsdale (2017). The hypothetical, gold denominated US consols promise the same annuity coupon payments as those in the UK consol yield series.

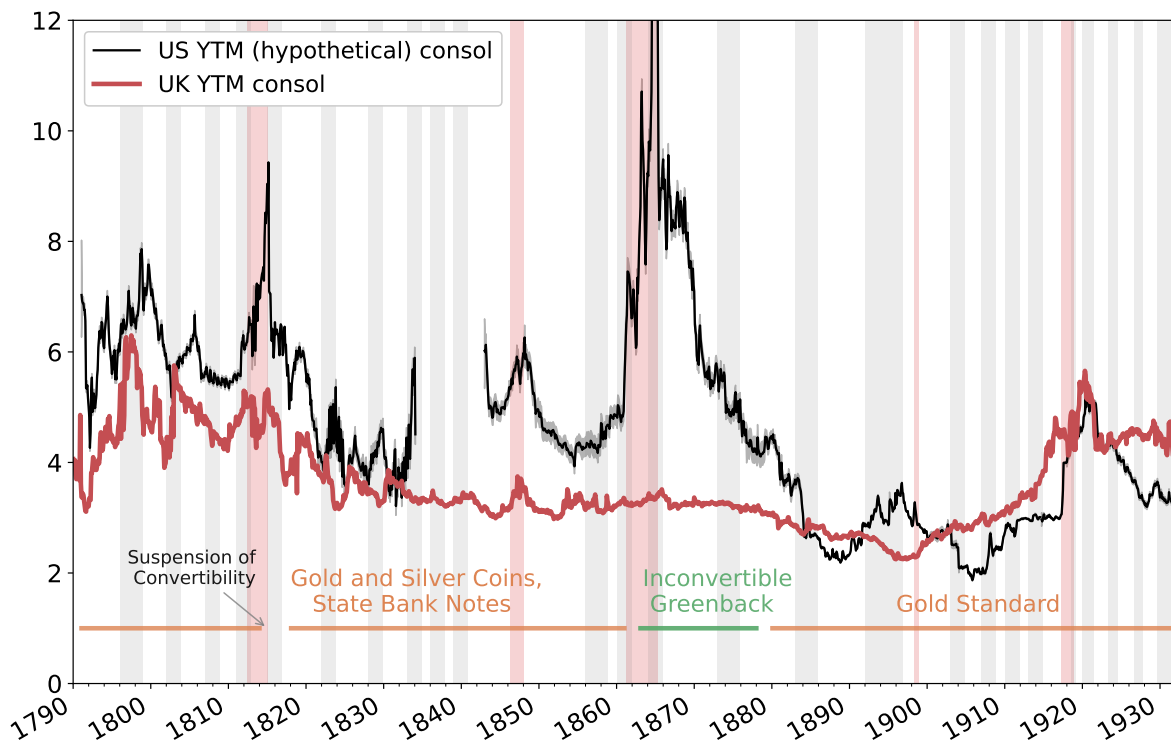


Figure VI: US and UK Consol Yields.

The solid black line depicts the median of our posterior estimate for the yield-to-maturity on hypothetical gold denominated US consols that promise the same coupon flows as the UK consols. The grey bands around the posterior median depict the 90% interquartile range. The red line depicts the UK long-term yield (implied by the 3% consol price) from [Thomas and Dimsdale \(2017\)](#). The light gray intervals depict recessions, and the light red intervals depict wars.

albeit with substantial haircuts to domestic creditors, and having completely retired all federal debt by the mid-1830s, along with activities of the First and Second Bank of the United States made significant contributions to Hamilton's project. However, the reemergence of the spread between US and UK debt during the period from 1840-1880 suggests that Hamilton's plan was not fully realized until disruptions from the Civil War had passed, the National Banking system had been introduced, and gold-greenback parity had been set in place in 1879. In particular, we see how much the reestablishment of order following the Civil War dominated US asset prices in the 1860-70s.

Differences between the yields to maturity on the UK consol and on the hypothetical US consol most likely reflect different default risks. UK debt was considered a safe-asset during the 19th century, whereas US wars and state-level defaults induced investors to regard 19th century US debt as risky. If there was no default risk on UK consols and gold inflation expectations were similar in the US and UK, then we can interpret the difference between US and UK consol yields as reflecting a risk premium on US federal debt. Under this interpretation, Figure VI indicates that US federal debt carried a risk premium until the late 19th century when it became another safe-asset. Our estimates show that this occurred well before US debt became the world's main reserve asset. Evaporation of those risk-premia thus set the stage for a realignment of global finance that ultimately let US government debt replace UK debt as the global safe-asset during and after the 1944-1971 Bretton Woods years.²⁰

6 Greenback Era: 1862-1878

It is useful to study how government credibility and borrowing costs were affected by monetary policy disruptions during 1862-1878, when greenback dollars traded at volatile discounts relative to gold dollars. Figure VII shows greenback to gold dollar exchange rates as well as prices of bonds that promised payment in gold. Evidently, bond prices started to track the greenback to gold exchange rate only for bonds nearing maturity. This suggests that investors did not expect a persistent deviation from greenback to gold parity, despite substantial devaluations of greenback dollars during the Civil War. That indicates the presence of a heavy nominal anchor. We shall formalize this idea by using our gold yield curves, price data for greenback paying bonds, and data on the gold to greenback exchange to estimate expectations about future exchange rates and a greenback denominated yield curve.

6.1 Historical Context: Greenback Dollars

Before the Civil War, the US dollar was defined in terms of gold and silver. The federal government minted gold and silver coins and did not issue paper dollars. Under financial strain from

²⁰Chen et al. (2022) describe this realignment in detail, focusing especially on its fiscal implications for both the UK and US.

Figure VII: Prices of Gold and Bonds: 1860-1880.

The solid orange line depicts the greenback to gold exchange rate (expressed as the number of greenback dollars required to purchase 100 gold dollars). The dashed lines depict observed prices (denominated in greenbacks) for the outstanding bonds. The grey lines depict prices of bonds that matured after 1868. The light red interval depicts the Civil War.

the Civil War, on February 25, 1862, Congress passed a Legal Tender Act that authorized the Treasury to issue 150 million dollars of a paper currency known as greenbacks that the government did not promise to exchange for gold dollars on demand. Subsequent acts authorized the Treasury to issue more notes, eventually totaling 450 million dollars. Investors could use greenbacks to purchase bonds from the federal government at their par values. Gold dollars continued to be used to settle international transactions, to pay US tariffs, and to pay coupons on some federal bonds. Figure VII shows that from 1862 to December 31, 1878 greenback dollars traded at discounts relative to gold dollars. On January 1, 1879, the US Treasury started converting greenbacks into gold dollars one-for-one.

6.2 Estimation Strategy

Let G_t denote the quantity of consumption goods that can be exchanged for one gold dollar at time t (i.e., the consumption goods price of gold dollars) and let P_t denote the number of gold dollars that can be exchanged for one greenback dollar at time t (i.e., the gold-to-greenback exchange rate at time t). We impose the following form of interest rate parity between gold and greenback zero-coupon bond prices.

Assumption 4. The gold price of a promise to one greenback dollar at time $t + j$ is:

$$q_t^{(j;d)} = q_t^{(j)} z_t^{(j)} \quad \text{with} \quad z_t^{(j)} := E[P_{t+j} | v_t] = P_t$$

where $z_t^{(j)}$ is a multiplier that converts $(t + j)$ -period greenback dollars to $(t + j)$ -period gold dollars and $v_t := f P_t; G_t g$ is a vector of observables following

$$\begin{aligned} v_{t+1} &= \mu_t + X_t + F v_{t+1} \\ x_{t+1} &= A_t x_t + K v_{t+1} \end{aligned} \quad v_{t+1} \sim N(0; I_2); \quad \mu_t \sim 0$$

where x_t is a hidden state vector, F and K are 2×2 matrices with F being lower triangular, and μ_t and A_t follow drift-less random walks with independent Standard Normal shocks.

Assumption 4 asserts that P_{t+j} is conditionally independent of the pricing kernel implicitly contained in $q_t^{(j)}$ and that all relevant information for forecasting P_{t+j} is contained in observable prices. Since the principal source of variations in the greenback-to-gold dollar exchange rate was most likely default risk due to battle field losses and political sentiments, this assumption can be interpreted as saying that all information relevant for forecasting the financial effects of the war is contained in the greenback-to-gold exchange rate and the price level. Although it is a strong assumption, greenback money issues during the Civil War were closely tied to Union fortunes on the battle field, particularly over a medium term horizon. We also find it convincing that the greenback-to-goods exchange rate tracks the gold yield curve during big Civil War changes.

Table II: Prior Distributions of the Exchange Rate Model

Parameter	Description	Priors	Hyper parameters
μ_0	initial long run mean	$N(\cdot; \Sigma)$	$\mu = [1; 1; 2]^0, \Sigma = [1; 1]^0$
A_0	initial persistence matrix	$N(\cdot; \Sigma)$	$\mu = [0; 9; 0; 0; 0; 0; 0; 9]^0$ $\Sigma = [0; 1; 1; 0; 1; 0; 0; 1]^0$
K	Kalman gain	$N(\cdot; \Sigma)$	$\mu = [0; 0; 3; 0; 0; 0; 0; 0; 3]^0$ $\Sigma = [0; 0; 5; 0; 1; 0; 1; 0; 0; 5]^0$
L_F	Cholesky of correlation Σ_F	LKJ(ν)	$\nu = 2$
Σ_F	forecast error volatilities	Exp(λ)	$\lambda = 20$
	volatilities of ϵ_t shocks	Exp(λ)	$\lambda = 50$
Σ_A	volatilities of A_t shocks	Exp(λ)	$\lambda = 50$
$\Sigma_m^{(i)}$	volatilities of pricing error	Exp(λ)	$\lambda = 0.1$

¹ We decompose the forecast error covariance $\Sigma_F^0 = \Sigma_F \Sigma_F^T$.

Let the parameters of the exchange rate model in Assumption 4 be denoted as θ . Under Assumption 4, we can infer the multiplier $z_t := f z_t^{(i)} g_{j=0}^1$ from prices of greenback bonds and observed exchange rates s_t . The resulting observation equation is

$$p_t^{(i)} = \prod_{t=0}^D q(t; \theta) z(t); m_t^{(i;d)} E + d_t^{(i)} m_t^{(i)} n_t^{(i)}$$

where \cdot is the element-wise (Hadamard) product, $m_t^{(i;d)}$ is a sequence of greenback dollar coupon and principal payments, and $p_t^{(i)}$ and $d_t^{(i)}$ are bond i 's observed period t gold price and Macaulay duration, respectively. To shield our baseline gold yield estimates against the influence of Assumption 4, we estimate the greenback yield curve conditional on gold yields. This gives rise to a two-step procedure. First, we approximate the posterior distribution of the gold yield curve parameters, $f_t g$ and θ , with a (correlated) Gaussian distribution. We treat that distribution as a second-stage prior along with priors for $f_t g$ described in Table II and use prices on greenback dollar bonds and the observed exchange rates to characterize the model's second-stage posterior.

6.3 Revisiting a Civil War Yield Puzzle

Figure VIII shows our estimates of long term greenback denominated yields from 1862-1878. We can see that the greenback yield is systematically below the gold denominated yield. In particular, greenback yields stayed flat at 6% throughout the Civil War reflecting that greenback bonds traded around par. [Friedman and Schwartz \(1963\)](#) (p. 69-70) write that:

The behavior of interest rates in the United States is one of the most interesting

Figure VIII: Greenback Yields

The black line is the median of our posterior estimate for the 10-year gold denominated zero-coupon yield. The green line is the median of our posterior estimate of the 10-year greenback denominated zero-coupon yield. The bands around the posterior medians depict 90% interquartile ranges. The light gray intervals depict financial crises, and the light red interval depicts the Civil War.

features of the Civil War period and has puzzled most of its historians. . . . demand for loan funds must surely have been larger than any private demand that was suppressed by the diversion of resources to war use . . . Yet interest rates were unusually low . . . In our view, this is explained by speculative capital movements induced by the rise in the greenback price of gold.

We can use our estimates to shed light on the hypothesis that anticipations of greenback appreciation kept greenback yields low by inferring how investors' expectations about the greenback-dollar exchange rate evolved during and after the Civil War.²¹ The top plot of Figure IX shows our estimate for the expected Gold/Greenback exchange rate 2 and 10 years into the future at each date. The bottom plot shows the expected appreciation of greenbacks. Throughout the greenback era, we notice that investors anticipated that greenback dollars would eventually trade for gold dollars one-for-one. That kept long term greenback yields low. It is

²¹ Roll (1972) also finds support for this hypothesis when he discusses the 1-year greenback yields during the Civil War.

Figure IX: Nominal Anchor

Top Plot: The black line shows the path of the gold/greenback exchange rate, P_t . The orange line shows the median of our posterior estimate for the expected Gold/Greenback exchange rate 10 years into the future at each date. The blue line shows the median of our posterior estimate for the expected Gold/Greenback exchange rate 2 years into the future at each date. The shaded areas depict the 90% interquantile ranges for our estimate.

Bottom Plots: Solid lines depict the median of our posterior estimates for the expected appreciation (yearly average) of the gold/greenback exchange rate over 2-year (in blue) and 10-year (in orange) horizons. The shaded areas depict the 90% interquantile ranges for our estimate. The period is broken into two subperiods, 1862-1867 and 1866-1879, to make magnitudes more visible. The light gray intervals depict nancial crises, and the light red interval depicts the Civil War.

particularly striking that this was true even during the large drops in the value of the greenback that occurred in 1863 and 1864 in response to bad news from the war front. However, we can also infer many fluctuations in investors' expectations about short term changes in greenback prices. These movements measure how political events affected asset prices. Thus, we infer that the start of the Grant administration in 1869 and the Resumption Act of 1875 coincided with important shifts in investors' expectations, reinforcing commentary by [Calomiris \(1988\)](#), [Mitchell \(1903\)](#), [Mitchell \(1908\)](#), and [Studenski and Krooss \(2003\)](#). We say more about this below.

The years 1865-1869 saw widespread debates about retiring and redeeming greenback dollars. Congress started to retire greenbacks in April 1866 at the urging of Treasury Secretary Hugh McCullough but suspended that policy in February 1868 when the greenbacks became a contested issue in the 1868 presidential election. President Andrew Johnson and much of the Democratic Party wanted to reduce debt servicing costs by redeeming the unit of account from gold to greenbacks. The Republican Party and its candidate, General Ulysses S. Grant, promised to service federal debts in gold dollars. Grant won. Ultimately, the resolution of this uncertainty in 1869 led to an increase in the price of greenbacks, a decrease in expected greenback appreciation, and the closing of the gap between the greenback and gold 10-year yields.²²

Following the banking panic in 1873, the resumption of convertibility stalled again. In 1874, a bill initially legislating specie resumption by January 1, 1876 had mutated into a bill to create additional greenbacks, which President Grant vetoed. With the Resumption Act of January 14, 1875 that Congress reversed course and promised that the Treasury would stand ready to convert greenback dollars into gold dollars one-for-one starting on January 1, 1879. We note that 2-year greenback-gold exchange rate expectations decrease throughout 1874 and 10-year expectations reach their lowest point. This indicates that by the early-1870s investors thought that discrepancies between gold and greenback prices would persist almost indefinitely and so gold and greenback yields converged.

Altogether, our results indicate widespread influences of the public's beliefs about prospective government policies.

7 A short-rate disconnect ?

Recent analysts have posited that the modern US federal debt yield curve exhibits a short-term disconnect, meaning that short term bonds are over-priced by pricing kernels that successfully price bonds at longer maturities.²³ In this section, we use our yield curves to infer that a similar short-rate-disconnect existed during some of the 19th century. We discuss how changes in short-rate-disconnects coincided with changing financial sector regulations.

²² See [Dewey \(1902, Chapter XIV\)](#) for descriptions of these episodes.

²³ For instance, see [Du ee \(1996\)](#), [Greenwood et al. \(2018\)](#), and [Lenel et al. \(2019\)](#).

7.1 Premium on short term bonds

Figure X shows our estimate of the short-rate-disconnect for the period 1800-1933. The pale blue dots depict differences between observed and model-implied yields to maturities for bonds with less than one year to maturity. Because our model was estimated using bonds with maturities greater than 1 year, these dots represent an out-of-sample test at the short end of the yield curve. The solid blue line depicts the 15-year centered moving average of these blue dots. The red solid line depicts the 15-year centered moving average of the difference between model-implied and observed yields-to-maturity for bonds with more than one year to maturity.

Evidently, differences between observed and model-implied yields to maturities average to about zero for bonds with long maturities but are systematically positive for extended periods for bonds close to maturity.²⁴ This means that a pricing kernel that successfully fits maturities greater than 1 year does not also fit maturities less than 1 year. Following the recent literature, we interpret this short rate disconnect as evidence for a premium on short term debt.²⁵ Under this interpretation, until the 1880s, bonds close to maturity traded with a premium in a range of 0.25 to 0.5 percentage points. The premium effectively disappeared from the 1880s until the First World War before reappearing in the 1920s.

7.2 Re-assessing the National Banking Era

The evolution of the short rate disconnect seems to reflect interactions among monetary policies, financial regulations, and US borrowing costs.

1791-1862: Bimetallism, Banks of The US, and State Banks At various times before the Civil War, state legislatures chartered state banks that could issue demand notes backed by combinations of state debts and gold. Initially, the First (1791-1811) and Second (1816-1836) Banks of the United States operated at the national level with the special privileges of acting as the banker for the federal government (depositing tax revenue and making loans) and operating across state boundaries. After President Jackson vetoed rechartering the Second Bank in 1832, some states issued charters to banks without requiring explicit approval from their legislature, an arrangement sometimes called free banking. Some state bank notes carried substantial and volatile discounts relative to gold dollars. The widespread circulation of such notes seems

²⁴As we saw in Figure II the differences also average out within a finer set of maturity bins. We take this as evidence that the short rate disconnect is not driven by the inability of the Nelson and Siegel (1987) parameterization to fit the maturities that we include in our estimation.

²⁵It is well known that Nelson and Siegel (1987) style parameterizations do not fit the short end of the yield curve well. We interpret this as reflecting a premium at the short end. By this, we mean that in a world without a liquidity premium, the parametrization would fit well at both the short and long ends. So, the error or disconnect in the fit of the Nelson and Siegel (1987) parameterization at the short end reflects the liquidity premium. We acknowledge that there are other possible interpretations. However, we believe the tightness of the concentration of errors very close to maturity zero, the systematic positive bias in the errors, and the tight fit away from zero make our interpretation sensible.

Figure X: Short Rate Disconnect

Pale blue dots depict the difference between model-implied and observed yield-to-maturities for bonds with less than one year to maturity. The solid blue line depicts the 15-year centered moving average of these dots excluding yield errors with a magnitude greater than 4 (to handle potential outliers from data issues). The red solid line depicts the 15-year centered moving average of the difference between model-implied and observed yield-to-maturities for bonds with more than one year to maturity. The light gray intervals depict recessions, and the light red intervals depict wars.

consistent with the persistent premium we inferred in the first half of the 19th century. Thus, the short rate disconnect was especially large early in the tenure of the Second Bank, which coincided with the Second Bank's attempt to restrict state banks' money creation and credit.

1862-1913: Greenbacks, Gold Standard, and the National Banking System
The outbreak of the Civil War in 1861 strained the Union's monetary and financial systems, provoking Congress to respond. In January 1862, state banks stopped converting their notes into gold dollars (they suspended convertibility). Congress passed four National Banking Acts in 1862, 1863, 1865, and 1866 that established a system of nationally chartered banks and the Office of the Comptroller of the Currency. National banks faced portfolio restrictions²⁶ and were allowed to issue bank notes up to 90% of the minimum of par and market value of qualifying US federal bonds²⁷. These national bank notes were intended to replace state bank notes and form a standardized national currency. Congress imposed a 10% annual tax on state bank notes, which was much larger than the annual tax rate on national bank notes of 1.0% before 1900 and 0.5% after 1900.

Key goals of the National Banking Acts were to increase supplies of liquid assets and to increase financial sector demand for long term US federal debt to help lower borrowing costs. In terms of our framework, the National Banking Acts sought to eliminate a short rate disconnect and decrease long term yields. Figure VI indicates that neither goal was immediately achieved during the 1860s but that by the 1880s both goals had mostly been achieved.

These findings shed light on a long standing puzzle about National Bank note issues. Because yields on eligible treasuries did not consistently fall enough to equal the tax rate on notes outstanding, researchers have argued that there was persistent under-issuance of national bank notes during the National Banking Era (see [Friedman and Schwartz \(1963\)](#), [Cagan \(1965\)](#), [Cagan and Schwartz \(1991\)](#), [Champ et al. \(1994\)](#), [Champ and Wallace \(2003\)](#), [Champ \(2007\)](#), [Calomiris and Mason \(2008\)](#) for discussions and potential resolutions to the puzzle). Our estimates confirm this observation: 2-year and 10-year yields typically exceeded the tax rate. However, as acknowledged by many researchers, because many other forces could have shifted levels of yield curves, comparing yields to the tax rate on note issuance might be a misleading way to infer effects of the National Banking Acts. Our analysis shows that, if we focus on the short rate disconnect rather than the spread relative to the tax rate, then it appears that the National Banking Acts achieved considerable successes after the Treasury began pegging the exchange rate between greenback dollars and gold dollars in January 1879. This timing indicates that parity between greenbacks and gold helped the National Banking Acts to work as intended,

²⁶National banks could only operate one branch. They were restricted from making mortgages unless they were operating in rural areas, where they could make a limited range of loans collateralized by agricultural land.

²⁷Technically, national banks could issue bank notes for circulation according to the following rules. Banks had to deposit certain classes of US Treasury bonds as collateral for note issuance. Permissible bonds were US federal registered bonds bearing coupons of 5% or more. Deposited bonds had to be at least one-third of the bank's capital (not less than \$30,000). Banks could issue bank notes up to an amount of 90% of the maximum of the market value of the bonds and the par value of the bonds. The 90% value was changed to 100% in 1900.

which in turn suggests that bank note issuance had initially been restrained by risks associated with currency devaluation, as hypothesized by [Cagan \(1965\)](#).

1913-1933: The Federal Reserve System The Federal Reserve System (Fed) was created in 1913 to act as a reserve money creator of last resort. Figure X shows that a short-rate-disconnect reemerged soon after the Fed's creation, increasing sharply from around 0 to 0.5 percentage points in 1920. This likely reflects changes in how the Fed managed the market for Certificates of Indebtedness interest-bearing securities with less than 1 year maturity since most of the blue dots that we see in Figure X during the Fed era correspond to these Certificates.

During World War I, the US Treasury used Certificates of Indebtedness to smooth the mismatch between quarterly tax receipts and the Liberty Bonds' irregular coupon and principal payments. Before 1920, these Certificates did not have a secondary market, but the Fed provided liquidity for banks via discount window lending secured by Certificates. However, after 1920, the New York Fed decided to create a secondary market for Certificates, which increased their liquidity relative to other government bonds. [Garbade \(2012, chapter 13\)](#) describes three innovations the New York Fed used to implement this change: (i) the Fed began raising discount rates enough to induce the Treasury to let certificates be traded below par, (ii) they extended credit to banks and dealers via repurchase agreements (repos) secured by certificates, and (iii) they offered a service for wire transfers of certificates.²⁸

Large variations in short rate disconnects across the different regulatory regimes opens the possibility of interpreting them as intended outcomes of regulatory changes.

8 Concluding Remarks

In three reports, 34 year old Alexander Hamilton advocated a project to improve the fiscal space of the federal government. His project sought to buffer medium-frequency government expenditure surges by sustaining a reputation for timely debt service (1790 Report on the Public Credit); to foster a stable bimetallic national currency (1791 Report on the Establishment of a Mint); and to help finance high-frequency government expenditure fluctuations by chartering a monopoly federal bank (1790 Report on the National Bank). We have inferred patterns in US federal debt financing costs from 1791 to 1933 that shed light on the long process of carrying out Hamilton's plan.

From 1790-1829 a sequence of actions unfolded that were designed to implement Hamilton's project. The federal government restructured Revolutionary War IOUs, established a gold dollar, restricted the states' ability to issue paper currency, and introduced the First and Second Banks of the United States to serve as fiscal agent of the federal government and to regulate state banks' creation of money and credit. We have described how these reforms reduced the spread

²⁸The US Treasury started issuing zero-coupon Treasury Bills in 1929.

between US and UK yields by the 1820s, indicating that federal policymakers seem to have fostered an improved reputation for servicing federal debts.

But these temporary achievements did not endure. Following political struggles about the role of the Second Bank of the US, Andrew Jackson's 1832 veto of a bill to recharter the Second Bank, and a series of state-level defaults during the 1840s, spreads between US and UK gold denominated yields returned to 1790s levels and then eventually rose well above 1790s levels during the Civil War. Facing high borrowing costs in 1861 and 1862, the Union government issued non-convertible greenback dollars. Although greenbacks rapidly depreciated relative to gold dollars, we infer that long run expectations of an appreciating greenback that served as a heavy nominal anchor allowed the Union to issue greenback paying bonds at low greenback-denominated yields throughout the Civil War.

Difficulties in financing the Civil War persuaded the Union to restart the Hamiltonian project by establishing the National Banking System (1862-6) and implementing gold dollar-greenback dollar parity after January 1, 1879. Our estimates of a short rate disconnect constitute indirect evidence about how those policies affected the demand for long term debt. We find that the money-like premium on short term government debt declined substantially in the 1880s and stayed relatively low until after World War I. During the 1880s, US yields again approach UK yields. Although US yields again temporarily rose above UK yields in the 1890s, by the turn of the 20th century, US yields were well below UK yields, portending the emergence of US debt as a global safe asset. Thus, by the late 19th century most of Hamilton's project had been completed.

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A Data Appendix

Here we provide details about how the data sets were constructed. We first outline which bonds are included and excluded in the different estimation exercises. We then describe the assumptions made in constructing the cash flow series. Finally, we discuss the recession bands that we use. Some of these points have already been referenced in the main text, but we collect the assumptions here for completeness.

A.1 Summary of Data Sources

We combined existing historical databases with transcription from the digital archives of newspapers and government reports. Table III summarizes the different data sources that we have used throughout the paper. The data set for bond prices and quantities is available at the Github repository <https://github.com/jepayne/US-Federal-Debt-Public> and construction methods are explained in [Hall et al. \(2018\)](#).²⁹ In this subsection of the appendix, we spotlight decisions about our data that we made to prepare for the statistical inferences presented in this paper.

Our bond price data are monthly. When available, we use the closing price at the end of each month. However, if a closing price is not available, then we use an average of high and low prices or an average of bid and ask prices. The sources for the price data from 1776 to 1839 are Global Financial Data, [Razaghian \(2002\)](#), and [Sylla et al. \(2006\)](#). Prices from 1840 to 1859 are from [Razaghian \(2002\)](#), The New York Times, and Global Financial Data. Prices from 1860 to 1925 are from the Commercial and Financial Chronicle, Global Financial Data, [Martin \(1886\)](#), Merchants' Magazine and Commercial Review, the New York Times, and US Treasury Circulars. When overlaps occurred, data were taken from the US Treasury Circulars. Prices from 1919 to 1925 are from United States Govt. Bonds tables in the New York Times. Prices after 1925 are taken from the CRSP US Treasury Database³⁰. Data on contractually promised dollar payments come from [Bayley \(1882\)](#) for the period from 1790-1871 and from [U.S. Department of the Treasury \(2015\)](#) Monthly Statements of the Public Debt for the period from 1872-1960.

The quantity data are quarterly from 1776 to 1871 and monthly thereafter. All quantity entries record the quantity outstanding on the last business day of the period. The quantities outstanding from 1790 to 1871 are imputed from the issue and redemption series reported by [Bayley \(1882\)](#). We cross-checked these quantities against the quantity outstanding series reported in [Register's Office \(1886\)](#). After 1871 our source for quantity outstanding series is the [U.S. Department of the Treasury \(2015\)](#) Monthly Statements of the Public Debt. The call data are from Annual Reports of the Secretary of Treasury for various years. Data on Treasury

²⁹ Only data from publicly available data sets are posted on the GitHub page.

³⁰ See <http://www.crsp.com/products/research-products/crsp-us-treasury-database>.

securities held in government accounts are from Banking and Monetary Statistics 1914-1941 prior to 1941 and from Treasury Bulletin thereafter.³¹

We require data on greenback-gold dollar exchange rates to estimate the greenback and real yield curves. For the gold-to-greenback exchange rate, we use Greenback price data from [Mitchell \(1908\)](#)³² for the period from 1862-1878 during which greenbacks and gold dollars both circulated. For the gold-to-goods exchange rate, we combine several series. For the period from 1800-1860, we use the wholesale price index from [Warren et al. \(1932\)](#). For the period from 1860-1913, we use the General Price Level Index from the NBER Macroeconomics Database³³. For the period from 1913-2020, we use the Consumer Price Index from the U.S. Bureau of Labor Statistics. Finally, we use the GDP series from [Ocer and Williamson \(2021\)](#).

A.2 Exclusion of Bonds

The estimation of the state space model of gold bond prices defined in Section 3.1 excludes all bonds that paid coupons and/or principals in any denomination other than gold. It also excludes short term Treasury notes that the US issued during the War of 1812. [Bayley \(1882\)](#) lists these notes as the Treasury Notes of 1812, Treasury Notes of 1813, Treasury Notes of March 1814, Treasury Notes of December 1814, and the Small Treasury Notes of 1815. These notes were used for payments well after their earliest redemption date and so probably earned a convenience yield. It also excludes the Panama Canal bonds, which we were not able to price consistently with the rest of the bonds, suggesting that they have a different pricing kernel.

For the estimation of the non-linear state space model of greenback bonds defined in Section 6.2 we exclude the following bonds, which [Bayley \(1882\)](#) documents had ambiguous denominations for the repayment of the principal: the Five-Twenties of March 1864, the Five-Twenties of June 1864, the Five-Twenties of 1865, the Consols of 1865, the Consols of 1867, and the Consols of 1868.

A.3 Construction of cash-flows

In order to estimate the yield curve, we need to construct the currency flows promised by each bond. For many of the early bonds in the sample, both the coupon dates and the maturity date have ambiguity because the bond information is imprecise and because it unclear whether newspaper prices are ex or cum dividend. For the coupon dates, we used the following rule. If [Bayley \(1882\)](#) lists exact coupon dates, then we use those dates. Otherwise, we identify the coupon dates from cyclical decreases in the price series at the frequency of coupon payment. We interpret these decreases as the price impact of the coupon payment.

For the maturity dates, we used the following rules. For bonds with an explicit maturity

³¹ See [Board of Governors of the Federal Reserve System \(1943\)](#) and [Register's Office \(1886\)](#).

³² See Table 2

³³ See <https://www.nber.org/research/data/nber-macrohistory-iv-prices>

Table III: Summary of Data Sources

Series	Period	Frequency	Source
Bond prices	1776-1839	M	Razaghian (2002) , Sylla et al. (2006) and <i>Global Financial Data</i> .
	1840-1859	M	Razaghian (2002) , <i>The New York Times</i> , and <i>Global Financial Data</i>
	1860-1925	M	<i>Commercial & Financial Chronicle</i> , <i>Global Financial Data</i> , <i>Merchant's Magazine</i> , <i>The New York Times</i> , <i>US Treasury Circulars</i> , and Martin (1886) .
	1925-1960	M	<i>CRSP US Treasury Database</i> .
Quantities	1790-1871	Q	Bayley (1882) .
	1872-1960	M	U.S. Department of the Treasury (2015) .
Contract Info.	1790-1960		1790-1871 from Bayley (1882) . 1872-1960 from U.S. Department of the Treasury (2015) .
Gold/Goods	1800-1860	M	Wholesale Price Index (Warren/Pearson)
Exchange Rate	1860-1913	M	U.S. Index of the General Price Level (NBER Macrohistory: Series NBER 04051)
	1913-2020	M	CPI (BLS)
GDP	1790-2020	A	Officer and Williamson (2021)
Gold/Greenbacks	1862-1878	M	Yale SOM ICF dataset
Exchange Rate			

¹ Repository for bond time series: <https://github.com/jepayne/US-Federal-Debt-Public>

date, we set the maturity to that date. For the three Hamilton bonds (which [Bayley \(1882\)](#) lists as *Six Per Cent Stock of 1791*, *Deferred Six Per Cent Stock of 1791*, and the *Three Per Cent Stock of 1791*), which were issued as annuities but ultimately redeemed early, we impose that investors had perfect foresight about the early redemption and set the maturity date to be the date at which greater than 90% of the outstanding bonds had been redeemed. For bonds with a redemption window, we calculate the minimum of the date at which 90% of the outstanding bonds had been redeemed and date at which the bonds started to trade at par value. We then set the maturity date to be the closest coupon payment date to that minimum calculation. For bonds that converted into different bonds, we set the maturity date to be the maturity of the bond into which it is converted.

A.4 CONSTRUCTION OF RECESSION BANDS

For the 1796-1914 period we use recession dates from [Davis \(2006\)](#). These are derived solely from the [Davis \(2004\)](#) annual industrial production index. The Davis index incorporates 43 annual series in the manufacturing and mining industries in a manner similar to the Federal Reserve Board's present-day industrial production index. For this reason, we regard it as an improvement over earlier more qualitative approaches of dating pre-World War I business cycles. Since the data used to date peaks and troughs is annual, the methodology is quite simple: A year immediately preceding an absolute decline in the aggregate level of Davis's industrial production index defines a peak, and the last consecutive decline following a peak defines a trough [Davis \(2006\)](#). For the 1915-present period we use recession dates from the NBER.