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A MODEL TO DISTINGUISH CREDIT QUALITY OF LATE 19TH-CENTURY RAILROAD BONDS

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Abstract

This document presents a model for analyzing the credit quality of long-term railroad bonds from the late 19th and early 20th centuries. The aim is to demonstrate that these bonds could be rated and priced according to their issuers' financial strength and priority of claim. The research assembles financial statement and market data to calibrate the model, and the results suggest that the bonds' credit quality was challenging to evaluate, requiring knowledge of the railroad's claims structure and financial ability to cover required payments. The study utilizes regression analysis, with yield as the dependent variable and financial leverage as an independent variable. The analysis shows that investors valued subordinated claims differently from first-tier claims; subordinated bonds generally had higher yields, reflecting their higher default risks. The research concludes that these bonds' rating information was available in real-time before the invention of bond rating agencies such as Moody's in 1909, and thus, judging their credit quality was possible by examining the priority of claim.

INTRODUCTION

The history of interest rates in the United States is complicated by periods during which bonds of unquestioned credit quality weren't actively traded. For the period between the Civil War and WWI, we have mainly relied on Frederick Macaulay's (1938) Basic Yields. These yields are averages of an evolving sample of actively-traded, long-term,high-grade railroad bonds. As helpful as these yields have been, they are deficient. As Thies (2005) showed, Macaulay's sample includes bonds of heterogenous quality (within the range of "high quality"), and this heterogeneity masks the effect of the Gold Clause on bond yields during the period of Silver Agitation. Specifically, by being more careful in selecting currency bonds and gold bonds, Thies showed that the gold bonds were priced at a premium relative to currency bonds during Silver Agitation. Similar to Macaulay's Basic Yields are David Durand's (1942) Basic Yields. See also Durand (1958) and Durand and Winn (1947). Durand's yields are monotonic envelopes of the yields of all actively-traded bonds arranged by term to maturity. These yields give an approximate idea of the slope of the yield curve. But, to suppose the Durand Basic Yields are precise

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measurements enabling, e.g., the inference of forward interest rates, would be a mistake (Durand, 1958, pp. 349-353).

In particular, Durand over-smoothed the yield curve, emasculating any humped yield curves during his study period. Despite Durand's warning, researchers have relied on his yields. Reuben Kessel (1971, p. 366) said, "Before the 1930s, judging by Durand's data, liquidity premiums were much smaller or nonexistent." David Meiselman (1962, p. 3) merely said, "these measurement problems … introduce some lack of precision." Thomas Sargent (1972, p. 94f) recognized that "the use of Durand's data, which are subject to substantial error, constitutes an important limitation on the confidence with which the empirical results of this study, and the host of other studies that have used those data, can be viewed."

By the 1970s, techniques were developed for inferring the term structure of interest rates from the market prices of U.S. Treasury securities. Stephen Schaefer (1973) recognized the forward interest rates of the term structure to be the shadow prices of a linear programming problem. Willard Carleton and Ian Cooper (1976) estimated the term structure via a bootstrap method. Both took advantage of the fact that, by the 1970s, Treasury securities spanned the time horizon.

Huston McCulloch (1971) took a radically different approach, inferring the term structure from the estimated coefficients of a regression in which the y-variable is the bond price and the x-variables are formed from the coupon and principal payments. See also McCulloch (1975a, 1976b). His approach uses spline curve econometrics which imposes smoothness onto the term structure. Smoothing thus resolves the term structure in places where it is over-identified and interpolates between locations where the term structure is under-identified. Other than being smooth, the estimated term structure is form free.

McCulloch (1971) used his technique to estimate the term structure from highly-rated railroad bonds from the interwar period. Thies (1985) extended McColloch's technique to use the data of all railroad bonds rated BBB or higher, as well as Treasury securities, to estimate several roughly-parallel term structures by credit quality during the interwar period. These newly-estimated interwar term structures behaved similarly to post-war term structures. In particular, the newly-estimated interwar term structures were humped just before business cycle peaks, and their risk spreads reflected Robert Merton's (1974) model. Term structure research has subsequently explored how the term structure might be represented parsimoniously, without imposing monotonicity, e.g., Baum and Thies (1992).

Later during the 1970s, Milton Friedman (1977) considered that the entire term structure might affect the demand for money not merely a single, short-term interest rate. He and Anna J. Schwartz (1982) incorporated a small set of parameters summarizing the term structure into a demand for money regression covering 1873-1975. For the earlier part of this period, Friedman and Schwartz used Macaulay's data on individual bonds plus bonds dropped by Macaulay because they fell less than ten years to maturity. This gave Friedman and Schwartz an essentially complete span of bonds by term to maturity without having to rate bonds.

Over the entire 103-year period of their study, Friedman and Schwartz obtained satisfactory results in their estimation of the impact of the term structure on demand for money. Heller and Khan (1979), who examined the post-WWII period, also obtained satisfactory results. But, during the 1920-1938, the results obtained with the Friedman and Schwartz data weren't acceptable. In contrast, results obtained using Thies' data performed well (Baum and Thies, 1989, pp. 495-97). As there is continuing interest in vintage financial markets, the work involved in rating bonds may be necessary.

THE RAILROAD BOND MARKET OF THE LATE 19TH CENTURY

The financial markets of the 19th Century were quite dynamic. At the start of the century, trading was mostly limited to U.S. Treasury securities, the Bank of the United States stock, and a handful of statechartered banks. Trading subsequently expanded to state and municipal bonds, the securities of the canal and turnpike companies, and, as the century progressed, those of steam railroads, street railways, other public utilities, manufacturers, and other "industrial" corporations. When Macaulay began tracking "high grade" railroad bonds in 1857, their yields were significantly higher than those of U.S. Treasury securities and Massachusetts state and municipal bonds. Within a few decades, the yields of high-grade railroad bonds were among the lowest.

With the country's wiring by telegraph, trading started to be concentrated in New York City. With the standardization of accounting and the emergence of auditing firms, accounting statements came to be reliable sources of financial information. An independent financial press became a source of statistics, news, and even rumors concerning corporations and their principal owners. In 1866, the *Commercial and Financial Chronicle*, a weekly newspaper, commenced publishing. In 1868, Henry V. Poor and his son published the first volume of *Poor's Manual of Railroads*. This manual was a compendium of financial statement data, operating statistics, physical descriptions of the road and equipment of railroad companies, and the claims structure of the company's securities. And in 1909, *Moody's Manual of Railroads*, a rival investment manual, included ratings of these securities.

At the same time, enormous changes were occurring within the railroad industry itself. These changes included waves of bankruptcy and reorganization, consolidations, adoption of standard gauge and conventions for the interchange of cars, attempts to set railroad rates through pools, and the promotion of western railroads through land grants and loan guarantees. Some state railroad authorities required the publication of statistics, and others embarked on rate of return regulation. In 1887, the Interstate Commerce Act was passed, giving an agency of the federal government power over shipping rates.

With these and other changes, it is a challenge to develop a model capable of distinguishing railroad bonds by credit quality, not to speak of the enormous task of compiling the requisite data.

A PROTOTYPICAL LATE 19TH-CENTURY RAILROAD

This study's financial analysis of late 19th and early 20th Century railroads focuses on identifying the priorities of the claim of the intricate pattern of securities issued or assumed by them. Usually, one to three tiers of claim are adequate to describe a road's claims structure, but sometimes four or five are necessary to do a good job.

Consider a case involving three tiers:

- First-tier – First mortgage bonds secured by the main line and equipment trust bonds.
- Second tier – Second mortgage bonds secured by the main line; first mortgage bonds secured by the more critical branch lines.
- Third tier – Third and inferior mortgage bonds secured by the main line; second and inferior mortgage bonds secured by the more important branch lines; first and inferior mortgage bonds securing by the less important branch lines; and, debentures.

In practice, some judgment is required to assign bonds to tiers. The Chesapeake & Ohio Railway of 1889 will serve as an illustration. As of that year, the Chesapeake & Ohio Railway included a main line from Old Point Comfort via Newport News, Virginia, to Big Sandy, West Virginia. It also had a significant branch line from Richmond via Lynchburg to Clifton Forge, Virginia. Together with lesser branch lines, the railway totaled 928 miles. Its bonded debt is shown in Table 1. In this case, the 1st 6s of 1908 (presented in the second line in the table) is treated as a first mortgage on the main line of the road (and, therefore, as part of the railway's first tier of claims), because of the relatively small amount outstanding of the Purchase Money 6s of 1898 (presented in the first line of the table).

TABLE 1 BONDED DEBT OF THE CHESAPEAKE & OHIO RAILWAY, 1889

(Outstanding amounts in thousands).

	Issued	Outstanding	Security
Purchase Money 6s 1898	1878	2,287	1st--504 miles (main line)
1st 6s 1908	1878	2,000	2nd--504 miles (main line)
Peninsula Ext 6s 1911	1881	2,000	1st--8 miles (main line)
Terminal 6s 1922	1882	142	Terminal
1st R&D Div 4s 1989	1889	5,000	1st--233 miles (branch line)

2nd R&D Div 4s 1989	1889	1,000	2nd--233 miles (branch line)
Elevator 4s 1939	1889	820	Elevator
cons 5s 1939	1889	19,768	3rd—504 miles and 2nd–12 miles
New River Br 6s 1898	1889	170	Bridge
equipment trusts	NA	686	Equipment

Given a bond's priority of claim, the quality of the bond is presumably a function of the railroad company's ability to cover the required payments on its securities. If (a) absolute priority of claim is presumed, (b) financial markets extrapolate any change in earnings into the indefinite future, (c) all bonds are traded as perpetuities, (d) the subjective distribution of earnings is a uniform distribution on [A, B], and (e) investors are risk-neutral, then:

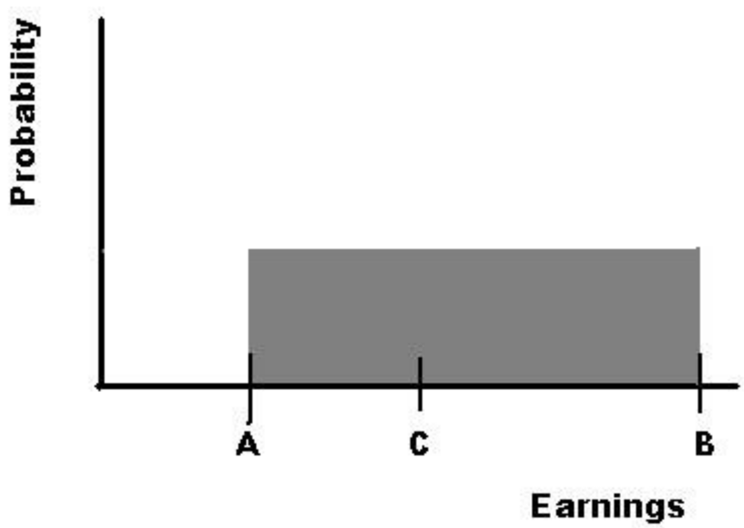
FIRST MORTGAGE BONDS

For bonds not junior to other bonds, the probability that earnings will fall below the amount C, where C is the required interest on these bonds, is

Pr(earnings fall below C) = (C – A) / (B – A) (1)

This relationship can be seen in Figure 1:

FIGURE 1 PROBABILITY THAT EARNINGS FALL BELOW REQUIRED PAYMENTS ON DEBT FIRST MORTGAGE BONDS



If earnings are less than C, the expected loss will be:

E(loss if earnings are less than C) = ½ (C – A) (2)

The first two relationships, (1) and (2), imply that the probable loss = ½ (C – A) (C – A) / (B – A), and that yield would have to be higher by this amount to be equivalent to the risk-free interest rate.

In terms of a regression equation, Y = □+ □X, where Y is yield, □ is the risk-free rate, □ is ½ (C – A), and X is (C – A) / (B – A), a kind of coverage ratio. Specifically, it's a marginal coverage ratio, the ratio of interest expense to earnings above a safe amount.

JUNIOR BONDS

For bonds that are junior to other bonds, the probability that earnings will fall below the amount D, where D is the required interest on the senior bonds, is

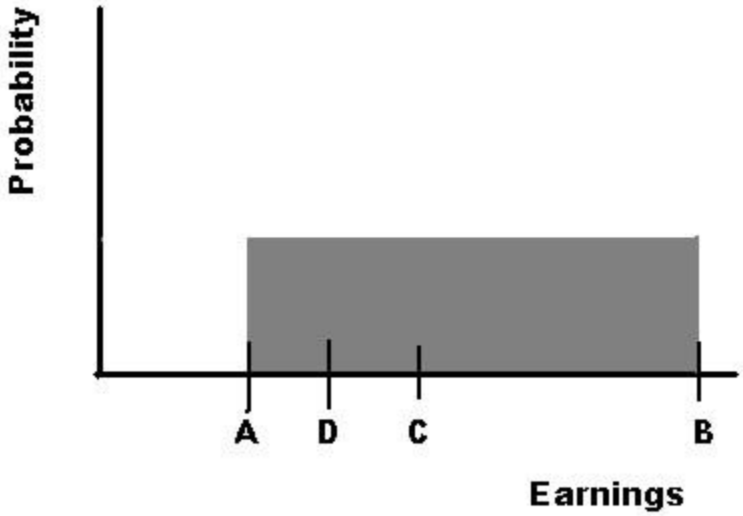
Pr(earnings being less than D) = (D – A) / (B – A) (3)

And the probability that earnings will fall above amount D and below amount C, is

Pr(earnings being between D and C) = (C – D) / (B – A) (4)

These two relations, (3) and (4), can be seen in Figure 2.

FIGURE 2 PROBABILITY THAT EARNINGS FALL BELOW REQUIRED PAYMENTS ON DEBT JUNIOR BONDS



If earnings are less than D, the expected loss will be total (i.e., the junior bonds will be wiped-out):

E(loss if earnings are less than D) = C (5)

If earnings are between D and C, the loss will be:

E(loss if earning are between D and C) = ½ (C – D) (6)

These relations imply that the probable loss will be C (D – A) / (B - A) + ½ (C – D) (C – D) / (B – A) so that yield would have to be higher by this amount to be equivalent to the risk-free rate of interest.

In terms of a regression equation, $Y = \square + \square_1 X_1 + \square_2 X_2$, where Y is yield, □ is the risk-free rate, $\square_1$ is C, $\square_2$ is ½ (C – D), X_1 is (D – A) / (B – A) and X_2 is (C - D) / (B – A); where, X_1 and X_2 are marginal coverage ratios; X_1 the excess of prior claims above the risk-free level of interest; and, X_2 the excess of claims of this bond's tier of claims over X_1, such a regression equation might be appropriate for a sample of bonds homogeneous except for their priority of claim. Bonds differ in many ways.

SOME REGRESSION RESULTS

Tables 2 and 3 present regression results for each of the years 1886 to 1893.

TABLE 1 RAILROAD BOND YIELDS, REGRESSION RESULTS, 1886-1889

	1886		1887		1888		1889	
Constant	4.32%	*	4.31%	*	4.51%	*	4.02%	*
Prior interest / Operating Income	2.44%	*	2.69%	*	2.26%	*	2.17%	*
Own Interest / Operating Income	1.39%	*	1.50%	*	1.31%	*	1.31%	*
Subord. Interest / Operating Income			0.06%				0.28%	*
Region 2 (Mid North)	-0.08%		0.23%	*	0.14%	*	0.26%	*
Region 3 (North West)	-0.08%		0.14%	*	-0.05%		0.18%	*
Region 4 (Pacific North)	1.65%	*	1.52%	*	0.99%	*	0.96%	*
Region 5 (South East)	0.43%	*	0.36%	*	0.65%	*	1.06%	*
Region 6 (Mid South)	0.38%	*	0.25%	*	0.53%	*	0.78%	*
Region 7 (South West)	0.79%	*	0.88%	*	0.63%	*	0.77%	*
Region 8 (Pacific South)	0.08%		0.26%	*	0.16%	*	0.02%	
Registered Bond	-0.38%	*	-0.39%	*	-0.36%	*	-0.20%	*
Not NY Stock Exchange	-0.18%	*	-0.10%	*	-0.05%	*	-0.04%	
Gold Bond	-0.12%	*	-0.12%	*	-0.09%	*	-0.13%	*
Small Issuer	0.95%	*	0.50%	*	0.48%	*	0.46%	*

Freight / Revenue	-0.32% *	0.25% *	0.00%	0.65% *
Callable-at the money	0.15%	0.10%	0.31% *	0.17% *
Callable-in the money	0.65% *	0.75% *	0.57% *	0.89% *
R^2	42.4%	43.5%	41.0%	37.9%
N	2,932	3,142	3,721	3,725

*significant at the (two-tailed) 5 percent level

Concerning dummy variables, the excluded case is a bond issued by a railroad operating in the North East region, that is a Coupon Bond traded on the New York Stock Exchange, that is a Currency Bond, and either isn't Callable, or its Call Feature is Out-of-the-Money.

Small Issuer = 1 if Revenue is less than \$2 million and linearly falls to zero as Revenue increases to \$4 million

Freight/Revenue = 0 if less than 80% and linearly rises to 1 as this ratio increases to 90%

TABLE 3 RAILROAD BOND YIELDS, REGRESSION RESULTS, 1890-1893

	1890	1891	1892	1893
Constant	4.15% *	4.04% *	4.38% *	4.18% *
Prior interest / Operating Income	1.46% *	1.90% *	3.84% *	3.47% *
Own Interest / Operating Income	0.99% *	1.43% *	1.93% *	1.75% *
Subord. Interest / Operating Income	0.30% *	0.32% *	0.11%	0.47% *
Region 2 (Mid North)	0.27% *	0.34% *	0.18% *	0.34% *
Region 3 (North West)	0.20% *	0.19% *	0.20% *	0.34% *
Region 4 (Pacific North)	0.83% *	1.38% *	1.57% *	1.87% *
Region 5 (South East)	1.10% *	1.09% *	1.33% *	0.88% *
Region 6 (Mid South)	0.73% *	0.84% *	1.22% *	1.43% *
Region 7 (South West)	0.84% *	1.00% *	1.18% *	1.49% *
Region 8 (Pacific South)	0.07%	0.24% *	0.33% *	1.30% *
Registered Bond	-0.24% *	-0.25% *	-0.24% *	-0.22% *
Not NY Stock Exchange	-0.16% *	-0.12% *	-0.08% *	0.10% *
Gold Bond	-0.09% *	-0.17% *	-0.15% *	-0.44% *
Small Issuer	0.38% *	0.36% *	0.41% *	0.73% *
	1890	1891	1892	1893
Freight / Revenue	0.33% *	0.32% *	-0.03%	0.50% *
Callable-at the money	-0.14% *	0.03%	0.22% *	-0.22% *
Callable-in the money	0.90% *	1.13% *	0.90% *	0.72% *
R^2	40.6%	46.2%	50.8%	46.7%
N	3,841	3,889	4,015	2,999

See footnotes to Table 2.

The samples of bonds used to test the model are all bonds meeting the following criteria:

- The bond had to have at least eight years remaining term to maturity.
- That month, the bond had to be traded in either the Baltimore, Boston, Cincinnati, New York or Philadelphia stock exchange.
- The bond had to be traded on that exchange in at least two of the prior twelve months.
- The company issuing the bond was not in receivership in either the current or prior year.
- The company had to have an average coverage ratio (expressed as interest expense/operating income) for the current and prior years of no worse than 1.5.

- The bond was a straight bond, i.e., neither an income bond nor a convertible bond nor a rising rate bond.
- If the bond was guaranteed, it had to be traded mostly based on its creditworthiness, not much on the credit enhancement provided by the guarantee.

For all actively traded bonds, financial statements for their railroads were abstracted from *Poor's Manual* or else *The Commercial & Financial Chronicle* for seven-year periods overlapping by one year; i.e., 1883-1889, 1889-1895, etc. These data are used for the calculation of coverage ratios and other purposes.

DISCUSSION

The constant in the regression for 1886, 4.32 percent, is an estimate of the default-risk-free interest rate for that year. The default-risk free interest rate estimates drifted down during the years thus far analyzed. These findings roughly accord with prior estimates of high-grade bond yields during this time.

The parameters representing the impact of financial leverage on a bond's yield are well-defined and relatively stable over the years thus far analyzed. Following the model, $\square_1 > \square_2 > 0$. Not only does the use of financial leverage raise yield, but the subordination of some bonds to others further raises yield for the subordinated bonds. The point estimate of the coefficient of interest on subordinated claims in the regression for the year 1886 was negative, and thus constrained to zero. However, this estimate has become positive and significant over the years thus far analyzed, although still modest in size. This trend may reflect the degradation of the absolute priority of claim upon the innovation of equity receivership and the treatment of railroads as public utilities. The degradation of the absolute importance of the claim enabled by the data accumulated in this study should be a focus of future research.

Regional interest rate differentials are moderately significant in the three southern regions, and dichotomous in the areas of Pacific coast. The south regional interest rate differentials continue into the early 1900s, while the Pacific coast regional differentials appear to dissipate by the early 1900s. The evolution of regional interest differentiations enabled by the data accumulated in this study should also be a focus of future research.

Gold Bonds sold at a modest premium (or lower yield) compared to currency bonds in 1886. This premium became substantial in 1893 and then quickly went away. These findings accord with prior estimates of the course of the gold premium during this time.

The model's performance suggests that financial statement data can play a role in rating late 19th century railroad bonds. However, these regressions reveal several conceptual problems. Should bonds of similar financial strength in terms of coverage and priority of claim be segregated by region if there are significant regional interest rate differentials? Likewise, should bonds of similar financial strength that differ by media of payment (gold versus currency bonds) be segregated, and should bonds issued by small railroads be segregated from bonds issued by large railroads? The answer to these questions may be deferred for the moment but will have to be addressed before this work is completed.

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