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Pricing free bank notes☆

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Abstract

During the pre-Civil War period, US banks issued distinct private monies, called bank notes. A bank note is a perpetual, risky, non-interest-bearing, debt claim with the right to redeem on demand at par in specie. This paper investigates the pricing of this private money taking into account the enormous changes in technology during the period, namely, the introduction and rapid diffusion of the railroad. A contingent claims pricing model for bank notes is proposed and tested using monthly bank note prices for all banks in North America together with indices of the durations and costs of trips back to issuing banks constructed from pre-Civil War travelers' guides. Evidence is produced that market participants properly priced the risks inherent in these securities, suggesting that wildcat banking was not common because of market discipline.

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1. Introduction

In this paper I study the pricing of private money issued by banks prior to the Civil War. These bank notes were perpetual, risky, non-interest-bearing, debt claims with the right to redeem on demand at par in specie. Between 1838 and 1863, the Free Banking Era, thousands of different bank notes circulated, constituting the overwhelming bulk of the securities market during this period. Taking account of the redemption option, I show how the value of these private money contracts depends on state-specific risk factors and on the technological ability of market participants to travel back to issuing banks to redeem notes. The pricing model is then tested to determine whether note prices reflect these factors.

Private money contracts have traditionally been viewed as very difficult to enforce. The basic critique of private money issuance has been articulated by Milton Friedman (1959):

> … the contracts in question are peculiarly difficult to enforce and fraud peculiarly difficult to prevent… individuals may be led to enter into contracts with persons far removed in space and acquaintance, and a long period may elapse between the issue of a promise and the demand for its fulfillment...A fiduciary currency ostensibly convertible into the monetary commodity is therefore likely to be overissued from time to time and convertibility impossible. Historically, this is what happened under so-called 'free banking' in the United States and under similar circumstances in other countries. (p. 6)

Friedman is referring to 'wildcat banks', banks that opened and then inflated their currency to the point where it could not be continuously redeemed.[1] The banker then absconded with the proceeds, leaving the private money worth less than par. The result was, possibly large, losses to the note holders. Indeed, examining the American Free Banking period, Cagan (1963) estimated that note holders suffered losses on their note holdings of 25% per year. According to Rockoff (1975) losses on notes ranged from 7 cents on the dollar in Indiana to 63 cents per dollar in Minnesota.[2] On the other hand, Rockoff (1971, 1974a, 1974b, 1975, 1989) argues that wildcat banking appears to characterize the experiences of only some states. Rolnick and Weber (1982, 1983, 1984) examined the timing of bank closings in four free bank states (Minnesota, Indiana, Wisconsin and New York), arguing that free bank failures and losses were not due to systematic wildcat banking, but to recessions.

[1] Friedman has apparently changed his views. See Friedman (1986,1987) and Friedman and Schwartz (1986).

[2] Knox (1903, p. 315) estimates the losses to note holders to have been 'about 5% per annum'.

The consensus seems to be that wildcat banking was not a prevalent feature of the ante bellum banking system. This view is based on an examination of *ex post* evidence concerning the incidence of bank failures and losses across different state banking systems. Using price data, I focus on the question of whether market participants priced the risk of bank notes *ex ante*. The idea is the familiar one that market participants may well have understood the risks inherent in private money and priced them correctly. This is important for addressing the question of *why* there was so little wildcat banking.

Wildcat banking may have been prevented because private institutional arrangements and state regulations constrained banks effectively. Another important consideration is the design of the bank note contract. Given the constraints of available data I concentrate on these two issues in analyzing the pricing of bank notes. First, I ask whether bank note prices reflect private institutional and state regulatory factors that independent evidence suggests were important determinants of risk. State banking systems varied in allowing branch banking, in providing state insurance, and in allowing 'free banking' in that entry into banking was less restrictive. (Free banking states required the deposit of state bonds against money issuance. Chartered banking states required a license from the legislature to operate, and imposed reserve and capital requirements.) Also banks in some states were members of formal or informal private bank associations which regulated members.

Secondly, to analyze bank note prices I take account of the redemption option in bank note contracts. This option may have been important in limiting bank risk-taking because it allowed note holders to run on banks which began to increase their risk, for example, by printing money. Pricing this embedded option requires taking account of the fact that to exercise the option a noteholder must return the note to the issuing bank. Returning the note to the issuing bank required using the available transportation technology. Indeed, Friedman's critique appears to be rooted in such considerations of technology; that is, if the bank is too far away then risk-taking cannot be effectively prevented. Others have also argued that the US was so technologically underdeveloped in this period that it was difficult to price the notes. Taylor (1951, p. 312) writes: "As long as transportation and communication were relatively slow and no effective clearing system had developed, mere distance from the centers of commerce was a valuable asset to a bank".

In pre-Civil War America communication and transportation were difficult, but dramatic change did occur. The introduction of the railroad drastically lowered transportation costs as it spread across the country during this period. Introduced in England in the 1820s, the railroad was quickly adopted in the US. Between 1838 and 1860 railroad mileage nationwide increased from about 3,000 miles to over 30,000 miles. (See Fogel (1964) and Fishlow (1965)). Also, starting in 1846, and typically following railroad tracks, the telegraph spread across the country (see Duboff, 1980,1983,1984; Thompson, 1947).

Technological change, in the form of the railroad and the telegraph, eased the cost of note redemption and made information flow much faster. The reductions in travel times were dramatic. For example, between 1836 and 1862 the travel time between Philadelphia and Boston was cut by 65% (to fourteen hours) (see Gorton (1989c)).

The simple note pricing model developed here provides a framework for addressing these issues. The main result of the model is the demonstration that a bank note is equivalent to risky debt with maturity equal to the time it takes to return from the particular location of the note holder to the site of the issuing bank. In that case standard Black and Scholes (1973) option pricing theory can be used to price the bank notes. This model then provides the basis for empirical tests.

To analyze these pricing issues, I use a newly discovered complete set of bank note discounts or prices from a bank note reporter, as explained below. The data consist of monthly bank note prices of over 3,000 banks in the US and Canada traded in the Philadelphia bank note market from February 1839 to December 1858. Also necessary for the analysis, given the technological change in transportation, are time series of measures of the durations and costs of trips from Philadelphia to the locations of these North American banks. Here, such measures are constructed from pre-Civil War travellers' guides.

The paper proceeds as follows. Section 2 discusses the workings of the bank note market, and introduces the data source. Section 3 presents an overview of the data. In Section 4 the note pricing model is explained. The implications of the model are confronted by the data in Section 5. Finally, Section 6 concludes.

2. The bank note market

Prior to the Civil War, banks issued distinct private currencies. Following the demise of the Second Bank of the United States which President Andrew Jackson refused to recharter in 1832, some states followed the lead of New York State which passed the Free Banking Act in 1838. The Act allowed anyone to open a bank, with the restriction that the private money issued by the bank be backed by designated securities deposited with state regulatory authorities.[3]

[3] Free banking laws varied by state but contained some common features. Typically, banks had to back their note issuance with designated state bonds deposited with state banking authorities. Bank notes were printed and registered under the direction of state authorities. Sometimes stockholders faced double liability. Free banking was effectively ended with passage of the National Banking Acts, passed during the Civil War. Further background can be found in Dewey (1910), Hammond (1957), Grant (1857) and Cleaveland (1857).

Banks in chartered banking systems also were allowed to issue private money, but entry was more restricted.[4] I concentrate on the American Free Banking Era, 1838–1863, because of data availability, as described below. Hundreds of distinct private monies, called bank notes, circulated as media of exchange during the period.

Table 1 lists the states which adopted free banking systems and the states which did not adopt free banking, but continued as chartered banking systems. It is important to note that most states that adopted free banking did so in the 1850s. Prior to that time New York is the only example of a state which adopted free banking and which saw many new banks open.

A bank note was a small denomination noninterest-bearing, perpetual, debt obligation of the issuing bank used as a medium of exchange. The note bearer had the right to present the note for redemption at par at the issuing bank at any time.[5] Despite government enforcement of various regulations there was always the possibility of a loss to the bearer of a bank note. The risk of bank failure, and consequent loss to note holders, varied by state for a variety of reasons other than that banks specialized in lending to borrowers with risks specific to their region. For example, bank default probabilities appear to have differed because state regulatory systems, and the degree of enforcement, varied. There was a distinction between free and chartered systems, but also variation within each type of system.

While the focus of previous research has been on the distinction between the type of banking system, free or chartered, banking systems differed in other, perhaps more important, ways. First, some banking systems allowed branching, while others did not. State bank charters limited banks' operations to that state (for their deposit business if not their loan business). Most states also prohibited branch-banking within the state. This seems to have been unfortunate since the branch-banking states (Virginia, North Carolina, South Carolina, Georgia, and Tennessee) appear to have been less prone to panics and bank failure, possibly because of the effects of diversification admitted by branching. Also, branch systems allowed for easy interbank loans in times of emergency (see Schweikart, 1987; Calomiris, 1989; Calomiris and Schweikart, 1988).

A second dimension of state heterogeneity concerns note insurance funds. Some states sponsored insurance funds, while others did not. In general, evidence suggests that banks in states with successful mutual-guarantee or co-insurance systems (Indiana, Iowa and Ohio) fared better than their counterparts in states without insurance. Banks covered by insurance suffered fewer failures

[4] Chartered banking systems were sometimes subject to abuse so that entry into banking was not always difficult. See Chaddock (1910), Hammond (1957, pp. 332–337), Knox (1903, p. 413), Ng (1987) and Sylla (1985).

[5] Note holders were the senior claimants on the bank. (see Breckenridge, 1899).

Table 1
States with and without free banking laws by 1860

States with free banking laws	Year law passed	States without free banking laws
Alabama	1849[b]	Arkansas
Connecticut	1852	California
Florida	1853[b]	Delaware
Georgia	1838[b]	Kentucky
Illinois	1851	Maine
Indiana	1852	Maryland
Iowa	1858[b]	Mississippi
Louisiana	1853	Missouri
Massachusetts	1851[b]	New Hampshire
Michigan	1837[a]	North Carolina
Minnesota[d]	1858	Oregon
New Jersey	1850	Rhode Island
New York	1838	South Carolina
Ohio	1851[c]	Texas
Pennsylvania	1860[b]	Virginia
Tennessee	1852[b]	
Vermont	1851[b]	
Wisconsin	1852	

[a]Michigan prohibited free banking after 1839 and then passed a new free banking law in 1857.
[b]According to Rockoff, very little free banking was done under the laws in these states.
[c]In 1845, Ohio passed a law that provided for the establishment of 'Independent banks' with a bond-secured note issue.
[d]Montana became a state in 1889. The free banking law was passed by a territorial legislature.
Source: Rockoff (1975, pp. 3, 125–130) as compiled by Rolnick and Weber (1983, p. 1082).

and losses and fared better during panics. For example, in Indiana no insured bank failed during the thirty years the fund was in operation. (New York, Vermont and Michigan had less successful insurance systems.) (See Calomiris, 1989).

A third way in which banking systems varied concerns the presence or absence of bank coalitions. The default risk associated with bank debt, in the form of bank notes, appears to have been reduced by organizations of banks which enforced their own restrictions on member bank risk-taking activity. The Suffolk system of New England is the main example of such self-regulation. The Suffolk Bank is often viewed as performing a central bank-like role in providing a clearing system for bank liabilities and concomitantly playing

[6] The Suffolk Bank system was a mechanism for clearing bank notes. Its effectiveness depended on the ability of the Suffolk Bank, a large bank at the center of the system, to control the risk-taking activities of the member banks. See Mullineaux (1987), Dewey (1910), and Whitney (1878). Gorton (1989a) presents a theoretical rationale for such bank coalitions.

a regulatory role with respect to other banks.[6] By the end of the Panic of 1839, for example, only four out of 277 banks in New England outside of Rhode Island suspended convertibility of notes into specie, and they remained solvent. In other areas of the country failure rates were much higher. For example, 13.4% of the banks in Ohio, Illinois and Michigan failed.

The evidence strongly suggests that banks in branched systems, banks covered by well-run state insurance programs, and banks which were members of well-functioning bank coalitions were less prone to fail or suspend convertibility during panics. When failure did occur, banks in these systems had smaller losses. It is not known how these factors interacted with the factor which has received relatively more attention, namely, whether the system was a free or chartered banking system.

3. Bank note reporters and the behavior of bank note prices

Once in circulation notes traded in informal secondary markets operated by note brokers. Note brokers were sometimes banks that quoted prices at which they were willing to buy and sell notes. Also, nonbank firms bought and sold notes, advertising their services in newspapers. Note brokers, often called 'Exchange and Brokers' Offices', gathered information on banks, quoted bid and ask prices, often bought notes at discounts and, possibly, redeemed them at the issuing bank. Note reporters, small newspapers, reported the prices at which notes traded in the secondary markets. Agents offered unfamiliar notes consulted such publications to price the notes and determine their authenticity. Sumner (1896) explains how agents relied on bank note reporters to value notes of distant and unfamiliar banks:

> It is difficult for the modern student to realize that there were hundreds of banks whose notes circulated in any given community. The bank notes were bits of paper recognizable as a specie by shape, color, size and engraved work. Any piece of paper which had these came within the prestige of money; the only thing in the shape of money to which the people were accustomed. The person to whom one of them was offered, if unskilled in trade and banking, had little choice but to take it. A merchant turned to his 'detector'. He scrutinized the worn and dirty scrap for two or three minutes, regarding it as more probably 'good' if it was worn and dirty than if it was clean, because those features were proof of long and successful circulation. He turned it up to the light and looked through it, because it was the custom of the banks to file the notes on slender pins which made holes through them. If there were many such holes the note had been often in the bank and its genuineness ratified.

Table 2
Coverage of Van Court's bank note reporter: states and dates

States with complete coverage, February 1839–December 1858		States with incomplete coverage[c]		States listed as 'uncertain' or not listed
United States	*Canada*	*United States*	*Canada*	
Alabama	Canada[b]	Arkansas	New Brunswick	Iowa territory
Connecticut	Nova Scotia	(1840–58)	(1840–48)	Minnesota
Delaware				Missouri
District of Columbia		Florida		Texas
		(1842–58)		
Georgia				
Kentucky		Illinois		
Louisiana		(July 1856–58)		
Maine				
Maryland		Indiana		
Massachusetts		(1857)		
Montana[a]				
Pennsylvania		Michigan		
New Jersey		(1853)		
New York				
North Carolina		Mississippi		
Ohio		(1839, 1841–43, 1852–58)		
Rhode Island				
South Carolina				
Tennessee		Nebraska		
Vermont		(1840–47)		
		New Hampshire		
		(1857–58)		
		Virginia		
		(1846–47, 1853–54)		
		Wisconsin		
		(1839–55)		

[a] Montana became the 41st state in 1889.
[b] Canada includes banks located in provinces other than Nova Scotia or New Brunswick.
[c] Incomplete coverage means that the Van Court bank Note Reporter did not quote a price for banks in that state that month. The state may have been listed, though, and the notes of banks in that state described as 'all uncertain'. Dates in parentheses indicate periods for which the data was missing.

Such bank note reporters were obtained like other newspapers, by subscription or from a newsstand. Typically, the reporters were printed monthly.[7]

[7] See Dillistin (1949) for a discussion of bank note reporters.

The data used in this study are from *Van Court's Counterfeit Detector and Bank Note List*, a bank note reporter printed in Philadelphia monthly from February 1839 through December 1858. It is a small tabloid which lists discounts on the notes of the banks of twenty nine states and territories and three provinces of Canada. Table 2 lists the coverage dates and localities of the reporter. Further detail on the data is provided by Gorton (1989b).

The prices quoted by *Van Court* are not necessarily transactions prices. *Van Court* never explained exactly where the prices came from and never provided volume data. But, it is not likely that every note for which *Van Court* quoted a price actually traded that month. Since the purpose of the reporter was to provide a price quotation to consumers on every conceivable note which might appear in a transaction, the coverage is extensive. Evidence suggests that the volume of notes circulating with origins outside the local area was sizeable. For example, Knox (1969, p. 368) notes that in 1857 the Suffolk Bank redeemed almost $400 million worth of other banks' notes. He also points out that for many years "Connecticut bank notes had been eagerly sought after for circulation in Ohio, Indiana and other Western States …" (p. 384). These observations are consistent with the sizeable inter-regional trade flows in ante bellum America. Fishlow (1964) presents quantitative evidence on these flows and Lindstrom (1975) specifically discusses Philadelphia.

Not all banks issuing private money during the Free Banking Era are covered by *Van Court*. Comparing Table 1 to Table 2, note that Oregon, Texas, California, and Minnesota were not covered by *Van Court*. Bank notes from these locations, if listed by *Van Court*, were described as of 'uncertain' value. Also, only partial coverage is provided for many locations, such as Canada, Wisconsin, and Montana. It is noteworthy that the locations which are not covered, or for which coverage is partial, are typically locations long distances from Philadelphia. While this is consistent with the notion that distance from Philadelphia back to the issuing bank is important in note pricing, it also suggests that the situation is more complicated. For example, Montana is further away than Minnesota. Yet, Minnesota, generally considered to be an example of a failed free banking state, is never covered. Below these observations about distance will be made more precise.

3.1. Free banking states, chartered banking states

Tables 3 and 4 provide summaries of the data from *Van Court* for two states. The two states, to some extent representative of the variety of state experiences, are Indiana and North Carolina. (Gorton (1989a) contains similar tables for all other locations.) Indiana adopted free banking in 1852. North Carolina was a chartered banking state for the entire period.

The tables list a variety of information about the note discounts, including the 'average modal discount' which is the annual average of the monthly modes. At

Table 3
Summary of Indiana bank note discount data[a]

Year	(1) Mean discount	(2) Standard deviation	(3) Minimum discount	(4) Maximun discount	(5) Average mode[b]	(6) Annual standard deviation of mode[c]	(7) Average modal%[d]	(8) Number of banks[e]	(9) Notes / Total assets	(10) Notes + Deposit / Total assets	(11) Specie / Total assets
1839	4.36	0.861	3.250	5.500	4.364	0.861	100.00	1	0.024	0.101	0.210
1840	4.83	0.389	4.000	5.000	4.833	0.389	100.00	1	0.026	0.083	0.156
1841	7.41	1.062	5.000	9.000	7.417	1.062	100.00	1	0.026	0.099	0.166
1842	21.67	23.800	5.000	70.000	10.417	4.940	87.50	2	0.027	0.076	0.187
1843	19.61	19.680	2.000	60.000	2.773	0.984	50.00	2	0.007	0.048	0.166
1844	10.01	8.640	1.500	22.500	1.688	0.155	50.00	2	0.012	0.055	0.209
1845	9.75	7.953	1.750	17.500	2.000	0.204	50.00	2	0.025	0.080	0.209
1846	7.31	6.422	1.500	17.500	2.125	0.506	50.00	2	0.014	0.082	0.183
1847	4.42	3.151	1.250	7.500	1.333	0.123	50.00	2	0.019	0.088	0.156
1848	4.81	2.762	1.750	7.500	2.125	0.433	50.00	2	0.043	0.137	0.156
1849	4.55	3.016	1.250	7.500	1.604	0.249	50.00	2	0.022	0.106	0.192
1850	4.48	3.089	1.000	7.500	1.458	0.209	50.00	2	0.015	0.111	0.187
1851	4.91	4.478	1.000	20.000	1.271	0.250	50.00	2	0.028	0.028	0.031
1852	9.05	9.363	0.750	20.000	1.313	0.188	48.10	5	0.043	0.129	0.161
1853	1.58	2.065	0.500	20.000	1.230	0.072	80.92	22	0.067	0.173	0.160
1854	6.60	6.251	1.130	15.000	5.105	6.012	99.72	91	0.046	0.159	0.125
1855	19.24	11.130	1.000	50.000	20.667	12.280	51.02	110	0.042	0.147	0.095
1856	26.73	27.980	1.000	80.000	5.000	0.000	33.24	97	0.046	0.198	0.153
1857	–	–	–	–	–	–	–	–	0.044	0.189	0.117
1858	9.70	17.04	5.000	75.000	5.000	–	90.91	33	0.043	1.197	0.163

[a]The missing values do not mean that the bank note reporter did not report the data. Rather, the reporter would list all the bank notes of the state as 'uncertain'.
[b]The average mode is the annual average of the twelve monthly modal discounts.
[c]The annual standard deviation of the mode measures the variation of the monthly modal discounts during the year.
[d]The modal percentage is the percentage of total banks with modal discounts. The average modal percentage is the annual average of the twelve monthly modal percentages.
[e]The number of banks in existence during the year.

Table 4
Summary of North Carolina bank note discount data[a]

Year	(1) Mean discount	(2) Standard deviation	(3) Minimum discount	(4) Maximun discount	(5) Average mode[b]	(6) Annual standard deviation of mode[c]	(7) Average modal%[d]	(8) Number of banks[e]	(9) Notes / Total assets	(10) Notes + Deposit / Total assets	(11) Specie / Total assets
1839	3.24	0.95	2.000	5.000	3.188	0.98	100.00	3	0.021	0.114	0.114
1840	1.88	0.66	1.000	3.000	1.875	0.68	100.00	3	0.035	0.116	0.091
1841	2.33	0.76	1.500	4.000	2.333	0.78	100.00	3	0.036	0.115	0.130
1842	3.96	2.30	2.000	10.000	8.958	2.37	100.00	3	0.054	0.147	0.143
1843	1.88	0.30	1.500	2.500	1.875	0.31	100.00	3	0.045	0.136	0.160
1844	1.27	0.07	1.250	1.500	1.271	0.07	100.00	3	0.035	0.133	0.152
1845	1.46	0.14	1.250	1.750	1.458	0.14	100.00	3	0.047	0.139	0.166
1846	1.78	0.22	1.500	2.250	1.729	0.23	100.00	3	0.061	0.150	0.176
1847	1.40	0.19	1.250	1.750	1.396	0.20	100.00	3	0.046	0.136	0.190
1848	2.08	0.38	1.750	2.750	2.083	0.39	100.00	4	0.039	0.118	0.176
1849	1.73	0.26	1.500	2.250	1.729	0.27	100.00	4	0.037	0.106	0.182
1850	1.35	0.12	1.250	1.500	1.354	0.13	100.00	4	0.050	0.139	0.176
1851	1.38	0.19	1.250	1.750	1.375	0.20	100.00	5	0.051	0.149	0.172
1852	1.34	0.17	1.000	1.500	1.344	0.18	100.00	7	0.051	0.149	0.172
1853	1.00	0.00	1.000	1.000	1.000	0.00	100.00	6	0.037	0.141	0.145
1854	2.64	2.75	1.000	15.000	1.796	0.68	81.98	11	0.043	0.164	0.129
1855	1.95	0.54	1.500	3.000	1.958	0.56	100.00	13	0.029	0.109	0.094
1856	1.38	0.13	1.250	1.500	1.375	0.13	100.00	13	0.022	0.099	0.095
1857	2.70	3.56	1.000	30.000	2.500	2.76	98.08	13	0.024	0.100	0.076
1858	3.43	4.13	1.000	30.000	2.458	1.77	91.78	13	0.026	1.098	0.072

[a]The missing values do not mean that the bank note reporter did not report the data. Rather, the reporter would list all the bank notes of the state as 'uncertain'.
[b]The average mode is the annual average of the twelve monthly modal discounts.
[c]The annual standard deviation of the mode measures the variation of the monthly modal discounts during the year.
[d]The modal percentage is the percentage of total banks with discounts. The average modal percentage is the annual average of the twelve monthly modal percentages.
[e] The number of banks in existence during the year.

each monthly date the bank notes of most banks at each particular distant location are trading at the same discount in Philadelphia. This number is the modal discount for the month. The annual average of the monthly modal discounts is the 'average modal discount'. The column entitled the 'average modal percent' gives the average of the monthly percentages of the total number of banks in that location which had the modal discount. The mean discount is higher than the modal discount because many of the banks with discounts listed by *Van Court* are insolvent.[8] The tables also provide the number of banks in existence each year. The leverage measures, constructed from the 1876 Comptroller of the Currency *Annual Report*, are measures of the annual aggregate leverage of banks in the particular location.

Indiana is often viewed as one of the worst examples of free banking, though its insurance system is considered to have been a success. Between 1834 and 1853 the State Bank of Indiana was the only bank in the state. It had branches throughout the state, but the 'branches' were separately owned and operated. The bank easily weathered the storm of the Panic of 1837. In 1853, however, the state constitution was changed to allow free banking. (Free banks were not covered by insurance.) As can be seen in Table 3, the number of banks quickly increased. The modal discount also increased dramatically. The modal percentage falls by one half implying that the newly entering banks' notes were more heavily discounted.

During the Panic of 1857 two thirds of the Indiana banks went bankrupt. In Table 3 there is no entry for this year because *Van Court* listed Indiana banks as all uncertain (even before the panic). Rockoff (1974b) cites evidence suggesting that the problem in Indiana was that the state auditor may have valued Indiana bonds, used to back bank note issues, at par when their market value was less than par.[9]

North Carolina is an example of a chartered banking system (without an insurance system). North Carolina authorized an official state bank in 1854. This bank had branches in four cities and agencies in six others, but did not have a monopoly because the legislature also authorized two other banks. The state government appears to have overseen these banks carefully. Between 1847 and 1860 the state authorized the incorporation of fourteen new private banks with twenty-six branches. These new banks were allowed to receive deposits but could not "issue any bill, note or other device in the nature of a bank note" (see

[8] The notes of insolvent banks had positive prices because insolvent banks were liquidated over a period of time. During the liquidation period some notes were redeemed and the value of the remaining assets fluctuated. Rockoff (1974a,b) also makes this point. *Van Court* does not indicate whether a bank is insolvent or not.

[9] For a further discussion of Indiana see Harding (1895) and Dewey (1910). See Calomiris (1989) on Indiana's insurance system.

Knox, 1969). Notably, as shown in Table 5, both the modal discount and the standard deviation of the modal discount are low compared to the free banking states.[10]

In Tables 3 and 4 the modal discount is most relevant. The modal discount is the focus of the subsequent empirical work because it represents the price at which the notes of solvent banks traded. In the Philadelphia note market, the notes of most of the banks at any specific distant location traded at the same price, the modal discount. Below I provide a theoretical reason for this phenomenon. All other discounts of banks at the particular location are higher, suggesting that those banks were insolvent. (In fact, for a sample of New York banks, I verified that banks trading at the higher nonmodal discount are insolvent. Insolvent banks were liquidated over a period of time during which their notes continued to trade.)

Several other important observations can be made about Tables 3 and 4. For any given location, the modal discount varies substantially over time and does not decline smoothly as might be predicted from a simple notion of how the discount relates to the diffusion of the railroad and the telegraph. Not only does the discount not decline smoothly, but the effects of the introduction of the railroad and the telegraph are not obvious. It seems clear that the modal discount is not solely a function of distance from Philadelphia to the issuing bank, though more will be said about this below. Finally, note the variation in the modal percentage over time for a given location. This reflects the number of insolvent banks with notes still in circulation.

3.2. *Note discounts, railroads, and panic*

Table 5 provides a summary of the data from *Van Court* for the year 1839, the beginning of the sample period. The table shows the monthly modal discounts for each location on which *Van Court* reported in each of that year. During this period there was a banking panic, visible in Table 5 as negative discounts.[11]

[10] For more information on North Carolina see Schweikart (1987).

[11] In Table 7 the reader will notice that there are some negative entries for modal discounts. These occur during the Panic of 1839 (and during a few months of the Panic of 1857). During periods of suspension of convertibility following banking panics *Van Court* apparently switched from quoting prices in terms of gold to quoting prices in terms of Philadelphia bank notes. During a period of suspension it was not possible to convert bank notes into specie on demand. Apparently, for this reason, *Van Court* switched to quoting prices in terms of Philadelphia bank notes during suspensions. Thus, in terms of Philadelphia notes, the notes of some banks would be worth a premium though still at a discount in terms of gold. See Gorton (1989b) for details. On the Panic of 1857 see Van Vleck (1943).

Table 5
Summary of 1939 discount data

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct	Nov.	Dec.
1) Alabama	–	3.50	3.50	10.00	10.00	10.00	14.00	12.50	15.00	12.50	10.00	2.00
2) Arkansas	–	12.50	15.00	15.00	15.00	15.00	15.00	15.00	–	–	–	–
3) Connecticut	–	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	− 3.00	− 5.00
4) Delaware	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5) Washington, DC	–	0.50	0.50	0.88	0.88	0.88	0.88	0.88	0.88	1.50	2.00	1.00
6) Georgia	–	3.50	3.75	5.50	5.50	5.50	5.50	4.50	5.00	10.00	10.00	5.00
7) Illinois	–	3.25	3.25	4.00	4.00	4.00	4.00	4.00	5.50	5.50	6.50	6.50
8) Louisiana	–	1.25	1.25	3.50	3.50	3.50	3.50	5.00	7.00	7.00	6.00	0.00
9) Maine	–	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	− 5.00
10) Massachusetts	–	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	− 3.00	− 3.00	− 5.00
11) Michigan	–	1.50	10.00	10.00	10.00	10.00	10.00	8.00	5.00	− 3.00	7.00	7.00
12) Montana	–	4.00	4.00	4.00	4.00	4.00	4.50	4.50	6.00	7.00	7.00	5.00
13) Maryland	–	0.50	0.50	1.00	0.50	0.375	0.375	0.50	0.50	2.00	0.75	0.75
14) North Carolina	–	2.50	2.50	3.00	3.00	3.00	3.00	3.00	4.00	5.00	5.00	2.00
15) Nebraska	–	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	0.00	–	–
16) New Hampshire	–	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	− 5.00
17) New Jersey	–	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	− 3.00	− 5.00
18) New York	–	0.75	0.75	1.00	1.00	1.00	0.75	1.00	1.00	− 6.00	− 5.00	− 5.00
19) Ohio	–	3.25	3.25	4.00	4.50	4.00	4.00	4.50	5.00	5.50	5.50	5.00
20) Pennsylvania	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21) Rhode Island	–	0.75	0.75	1.00	1.00	1.00	0.75	1.00	1.00	− 3.00	0.00	0.00
22)South Carolina	–	2.50	2.50	3.00	3.00	2.75	2.75	3.00	5.00	7.00	3.00	0.00
23) Tennessee	–	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24) Vermont	–	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00	− 2.00	− 3.00	− 5.00
25) Virginia	–	0.75	0.75	1.00	1.25	1.25	1.00	1.00	1.50	4.00	2.00	1.00

As expected, the modal discount for Pennsylvania is always zero. Also, the modal discounts for New England states tend to be lower than other states, possibly reflecting the Suffolk system. But another possibility is simply that New England was a long-settled, possibly less risky, region. Moreover, there was almost no free banking in New England. But, it has been argued that state legislatures in this region were quick to grant bank charters so that entry into banking was similar to a free banking state (see Sylla, 1985).

Table 5 also makes clear that distance is not related to note discounts in any simple way. The table provides several examples where the discounts are *higher* on the notes of banks at locations which are *closer* to Philadelphia. For example, the discounts on the notes of Tennessee are zero in Table 5. Yet, Tennessee is clearly farther from Philadelphia than many of the other locations. The Tennessee banking system was dominated by an official state bank, the Bank of Tennessee, which at the beginning of the period was fully backed by the state and acted like a central bank (see Campbell, 1932). Also, note that the discounts of Vermont's banks' notes are the same as those of New Jersey bank notes. There are many examples of this sort in the data, though New Jersey borders Pennsylvania.

3.3. Travelling from Philadelphia to the bank of issuance

In order to exercise the redemption option feature of the note contract, the note bearer had to travel to the location of the issuing bank. Also, for much of the period and many locations, information would have to have travelled by the same mode of transportation that people used. Consequently, the cost of such a trip in terms of time or money would naturally seem to be related to the note discounts or prices. Banks which are more distant from Philadelphia should have notes which are more heavily discounted, *ceteris paribus*. In fact, a traditional hypothesis explaining the cross-section variation in note discounts is that the cost of returning from the note holder's location to the bank of issuance is the dominant factor. Since banks were risky institutions it is not clear to what extent the discounts reflect travel costs and to what extent they reflect other factors.

In order to analyze the relations between travel costs and note discounts, and to evaluate the note pricing model to be described in Section 4, measures of the distance from Philadelphia back to the location of the banks covered by *Van Court* are needed. In particular, measures of the costs and the durations of such trips are needed. Such measures would capture the dramatic diffusion of the railroad across the eastern part of the US, as well as the improvements in canals and steamships.

Gorton (1989c) constructs transportation costs and trip duration indices using pre-Civil War travellers' guides and historical information on the costs and speeds of various modes of travel. The travellers' guides provided the

pre-Civil War traveller with the most commonly used routes from Philadelphia to various other locations in North America. The guides detail the route to be taken, and indicate whether each leg of the journey was to be by stagecoach, canal, steamboat, or railroad. Combining this information with estimates of the speeds and costs of each mode of transportation, indices were constructed for three years: 1836, 1849 and 1862 (the only years for which such guides could be located).

Examination of these indices confirms that improvements in transportation technology were dramatic. The time and costs of a trip from Philadelphia to other locations in North America were greatly reduced. Fig. 1 graphically portrays the reductions in the durations of trips from Philadelphia to the capitals of selected other locations.

To what extent does the distance to the issuing bank explain cross-section variation in the discounts? Table 6 reports the (Spearman rank) correlations of discounts with the measures of the cost of the return trip and the duration of the return trip.[12] Cross-section regressions of the (annual average) modal discount on both transportation indices jointly yield:

For 1839:

$$\underset{}{\text{Modal discount}} = \underset{(4.3)}{-1.07} - \underset{(4.2)}{0.44} * \text{Trip Cost} + \underset{(5.3)}{0.122} * \text{Trip Time},$$

$$R^2 = 0.31.$$

For 1849:

$$\text{Modal discount} = \underset{(1.19)}{0.326} - \underset{(0.27)}{0.011} * \text{Trip Cost} + \underset{(3.05)}{0.04} * \text{Trip Time},$$

$$R^2 = 0.12.$$

For 1858:

$$\text{Modal discount} = \underset{(3.3)}{0.333} - \underset{(4.08)}{0.059} * \text{Trip Cost} + \underset{(7.3)}{0.067} * \text{Trip Time},$$

$$R^2 = 0.11.$$

t-statistics are given in parentheses. The results in Table 6 and the above

[12] Note that only the year 1849 is the correct match of the distance data with the discount data. Unfortunately, the distance data for 1836 had to be matched with 1839. Similarly, 1858 and 1862 were matched.

Table 6
Correlations between discounts and distance[a]

	Cost of trip	Trip duration	Modal discount	Avg. nonmodal discount
		1839		
Cost of trip	1.000	0.96	0.656	0.525
	(0.000)	(0.000)	(0.001)	(0.021)
Trip duration		1.000	0.653	0.523
		(0.000)	(0.001)	(0.022)
Modal discount			1.000	0.593
			(0.000)	(0.008)
Avg. nonmodal discount				1.000
				(0.000)
		1849		
Cost of trip	1.000	0.95	0.794	0.280
	(0.000)	(0.000)	(0.000)	(0.261)
Trip duration		1.000	0.787	0.300
		(0.000)	(0.001)	(0.226)
Modal discount			1.000	0.422
			(0.000)	(0.081)
Avg. nonmodal discount				1.000
				(0.000)
		1858		
Cost of trip	1.000	0.96	0.800	0.674
	(0.000)	(0.000)	(0.000)	(0.003)
Trip duration		1.000	0.789	0.669
		(0.000)	(0.001)	(0.003)
Modal discount			1.000	0.317
			(0.000)	(0.215)
Avg. nonmodal discount				1.000
				(0.000)

[a]Pearson correlation coefficients. Probability of zero correlation in parentheses. 288 observations for each year. See Gorton (1989d) for details.

regressions confirms the popular notion that the return trip to the issuing bank is a prime determinant of the discount in cross-section. The traditional hypothesis does fairly well.

But travel time by itself does not appear to completely satisfactory explanation. The main difficulty concerns examples like those noted above where

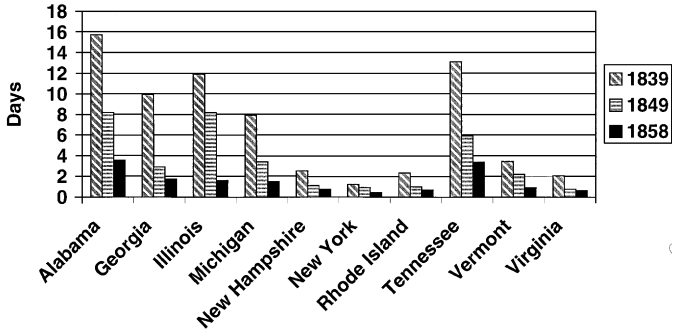

Fig. 1. Trip times from Philadelphia to ten state capitals.

discounts were higher on the notes of banks which were relatively closer to Philadelphia. Either there are other important determinants of the discounts or the note market was inefficient. Are these other determinants the risk attributes of the banking system of that state? Were these risks priced? In order to analyze this question the next section presents a model of bank note pricing.[13]

4. Pricing bank notes

In this section a very simple, stylized, model of bank note pricing is presented. The model is based on Svensson (1985). (See also Gorton, 1996). The goal of the model is to relate the note price to the duration of a trip back to the bank of issuance. Then the above transportation indices can be used to study the effects of technological change.

4.1. A model of bank note pricing

Assume that agents are spatially separated. Let 'd' be a measure of the distance from an agent's home to the market which is the location of the agent's trade at time t. Thus, d indexes location. (A time subscript on d will be omitted, except as necessary.) Each agent owns a firm at the home location. Firms at each location receive a stochastic endowment of a single nonstorable good, $y(d)_t$. Output is assumed to be independently, identically, lognormally distributed at each date t and location d. The standard deviation of output at location d is given by $\sigma(d)$.

[13] It is worth noting that a linear Tobit model with the modal discount as dependent variable and trip time and risk measures as independent variables does very poorly (see earlier versions of this paper). If the model of the next section is correct, then there is a nonlinear relationship between note price and the other variables, suggesting that the linear specification is incorrect.

Each household-firm begins period t with equity, Q_{t-1}, and debt, D_{t-1}, outstanding. These are claims on the household's endowment stream. The debt of a firm consists of small denomination noninterest-bearing perpetuities with embedded American put options allowing conversion of the debt into consumption goods on demand at par. The debt is called 'bank notes'. All output not used to honor debt is paid out as dividends since goods are nonstorable. Each household is a money-issuing firm so the terms 'bank', 'household' and 'firm' all refer to the same economic unit.

The representative household (at a representative location) is assumed to prefer goods procured from locations further from home rather than procured nearer home:

$$E_t\left\{\sum_{j=t}^{\infty}\beta^{j-t}U(C,d)\right\}, \tag{1}$$

where $0<\beta<1$, $U'_C>0$, $U''_{\infty}<0$, $U'_d>0$, $U''_{dd}<0$. The assumption that utility depends on distance is intended to capture the notion of a division of labor. The introduction of distance as an argument of the utility function is a device to model a desire for goods from other locations.[14]

Each household is to be thought of as consisting of a buyer and a seller, as in Lucas (1980). The seller stays at home and sells the output of the firm receiving bank notes in exchange. The buyer chooses to travel a distance, d, to buy consumption goods, paying for them with bank notes. (Assume the buyer chooses the distance d, but that the direction is random. All expectations below will be taken over this uncertainty.) Only one market can be visited at each date t. Buyers face a cash-in-advance constraint which can only be satisfied by bank notes.[15] Let $P_t(d)$ be the price (in terms of consumption units) of bank notes

[14] In ante bellum America there was a spatial division of labor. The traditional thesis concerning this division of labor was articulated by Schmidt (1939) and Callender (1909). Also see Mercer (1982) and Pred (1980). The main point is that interregional trade flows between different locations were sizeable. It is not known to what extent these flows imply a large volume of bank notes moving around the country.

[15] For simplicity the model omits specie as an alternative medium for satisfying the cash-in-advance constraint. Since, as will be seen, a capital loss is associated with carrying notes to distant markets, gold or silver would appear to be preferable as a means of exchange. Thus, unless there is some cost to using gold or silver, bank notes would not circulate much beyond the location of the bank of issuance. During the ante bellum period the costs of using specie were sizeable. First, specie is heavy and difficult to transport. Second, insofar as there were coins available, there was a confusing array of denominations because many (possibly most) of the coins in circulation were foreign. The US mint was incapable of reminting the foreign coins because of poor mechanical minting equipment and because of the transportation costs of moving specie. See Carothers (1930) and Dewey (1910). Third, there was a shortage of small coins which was met by bank notes (see Carothers, 1930, p. 79).

issued by the representative agent and traded at location, d, at time t. Thus, the buyer is constrained by

$$C_t \leq \Sigma_d P_t(d) D_{t-1}(d), \tag{2}$$

which is the cash-in-advance constraint. In Eq. (2), the buyer carries a portfolio of bank notes from banks at different distances (indicated by the argument d) from the market that is chosen for transactions at date t. This market will be a distance d away from the home location.

The sequence of events in a period, t, is as follows. At the start of period t, the current state, $y(d)_t$, is learned for each location, d.[16] Then the goods market opens. The household buyer travels the distance d carrying the predetermined portfolio of bank notes. (The portfolio was held over from date $t-1$.) The buyer purchases C_t consumption units from sellers at location d, using bank notes, and then returns home. Meanwhile, the seller sells goods in the home market, receiving bank notes in exchange for consumptions goods. After the goods market closes, and buyers have returned home, the securities market in which notes and shares are traded opens at each location. At this time a household chooses a portfolio of notes and shares and, in particular, may decide to redeem some notes. When the securities market opens, prices for the notes will already have been established in the goods market. At those prices households decide to hold notes or redeem notes, depending on whether they expect to travel a greater or lesser distance next period.

In order to model the idea that note redemption requires a time consuming trip, the following assumption is made. The receipt of a note issued by a firm at distance d from the issuer's location is assumed to imply that it takes d periods to return for redemption, if the holder wants to redeem it. In other words, there is assumed to be an asymmetry between household buyers and sellers. Buyers can carry a note a distance d during a single period, but, a seller who receives the note requires d periods to return it if the redemption option is exercised. Thus, it is costly to redeem notes in the sense that it is time consuming. Since it is time consuming to redeem notes, the amount of debt which will actually be redeemed in period t was, in fact, determined at past dates, and so is predetermined at the start of period t.

The amount of debt that will be redeemed in the current period depends upon the profile of locations, and hence, dates in the past, from which debt was sent for redemption. Notes sent for redemption at date t will be *in transit* for d_t periods.[17] Suppose that a note of a bank located at a distance d from the home location was sent for redemption k periods ago. This note will be in transit for

[16] This assumption is consistent with the existence of the telegraph.

[17] Once notes have been sent for redemption, it is assumed that they cannot be called back.

d periods before it is redeemed. At any time t, if $d > k$, then the note will be redeemed in $d - k$ periods. If, at time t, $d = k$, then the note is presented for redemption in the current period. Let $D_t^R(d)$ be the amount of notes sent for redemption d periods ago. When $d = 0$ the amount of notes bank must redeem is $D_t^R(0)$.

The situation of the firm, at time t, is as follows. When selling output at time t, the firm receives bank notes which are the obligations of banks various distances away. At the home location the amount received from sales in period t is: $\Sigma_d P_t(d)D_t(d) = y_t(0)$. At the firm's own location the price of a dollar of its own notes is $P_t(0)$. This is the price at which its notes will be redeemed in period t. The amount of debt which the firm will redeem (in consumption units) is: $P_t(0)D_t^R(0)$. ($P_t(0) = 1$ if the firm is solvent.)

The firm may also issue new debt and new equity. For simplicity assume that no new equity is issued and that the face value of new debt issued, $D_t^N(0)$, always equals the face value of the amount redeemed, so long as the firm is solvent. Thus, the firm's leverage is constant. Since debt does not pay interest, the dividends the representative household pays out are always y_t.

Let $q_t(d)$ be the price of shares of banks at location d in period t and let $v_t(d)$ be the dividend paid to an owner of a share of stock issued by a household from location d. Then, the resources available to the household consist of: (i) shares and dividends, $\Sigma_d[q_t(d) + v_t(d)]Q_{t-1}(d)$; (ii) the value of the debt of other firms redeemed, $P_t(0)D_t^R(0)$; and (iii), any monies not spent satisfying the cash-in-advance constraint. In the securities market these resources will be used to finance: (i) a portfolio of bank shares; (ii) a portfolio of bank notes of various types to be held until the next period to finance consumption; and (iii), an amount of each bank's notes to be sent for redemption. So the budget constraint is

$$\Sigma_d\{q_t(d)Q_t(d) + P_t(d)[D_t(d) + D_t^R(d)]\} + P_t(0)D_t^N(0) \leq \Sigma_d P_t(d)D_{t-1}(d) - C_t + P_t(0)D_t^R(0) + \Sigma_d[q_t(d) + v_t(d)]Q_{t-1}(d). \quad (3)$$

4.2. Equilibrium

The representative agent chooses a distance to travel in period t, d_t, an amount of notes of each type, d, to be sent for redemption $D_t^R(d)$, an amount of notes of each type, $D_t(d)$, to be carried to next period, and an amount of equity shares of each type, $Q_t(d)$, to hold to maximize (1) subject to (2) and (3). Let μ be the Lagrange multiplier associated with the cash-in-advance constraint, (i). The first-order conditions with respect to choice of $D_t(d)$, $D_t^R(d)$, d_t and $Q_t(d)$, respectively, assuming an interior solution, can be written as

$$U'_{Ct} = \beta E_t\{U'_{Ct+1}[P_{t+1}(d)/P_t(d)]\} + \beta E_t\{\mu_{t+1}[P_{t+1}(d)/P_t(d)]\}, \quad (4)$$

$$U'_{Ct}P_t(d) = \beta^d E_t\{U'_{Ct+d}P_{t+d}(0)\}, \tag{5}$$

$$U'_{dt} = -U_{dt}\Sigma_d P'_{dt}\{D_{t-1}(d) - [D_t(d) + D_t^R(d)]\} + \mu_t \Sigma_d P'_{dt} D_{t-1}(d), \tag{6}$$

$$U'_{Ct}q_t(d) = \beta E_t\{U'_{Ct+1}q_{t+1}(d)\}, \tag{7}$$

where E_t indicates the expectation conditional on information available at time t. (There are also transversality conditions for each note.)

Equilibrium requires that: (i) the goods market at each location clear, i.e., $C_t(d) = y_t(d)$ for each d; (ii) the market for each bank's equity clear, $Q_t(d) = Q_{t+1}(d) = 1$, for each d; (iii) the market for each bank's debt clear, $D_{t-1}(d) = D_t^R(d) + D_t(d)$, for each d; (iv) $\Sigma_d v_t(d) = y_t(d)$, for each d, that is, each household pays out dividends in the amount of the firm's proceeds that period; (iv) by assumption, $D_t^R(0) = D_t^N(0)$, that is, the amount of new notes issued equals the amount retired.

The first-order condition (4) determines the optimal choice of $D_t(d)$, the face value amount of bank notes from location d to be carried over to next period to provide the household buyer with bank notes to satisfy the cash-in-advance constraint. A bank note dollar held to next period has a direct return, as part of wealth, the first term on the right-hand side of Eq. (4), and a future benefit in the form of future liquidity services when the note dollar is used to satisfy next period's cash-in-advance constraint, the second term. See Svensson (1985) for a discussion.

Conditions (5) and (7) price the firm-bank's debt and equity, respectively. Write Eq. (5) as

$$P_t(d) = \beta^d E_t\{P_{t+d}(0)[U'_{Ct+d}/U'_{Ct}]\}, \tag{8}$$

where $P_{t+d}(0)$ is the redemption value of a note d periods from now. This price assumes a first-come-first-served rule since at date $t + d$, $D_{t+d}^R(0)$ notes have been presented for redemption, and only this debt must be honored at that time. Bankruptcy is defined by whether or not the bank can honor the amount of debt being presented for redemption, $D_t^R(0)$, and not by the outstanding amount of debt.

In considering redemption a complication arises because notes may have been sent for redemption in the past which have not yet reached the issuing bank. These notes are in transit to the bank. Suppose, for the moment, that there are no notes in transit. (This would be known at time t.) If there are no notes in transit, then there is no question of the bank defaulting prior to presentation of the notes currently being sent for redemption. The value of the bank at time t and location d is $V_t(d) = P_t(d)D_t + q_t(d)Q_t$.

We now turn to pricing the bank notes. To begin with, see Proposition 1.

Proposition 1. The bank notes of a bank a distance d away are valued as risky pure discount debt claims with a maturity of d periods.

To see this note that from Eq. (5), which can be solved for the price of the bank note at location d, $P_t(d)$, the representative agent must, in equilibrium, be indifferent between holding a one dollar note and sending the note for redemption. The value of a note sent for redemption is given by Eq. (8) values the note as a risky debt claim maturing d periods later. Even though the debt is perpetual, from the point of view of the representative agent, since it takes d periods to redeem, it can be priced as debt of maturity d. Thus, we can state the second proposition.

Proposition 2. Assume that preferences display constant relative risk aversion. Then, if $D_t^R(d)$ is the face value of the amount of debt sent for redemption at date t, from location d, its value at date t is given by

$$P_t(d) = [D_t^R(d)]^{-1}\{V_t(d)[1 - N(h_D + \sigma)] + (1 + r_f)^{-1} D_t^R(d) N(h_D)\}, \tag{9}$$

where $h_D \equiv \{\ln[V_t(d)/D_t^R(d)] + \ln(1 + r_f)\}/\sigma - \sigma/2$.

σ is the standard deviation of one plus the rate of change of the value of the bank (i.e., the standard deviation of output), and r_f is the risk free rate of interest (assumed constant). $N(\bullet)$ indicates the cumulative Normal distribution function.[18] The proposition says that bank notes can be priced using Black and Scholes (1973) option pricing formula. The proof of this proposition is standard and due to Rubinstein (1976).

Propositions 1 and 2 were derived under the assumption that there were no notes in transit. If there are notes in transit, then, between the current date, t, and date $t + d$, these notes will, successively, be presented for redemption. These notes are more senior claimants in a sense. The bank may default on one of these payments. From the point of view of the household/bank these successive redemptions are akin to coupon payments. The stock is then a compound option because until the current amount, $D_t^R(d)$ has been redeemed at date $t + d$, the stockholders have the option of buying the option to redeem the next amount which will be presented. Under these conditions a proposition analogous to Proposition 2 can be proven. That is, assuming that preferences display constant relative risk aversion, the bank notes can be priced according to Geske's (1977) extension of Black–Scholes.

Equilibrium in the goods market requires that the note price, $P_t(d)$, adjust to clear the market given choice of location d. Then, in the securities market, notes will be demanded for satisfying future liquidity constraints. We can now inquire as to when the redemption option is worth exercising. A note dollar held must satisfy Eq. (4); a note dollar sent for redemption must satisfy Eq. (5). Thus, the

[18] For simplicity the model has no riskless security. However, the shadow price of a riskless bond can always be calculated. A riskless security could easily be incorporated.

option is 'in the money' when a note dollar is more valuable being sent for redemption, i.e., when the value of a note given by the right-hand side of Eq. (5) is greater than the left-hand side and vice versa for Eq. (8).

4.3. Equilibrium note price characteristics

Since bank notes can be priced using Proposition 2, Black and Scholes' option formula, some useful comparative statics are immediate.[19] In particular, the value of the notes, $P_t(d)$, varies inversely with d, σ, and leverage of the bank (see Merton, 1974). These results, will provide the basis for confronting the data, starting in the next section.

An important feature of the data is that *Van Court* quoted 'all uncertain' for banks a long distance from Philadelphia, suggesting that the notes of these banks were very highly discounted, perhaps to zero. Locations even further away were not listed. The above valuation model implies that, at the same distance from the issuing bank, not all notes will circulate. Condition (6) determines the optimal choice of distance from home, d_t^*, the buyer should travel to buy consumption goods. To understand Eq. (6), recall that in equilibrium $D_{t-1}(d) = D_t(d) + D_t^R(0)$, i.e., the stock of bank notes outstanding for each bank and carried over into period t, must be divided into an amount held until next period and an amount sent for redemption.[20] Thus, in equilibrium, Eq. (6) becomes:

$$U'_{dt} = -\mu_t \Sigma_d P'_{dt} D_t(d). \tag{10}$$

By Proposition 2, $P'_{dt} < 0$, i.e., the value of notes issued at the home location falls as distance increases because the maturity of the debt increases. Condition (10) says that d_t^* is chosen to equate the marginal benefit of increased distance to the marginal cost of the capital loss associated with carrying the notes further away from home. The notes decline in value with distance leaving the buyer with less on hand to satisfy the cash-in-advance constraint, i.e., while consumption goods purchased further away 'taste' better, a note carried further away drops in value as a function of d so fewer goods can be purchased. This is summarized in the following peoposition.

Proposition 3. At each date, t, there exists a critical distance, d_t^*, beyond which bank notes of banks at location d will not circulate.

[19] If the volume of notes in transit were known, so that Geske's (1977) formula was appropriate, the same comparative statics would hold (Geske, 1977).

[20] Note that if there are notes in transit then, in equilibrium, the outstanding amount of notes would be divided between notes in transit, notes sent for redemption, and notes held until next period.

The optimal distance depends on σ and leverage. Note prices which at various times are quoted in Philadelphia as 'uncertain' (or which are note listed at all) may, at other times, be quoted because σ or bank leverage have changed. For example, in Table 5, Arkansas and Nebraska are initially quoted, but subsequently are not quoted, even though the notes of more distant banks are quoted.

Now consider what happens if the household buyer goes to the home market and purchases goods from the household seller using bank notes from the home location, i.e. $d_t = 0$. Then, since the debt has no maturity, the option could be exercised instantly. If a bank note issued by a bank at the home location traded at discount at the home location, it could be costlessly converted into consumption goods at par as long as the bank is solvent. If the note were not priced at par, then this would occur until the bank was closed. Hence, the notes of banks at the home location must have no discount at the home location. By Proposition 2, if $d = 0$, then the discount is zero if the bank is solvent. Thus, $d = 0$ implies that those notes are risk free. Consequently, the notes of Philadelphia banks should always have a zero discount (which they do in the data).

During the Free Banking Era transportation costs and the duration of trips declined greatly with the spread of the railroad across the continent. This corresponds to an exogenous reduction in the time it takes to get back to a given location, i.e., to a reduction in d for a given location. Technical change reduces d, and hence increases notes prices (reduces discounts), *ceteris paribus*. But, if other factors change, while technical progress is occurring, then note discounts will not necessarily decline smoothly.

Note discounts are not monotonically increasing in time to return, d^*, because of the effects of risk (σ) and bank leverage. The factors which *a priori* evidence suggests affect bank risk are captured by σ. Coalitions of banks which may have effectively been self-regulating, in particular the Suffolk Bank system, encompassing the banks of New England, correspond, in the context of the above model, to a reduction of σ. Similarly, σ can be interpreted as capturing the effects of branching restrictions, insurance, and the default risk associated with bank issuance of additional money by wildcat banks, and whether or not the type of banking system, free or chartered matters.

A final feature of the equilibrium note prices is proven in Gorton (1996) in the context of the same model (but where σ is not exogenous). This feature concerns the modal discount. We state it here to explain the subsequent use of the modal discount in the empirical work. It would seem that the notes of different solvent banks at the same location could be priced differently at some particular distant location so long as the different prices reflected the different default risks. This would be true in efficient markets if notes were not used as a medium of exchange. The fact that notes are used as a medium of exchange, however, changes this intuition. Gorton (1996) shows this as given in the following proposition.

Proposition 4. All solvent banks at the same location will have identical discounts at given distant locations and given date, t (assuming banks have the same leverage).

The proposition says that equilibrium requires all banks to choose their asset risk, σ, to be the same. While this is beyond the current model, the intuition for this result can be easily seen based on the above results. Consider the notes of two banks the same distance away, but with different risks (σ). A consumer holding notes of these two banks will not be indifferent between them even when their default risks are accurately priced. The reason is that if the consumer moves still further away from the issuing banks' location, increasing the time to redemption (maturity), the riskier banks' notes will decline in value by relatively more, hence purchasing less consumption units at the distant location. A less risky bank's notes will be preferred as a medium of exchange while the riskier bank's notes will be sent for redemption. But then equilibrium requires all banks with circulating notes to have the same risk and, hence, they are priced the same. This price is the modal discount.

5. The behavior of bank note prices

If secondary note markets accurately priced risk, that is, accurately priced the redemption option, then the private money contract was enforceable in the sense that note holders would not suffer an unanticipated (i.e. unpriced) transfer to the note issuer (via issuance of additional currency as in wildcat banking or via increases in bank asset risk). The question to be addressed now is: Do bank note prices reflect bank risk?

To begin, a measure of bank risk is required. In the note pricing model, bank risk is completely captured by the variance or volatility of bank asset values. If bank notes can be priced with the Black-Scholes model as applied to corporate debt by Merton (1974), using the above result, then the volatilities of bank assets, i.e., σs, implied by the note prices can be extracted be inverting the Black–Scholes formula. Using the closed-form Black–Scholes solution depends upon some strong assumptions. These are discussed below.

The volatility measure of risk is obtained from the note prices by inverting Eq. (10) for each state and date. Note that it is in this step that the importance of the redemption option and technological change enter the procedure. Leverage and trip time (i.e., maturity) are used in the formula to obtain the implied volatilities and do not enter the subsequent regressions. Technological change is captured in the calculation of the implied volatilities since maturity declines as transportation improves.

The method outlined above uses the exact closed form pricing solution for bank notes obtained in Proposition 2 under the assumption that there are no

notes in transit or that agents behaved as if there were no notes in transit.[21] Application of the Black–Scholes formula also requires assuming that the volatility and risk-free interest rate are constant through time. The first of these assumptions may be violated. Evidence suggests, however, that this violation is not likely to be important.[22] The second of these assumptions may also be violated. But, the implied returns on the bank notes are so high that the results are robust to a number of interest rate assumptions.[23]

The next step in empirically testing the model is to relate the measures of bank riskiness extracted from note prices to the measures of bank riskiness: the implied risk measures are regressed on the measures of bank riskiness discussed above. If secondary note markets functioned efficiently then the risk attributes of state banking systems should be priced. Explanatory variables, thus, include a dummy variable indicating whether the state is a member of the Suffolk System (*SUFFOLK*), a dummy variable indicating whether the state is a branch banking system (*BRANCH*), and a dummy variable indicating whether there is a state sponsored insurance arrangement (*INSURANCE*), and a dummy variable indicating whether the state is a free banking state (*FREE*).[24] (There are only a handful of risk variables available due to the data limitations associated with this period.) Finally, two variables capturing aggregate factors are included: a monthly index of stock prices (*SDEX*), and a dummy variable for the periods of suspension (*SUS*).

Table 7 reports the results of regressing the implied volatilities on the risk measures. Remarkably, the results in Table 7 are largely as expected. The R^2s are comparable to similar studies of modern bank debt (e.g. Flannery and Sorescu, 1995). The estimated coefficients on Suffolk system membership, branch banking, and insurance are all of the correct sign and significant. The presence of any of these factors is associated with lower volatility of bank assets (and hence lower discounts ceteris paribus). (This is true whether year dummies are included or not.)

[21] The assumption that there are no notes in transit is made because there are insufficient data to make any other assumption.

[22] The results of Schmalensee and Trippe (1978) and Latane and Rendleman (1976) demonstrate the value of using the Black–Scholes model to predict volatilities despite the inconsistency of using a model which assumes a constant variance to recover a possibly nonstationary variance. See Galai (1983) for further discussion.

[23] A variety of interest rate assumptions were attempted. A series of annual commercial paper rates from Macaulay (1938) was used. Also, the risk free rate was, alternatively, exogenously set to zero and three percent for the period. No interest rate assumptions affects the results because the implied returns on the bank notes are so high.

[24] The dummy variable is set to one when a state adopts free banking. In fact, such a state would have both free and chartered banks, but there is no feasible way to incorporate this information since it is not generally available.

Table 7
Implied volatality regressions ($N = 3384$)

Independent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	38.86[a]	37.79[a]	38.87[a]	37.82[a]	51.41[a]	49.10[a]	51.61[a]	49.31[a]
	(1.73)	(3.33)	(1.71)	(3.30)	(1.64)	(3.03)	(1.65)	(3.033)
Suffolk member	− 1.82[a]	− 2.37[a]	− 0.93	− 1.49	− 10.89[a]	− 11.93[a]	− 11.16[a]	− 12.25[a]
	(0.671)	(0.680)	(0.670)	(0.683)	(0.70)	(0.704)	(0.737)	(0.744)
Suspension	− 11.32[a]	0.573	− 11.33[a]	0.589	− 14.56[a]	0.961	− 14.50[a]	0.966
	(0.941)	(2.54)	(0.933)	(2.52)	(0.863)	(2.29)	(0.864)	(2.29)
Free banking	1.89[a]	0.77	–	–	− 0.82	− 2.58[a]	–	–
	(0.66)	(0.736)			(0.606)	(0.674)		
Good free	–	–	− 0.43	− 1.69	–	–	− 0.54	− 2.24[a]
			(0.717)	(0.791)			(0.656)	(0.720)
Bad free	–	–	8.37[a]	7.19	–	–	− 1.78	− 3.68[a]
			(1.05)	(1.09)			(1.04)	(1.07)
Branch banking	–	–	–	–	− 17.11[a]	− 17.50	− 17.41[a]	− 17.85[a]
					(0.76)	(0.752)	(0.805)	(0.797)
Insurance	–	–	–	–	− 22.67[a]	− 23.28[a]	− 22.98[a]	− 23.66[a]
					(1.10)	(1.10)	(1.13)	(1.13)
Stock index	− 0.11[a]	− 0.05	− 0.12[a]	− 0.05	− 0.145[a]	− 0.056	− 0.145[a]	− 0.056
	(0.19)	(0.05)	(0.019)	(0.051)	(0.017)	(0.046)	(0.017)	(0.046)
Year dummies	No	Yes	No	Yes	No	Yes	No	Yes
R^2	0.056	0.081	0.07	0.10	0.22	0.25	0.22	0.25
F-value	51.94	14.04	54.64	16.34	164.52	46.98	141.20	45.25
(Prob. > F)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)

Notes: Standard errors in parentheses.
[a]Indicates significance at the 0.05 confidence level.

Free banking, however, does not appear to be associated with higher risk. In columns (1) and (2), where the branching and insurance factors are omitted, free banking increases risk, consistent with the traditional assertion, but is not significant in column (2). When the branching and insurance factors are included, columns (5) and (6), free banking lowers risk (but again is insignificant in one of the cases). Suppose a finer distinction is made, following Rockoff (1974b). On the basis of independent evidence Rockoff (1974b) suggests that the free banking states can be usefully divided into two groups: 'good' free banking states and 'bad' free banking states.[25] The results imposing this distinction, columns (3) and (4), and columns (7) and (8), still provide a mixed pattern of results. In column (8) both variables are significantly negative, but insignificantly different from one another.

That free banking was not perceived to be riskier is consistent with the evidence that wildcat banking was not common. The extensive commentary about wildcat banks by contemporaries of this period rarely distinguished between free banking states and chartered banking states. Moreover, many chartered banking systems were subject to abuse so that entry was not always difficult (see Chaddock, 1910; Hammond, 1957, pp. 332–37; Knox, 1903, p. 413; Ng, 1987; Sylla, 1985). It is also worth noting that, aside from New York, almost all of the entry into banking under free banking laws occurred in the 1850s, by which time the railroad and telegraph were widespread. One conjecture might be that by this point the redemption option was a powerful device for preventing risk-shifting.

Finally, notice that volatility rises when the stock market declines. The suspension variable is difficult to interpret since its sign depends on whether the year dummies are present or not. Though not reported, it is worth noting that seasonal dummies were always insignificant.

6. Concluding remarks

Previous research indicates that wildcat banking was not a prevalent problem during the Free Banking Era. The reason for this may be that market participants could discipline banks by pricing factors that affected risk and via the contractual redemption option. Properly pricing risk means that a bank which set out to overissue notes would obtain a market price of zero on its notes. The contract device of the redemption option may have allowed note holders to run on banks which attempted to add risk. This paper has investigated whether note markets functioned in this way. Taking account of the redemption option, and

[25] Following Rockoff the 'bad' free banking states were identified as Michigan, Indiana, Illinois and New Jersey. The remaining free banking states were classified as 'good'.

the affects of technological change on this option, the above results are quite suggestive of the ability of market participants to price bank risk. The results also suggest that the type of banking system, free or chartered, was not the primary factor determining the relative risk of different banking systems. Other risk attributes appear to have been more important. This is consistent with previous findings.

7. For further reading

The following references are also of interest to the reader: Gorton, 1985; Rockoff, 1985; Rockoff, 1990; Rolnick, 1988.

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