JOURNAL OF FINANCIAL AND QUANTITATIVE ANALYSIS Vol. 58, No. 5, Aug. 2023, pp. 1973–2023

doi:10.1017/S0022109022000795

Access to Finance and Technological Innovation: Evidence from Pre-Civil War America

Yifei Mao
Cornell University SC Johnson College of Business
ym355@cornell.edu (corresponding author)

Jessie Jiaxu Wang
Board of Governors of the Federal Reserve System and Arizona State University W.P. Carey School of Business
jessiejiaxuw@gmail.com

Abstract

This article provides new evidence on how access to finance affects technological innovation and establishes the role of labor practices in shaping this relation. We exploit a unique setting, pre-Civil War America, where staggered adoption of free banking laws across states encouraged bank entry, and variation in the use of exploited workers in agriculture generated differences in producers' demands for labor-saving technologies. Results show that access to finance spurred innovation; the positive effect on agricultural innovation diminished with labor exploitation. We establish the causal role of labor exploitation using the 1850s cholera pandemic and the influx of Irish immigrants.

I. Introduction

There is a long-established consensus that financial markets are vital for economic growth (Schumpeter (1934), King and Levine (1993a), and Levine (1997)). Yet, the way financial markets affect innovation and, in particular, the effectiveness of access to finance in promoting innovation is not fully understood (Hall and Lerner (2010), Kerr and Nanda (2015)). In this article, we make two contributions to the understanding of the factors that drive innovation. First, using a novel bank-deregulation shock, we provide new evidence on how access to finance impacts technological innovation. Second, we fill a gap in the literature by examining the effect of finance on innovation when producers use different labor

We thank an anonymous referee, Daron Acemoglu, Andres Almazan, Ramin Baghai, Charles Calomiris, Michael Ewens, Carola Frydman, Jarrad Harford (the editor), Matt Jaremski, Andrew Karolyi, Peter Koudijs, Debarshi Nandy, Jordan Nickerson, Maureen O'Hara, Paul Rhode, Joshua Rosenbloom, Elena Simintzi, Guillaume Vuillemey, Nicolas Ziebarth, and Miao Ben Zhang, as well as seminar and conference participants at WAPFIN@Stern, 2018 Texas A&M YoungScholars Finance Consortium, 2018 Chicago Financial Institutions Conference, 2018 Texas Finance Festival, 2018University of Kentucky Finance Conference, 2018 SFS Cavalcade, 2018 WFA, 2018 NBER SI Innovation, 2018 EFA,2019 AFA, 2019 FIRS, Cornell University, Arizona State University, Auburn University, University of Calgary, University of California Los Angeles, and the Board of Governors of the Federal Reserve System for helpful comments. The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of anyone else associated with the Federal Reserve System.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

practices. We find that access to finance, which generally promotes innovation, can also depress innovation by reducing the cost of labor. Our results suggest that producers facing high labor costs have a strong incentive to finance technological innovation. But if the cost of labor declines with access to finance, the incentive to innovate will also decline; the net effect on innovation is ambiguous and has not previously been explored.

Identifying the effects of finance and labor practices is challenging in today's world because financial markets are interconnected, and labor is mobile. We tackle these challenges by turning to pre-Civil War America as an ideal laboratory; in particular, we examine the period from just after the War of 1812 until 1860, before the onset of the Civil War. First, this period witnessed the staggered passage of free banking laws in 18 states, a novel setting in which to identify banking shocks. Due to transportation costs and restrictions on interstate branching, banks before the Civil War were mainly local businesses. Access to banks was limited because the chartering system posed significant barriers to entry. By replacing charter requirements with "free entry" under a fixed set of standards, the passage of a free banking law encouraged bank entry and thus provided a positive shock to a state's access to finance.

Second, during the pre-Civil War era, exploitative labor practices enabled by the institution of slavery were prevalent. Because of their property rights over enslaved workers, planters were able to extract the lion's share of enslaved labor's marginal product, paying a low maintenance cost.[1] These planters had less incentive to shift away from labor-intensive production methods than farmers who faced competitive labor costs. Hence, regional divergence in the use of exploited workers in agriculture led to heterogeneity in producers' demand for labor-saving technologies. Furthermore, where exploitative labor practices were pervasive, banks' assistance in trading and mortgaging enslaved workers aggravated exploitation. In comparison, banks elsewhere provided financing for merchants and manufacturers who competed with agriculture for workers, further increasing the demand for agricultural mechanization. This unique feature allows us to shed light on the net effect of finance on innovation.

To assess the causal impact of access to finance on innovation, we use a difference-in-differences approach that exploits the staggered passage of free banking laws. The historical narrative appears to suggest that the timing of the law's enactment across states was plausibly exogenous.[2] Using a hazard model, we show that the likelihood of a state passing a law was not affected by state-level determinants of innovation or trends in innovation prior to the law's passage. Furthermore, a significant number of free banks entered following the law's

[1]Enslaved labor should not be understood as "cheap labor," as Wright (2006) stresses. In fact, the market *value* of an enslaved worker was high. In this article, we use the terms "labor costs," "cost of labor," and "unit cost" interchangeably to refer to the notion of marginal labor cost faced by the producer. The marginal cost of using an enslaved worker was reflected in the maintenance cost or the hire rate, which is to be distinguished from the market value. The key difference between an exploited worker and a wage-earner is the marginal cost of labor relative to the marginal product: the subsistence return received by enslaved workers was much lower than the value created by them.

[2]For example, the law's passage in New York State was triggered by a kidnapping incident and was referred to as having a "serendipitous nature" (Bodenhorn (2006)).

passage, whereas charter banks did not exit or become smaller. The evidence supports the notion that the adoption of free banking imparted a positive shock to a state's access to finance.

Our baseline regressions establish a significant, positive effect of improved access to finance on technological innovation. After a state adopted the free banking law, the number of patents granted increased significantly in subsequent years. The economic magnitude is consequential. On average, a state that passed the law generated 12.13 more patents in the third year of free banking than did states without free banking; this magnitude accounted for 16.1% of the state-level patent variability. The results are robust to controlling for state and year fixed effects, as well as for time-varying, state-specific characteristics. Free banks at times operated as innovation-inducing Schumpeterian financiers by directly supporting local innovators and entrepreneurs, as the microlevel evidence from Bodenhorn (1999) suggests. Also, free banks potentially promoted innovation through indirect channels, such as improving bank competition, boosting the money supply, and expanding the railroad network.

We conduct a battery of tests to support a causal interpretation of our results. First, we examine the dynamics of innovation surrounding the law's passage. The innovation output shows no prior trend, indicating that reverse causality is unlikely a concern. Second, we conduct a placebo test using pseudo-treated groups and conclude that the results cannot occur mechanically in the data. Finally, we confirm that our results are not driven by observations with zero patents, earlier pre-Civil War years, or contemporaneous law changes.

Consistent with the local nature of the pre-Civil War banking markets, we find that access to free banks was positively and significantly associated with innovation outcomes at the county level. To address the concern that the entry of free banks in a county might be endogenous to local economic conditions, we employ an identification strategy that resembles a regression discontinuity design. Specifically, we compare contiguous counties along a shared state border, where the free banking law was passed on one side. This method allows us to minimize the confounding effects of unobservable variation in local economic conditions. Results show that the coefficient estimates on free banks' entry continue to be positive and statistically significant, reinforcing the causal effect of free banking on local innovation outcomes.

Having established a robust and positive impact of access to finance on technological innovation, we turn to the role of labor practices in shaping the finance-innovation nexus. Slavery before the Civil War, an extreme form of exploitation, provides a window through which to study the impact of exploitative labor practices. Enslaved laborers worked primarily in agriculture; they were forced to work long hours with little or no pay. Planters' property rights enabled them to extract a large share of the marginal product of enslaved labor while paying a low maintenance cost. If economizing on labor costs poses a strong incentive to replace labor, producers using exploitative labor practices would be less keen to shift away from labor-intensive production methods. In contrast, producers without access to exploited labor faced a marginal cost of labor comparable in magnitude to labor's marginal product and had stronger incentives to replace labor with machines.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

Accordingly, we predict that access to finance has a weaker impact on labor-saving innovation in regions with exploitative labor practices.

To test this prediction, we measure the extent of labor exploitation using the fraction of a state's (county's) population that was enslaved when the state entered the pre-Civil War era. This initial value is arguably exogenous to local economic and financial development, thus alleviating concerns about reverse causality. Because the spatial variation in labor exploitation was manifested chiefly in agriculture, we focus on pre-Civil War agricultural patents, which are commonly considered labor-saving.[3] Consistent with our prediction, the estimates show that labor exploitation was negatively associated with the impact of free banking on agricultural innovation. The results are robust to controlling for the level of free bank entry and observable state characteristics, including industry composition, educational attainment, foreign-born population, innovation growth, and access to railroads. To mitigate concerns about unobservable differences between areas that abolished slavery and those that did not, we restrict the analysis to the subsample that performed exploitative labor practices and find the results continue to hold.

To establish the causal effect of exploitative labor practices, we use two plausibly exogenous shocks to the supply of exploitable workers. The first shock is the 1849–1854 cholera pandemic, a deadly outbreak that disproportionately struck the lower classes. This pandemic caused sudden reductions in the enslaved population in affected counties, generating a negative shock to the extent of labor exploitation by planters and a stronger incentive for them to switch to machines. To measure the county-level exposure to the shock, we hand-collect novel data from the 1850 Census Mortality Schedules. The second shock is the influx of Irish who migrated to America during 1820–1860 to escape famine and religious persecution. These Irish immigrants often took any jobs they could get at meager pay and were exploited by employers. The arrival of Irish immigrants thus provided a positive shock to the supply of exploitable workers by local producers. Since the Irish primarily settled in the northern states, this setting assesses the external validity by extending the analysis to geographic areas distinct from those where slavery was predominant. Our results show that innovation responded more positively to access to free banks in areas where planters faced more cholera-caused deaths among the enslaved population, and in areas with fewer arrivals of Irish immigrants. Together, our evidence substantiates a causal interpretation of the relation between labor exploitation and the sensitivity of innovation to financial development.

[3]While technical change since the twentieth century has been skill-biased and labor-complementary, technology in nineteenth-century America was predominantly a substitute for human strength and skilled labor (Goldin and Sokoloff (1984)). Acemoglu ((2010), p. 1040) notes that "it may well be that the technological advances of the late eighteenth and nineteenth centuries in Britain and the United States were strongly labor saving and did induce innovation and technology adoption." There are several explanations for the structural change. First, the high land-labor ratio in the early settlements made labor a very expensive factor at that time (Temin (1971)). Second, technology-skill complementarity emerged in manufacturing early in the twentieth century as technologies, known as batch and continuous-process methods of production, spread (Goldin and Katz (1998)). Finally, the education and skill sets of workers shifted the nature of technical change in the twentieth century (Acemoglu (2002)).

Our estimates reveal that although, on average, agricultural patenting increased after the arrival of free banking, agricultural patenting declined in states where labor exploitation was severe. While surprising at first glance, this finding is consistent with the mechanism of finance impeding innovation by exacerbating the extent of exploitation and reducing labor costs. In states where slavery was pervasive, enslaved people represented the bulk of planters' investment and wealth (Wright (2006)). Bankers provided mortgages and equity loans, enabling the financialization of slavery (see, e.g., Martin (2010), Murphy (2017a)). Hence, improved access to finance likely increased the use of exploited labor and reduced producers' marginal labor cost. This dynamic response to labor cost discouraged producers from adopting labor-saving technologies, thereby breaking the previously documented finance-innovation nexus.

Consistent with the proposed mechanism, we find that free banking increased wage rates in areas without labor exploitation and decreased the marginal cost of labor in areas where exploitation was pervasive. Our evidence supports two potential channels for the decline in labor costs in areas with exploited workers. One channel is that free banking led to an increase in the enslaved population and to more widespread slavery, consistent with historical accounts of the interregional trade and migrations of enslaved people (Fogel and Engerman (1974)). Another channel is the increased concentration of enslaved workers on large plantations after passage of the free banking law. Economies of scale on large plantations likely led to more intense monitoring, lower operating costs, and higher productivity, suggesting an increase in labor exploitation. Both channels accord with the mechanism that free banking aggravated exploitation, reduced labor costs, and slowed technical progress in agriculture. Our results thus highlight a novel and nuanced interaction between access to finance and labor practices, which jointly determine innovation outcomes.

Our paper contributes to the literature on the finance-growth nexus. Pioneered by Schumpeter, this vast literature has established a positive link between financial development and economic growth.[4] However, recent evidence is mixed on the effect of banks on innovation. Hall and Lerner (2010), for example, discuss concerns about the effectiveness of banks (and credit) in financing innovation, whereas studies that assess US banking deregulation from the 1970s to the 1990s show that bank financing is vital for firms that engage in innovation (Amore, Schneider, and Žaldokas (2013), Chava, Oettl, Subramanian, and Subramanian (2013), and Cornaggia, Mao, Tian, and Wolfe (2015)). Adding to this literature, we use the staggered adoption of free banking laws in pre-Civil War America as a shock to bank entry.[5] Our evidence reveals a novel mechanism of finance having

[4]See, for example, King and Levine (1993a), (1993b), Jayaratne and Strahan (1996), Levine (1997), Beck, Levine, and Loayza (2000), Bodenhorn (2000), Black and Strahan (2002), Brown, Fazzari, and Petersen (2009), Kerr and Nanda (2009), Chemmanur, Loutskina, and Tian (2014), and Carlson, Correia, Luck (2022).

[5]We are among the first to examine the staggered rollout of the free banking laws. Our study thus also adds to the assessment of the real effects of free banking (see, e.g., Rockoff (1974), Rolnick and Weber (1983), Bodenhorn (1990), and Economopoulous and O'Neill (1995)). Jaremski and Rousseau (2013) find that free banks did not play a direct role in sustaining economic growth when compared to charter banks. Their data and approach differ from ours, which potentially explains the different conclusions.

an ambiguous effect on innovation by shifting the cost of labor. Ours is the first study we are aware of that highlights a nuanced interaction between two factors (labor practices and access to finance) which jointly determine innovation outcomes.

By examining an extreme form of exploitation in history, our study reveals the subtle and pernicious economic effects of exploitative labor practices, which remain a widespread phenomenon today.[6] In line with historical institutions and practices having persistent and long-term consequences (see, e.g., D'Acunto (2018), D'Acunto, Prokopczuk, and Weber (2018)), slave trades are shown to have adversely affected present-day economic outcomes (see, e.g., Nunn (2008), Pierce and Snyder (2017)). Our findings highlight a first-order channel through which exploitative labor practices depressed growth: producers using exploited workers lacked an incentive to adopt labor-saving technologies. In this sense, our findings are in line with Wright (2006), who emphasizes the long-run inefficiency of slavery. Although slavery might have seemed an "efficient" means of production for planters at the time, such exploitative conduct likely crowded out investment in machinery and locked people into a production method that would have proven inefficient in the long run.

This article proceeds as follows: Section II provides historical background and develops hypotheses. Section III describes the data. Section IV examines the effect of free banking on innovation, and Section V focuses on the role of labor practices in shaping this relation and provides causal evidence using the 1850s cholera pandemic and the influx of Irish immigrants from 1820 to 1860. Section VI concludes.

II. Historical Background and Hypothesis Development

A. Pre-Civil War Technological Innovation

The pre-Civil War era refers to the period in US history from just after the War of 1812 until 1860 before the beginning of the Civil War. During this time, the country experienced rapid economic growth. Innovations such as the mechanical reaper, the steel plow, the rotary printing press, and the sewing machine radically transformed the production process. Behind this vigorous inventive activity was a sustained acceleration of patenting and a solid patenting system that provided avenues for commercializing innovations. It took several months for a patent to

First, they measure growth using decadal changes in urbanization, manufacturing capital, and farm capital in the 1850s and 1860s; instead, we measure growth using patenting activity at annual frequency (a more granular account of growth via technological advances). Second, their analysis uses county-level aggregates for free and charter banks as independent variables and focuses on the cross-sectional association between banks and economic outcomes for the 2 decades. Instead, our specification uses the staggered bank-deregulation shocks, which sheds light on the causal effect.

[6]Although forced labor has been banned, labor exploitation remains widespread. According to a report by International Labour Organization (2017), 25 million people worldwide were forced into exploitative labor in 2016. Victims of forced labor suffered multiple forms of coercion from employers, including withheld wages, threats of nonpayment of wages due, and threats of violence.

be examined after the filing of an application. At times inventors would sell their patents to manufacturers who were better at commercializing and producing.[7]

The boom in patenting appears consistent with an emphasis on demand-induced advances in inventive activity. In particular, labor cost acted as a potentially powerful inducement for the invention of labor-saving tools and technologies. As Habakkuk ((1962), p. 17) noted, “the dearness and inelasticity of American, compared to British labour, gave the American entrepreneur … a greater inducement than his British counterpart to replace labour by machines.” This labor-saving incentive was especially relevant in agriculture, in which tasks such as reaping, threshing, and winnowing were labor intensive (Rasmussen (1982)). For example, in New York, Pennsylvania, and Ohio, where farm labor was scarce, inventions for winnowing grain were in great demand. However, on southern plantations, completing the same task relied intensively on enslaved workers who used winnowing baskets and winnowing barns.

B. Limited Access to Banks and the Passage of Free Banking Laws

Access to finance was generally limited in the early nineteenth century. The widespread use of capital markets was uncommon, and banking services were local. Banks needed to be chartered by a state legislature. A state typically had only a few charter banks, which operated in major cities. Due to restrictions on interstate branching, information frictions, and transportation costs, banking was legally and economically a local affair.[8] A legislative committee from Rhode Island reported “the greater part of the banks are, properly speaking, local, and managed for the accommodation of the people residing in or near the places of their location” (Congress ((1837), p. 44)).

Several factors contributed to the limited access to banks. First, the chartering system was a tedious and cumbersome process that severely restricted the number of banks opened. Second, the approval of a charter often depended on the political influence that was aimed at protecting the interests of incumbent banks. Once a bank was successfully chartered, its supporters then lobbied heavily against the formation of new, competing banks. As Hammond wrote, “It had long been difficult to get new bank charters in New York, because the [Albany] Regency kept the number down conservatively” (Hammond ((1957), p. 574)). As a result, some parts of the country had little access to banking facilities, while banks in many other locations enjoyed a virtual monopoly (see, e.g., Murphy (2017c)). Third, early charter banks operated only in major cities and rarely provided financial services to ordinary households in peripheral areas. In fact, these charter banks conducted

[7]For instance, Walter Hunt was granted a patent for the safety pin in 1849. He sold the patent right for about $10,000 (in today’s dollars) to W. R. Grace and Company, who then mass-produced the safety pin.

[8]Charters and corporate bylaws that restricted a bank’s office to a specific place did not restrict its lending to that place, but information asymmetries narrowed the pool of potential borrowers. Familiarity with customers was closely associated with geographic proximity because proximity lowered the cost of gathering information, monitoring borrowers, and enforcing the terms of the lending agreement (Bodenhorn (2006)). The Second Bank of the United States operated from 1816 to 1836 and had 25 branches. The bank’s essential function was to regulate the public credit issued by private banks through the fiscal duties it performed for the US Treasury (see, e.g., Hammond (1957)).

TABLE 1

Passage of Free Banking Laws

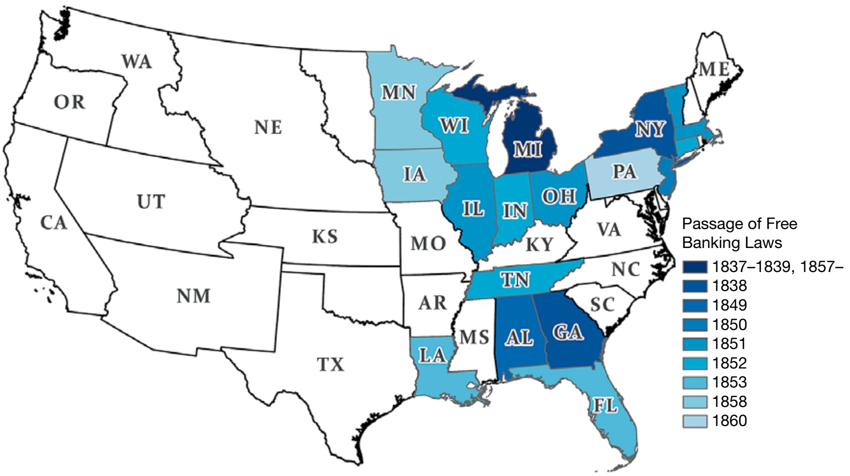
Table 1 lists the passage year of the free banking law for the 18 states. Michigan passed the free banking law in 1837, abolished it in 1840, and reinstated it in 1857. The passage years are from Rockoff (1974).

State	Year of Passage	State	Year of Passage
Michigan	1837, 1857	Connecticut	1852
New York	1838	Indiana	1852
Georgia	1838	Wisconsin	1852
Alabama	1849	Tennessee	1852
New Jersey	1850	Louisiana	1853
Vermont	1851	Florida	1853
Ohio	1851	Minnesota	1858
Massachusetts	1851	Iowa	1858
Illinois	1851	Pennsylvania	1860

FIGURE 1

Passage of Free Banking Laws

Figure 1 maps the staggered timeline of passage of free banking laws in individual states. The states and territories are labeled with their abbreviations, and their borders drawn according to the 1860 map. States established after 1812 only enter our sample starting from the year of establishment, as listed in Table A.1 in the Supplementary Material.



extensive insider lending to members of their own boards of directors or to others with close personal connections to the boards (see, e.g., Lamoreaux (1996)).

The free banking laws initiated banking deregulation reforms by removing the necessity of a legislative charter for a bank to be established.[9] The adoption of free banking laws was staggered across 18 states; the first was in Michigan in 1837 and the last was in Pennsylvania in 1860. Table 1 lists the 18 states and their adoption year. These states included 7 in the Midwest, 5 in the South, and 6 in the Northeast. As shown in Figure 1, free banking spread through every region. The laws allowed "free entry" upon a bank's satisfaction of the stipulated requirements, thereby

[9]The free banking laws did not preclude the legislatures from issuing charters. In fact, many free banking states continued to issue charters, thus establishing a dual banking system.

lowering barriers to entry (see, e.g., Economopoulous and O'Neill (1995)). In effect, anyone who had the required paid-in capital was allowed to open a bank that could issue its own notes, take deposits, and make loans.[10] This deregulation appealed both to Jacksonian Democrats, who believed the chartering system was too monopolistic and aristocratic, and to the more commercially oriented Whigs, who thought that the chartering process was too slow to address the financial needs of a rapidly expanding frontier.

Historians have not yet reached a consensus on the factors that determined where and when the laws were passed. In the Supplementary Material, we provide a brief narrative on state-banking legislative history regarding events leading up to the law's passage. Overall, early banking legislation was in its infancy, and the development of events was fairly idiosyncratic across states. In some states, the timing of the law's enactment seems to have been initiated by accidental events. An interesting example is from the state of New York, as discussed in Bodenhorn (2006). The legislation was triggered by an unlikely event, the kidnapping of a man named William Morgan after he threatened to reveal the secrets of the Masons. Investigations into the kidnapping implicated several famous Masons who were politically connected with the Regency. As legislative debates on banking policy became anti-Masonic, the Regency lost support and the free banking law was eventually adopted. Bodenhorn calls this the "serendipitous nature of economic reform." We formally test the exogenous nature of the adoption across states in Section IV.A.

Microlevel evidence suggests that free banks before the Civil War assisted, perhaps even animated, inventions and entrepreneurship. Bodenhorn (1999) examines surviving loan-level records of the Black River Bank of Watertown, New York, and shows that the bank operated as an *innovation-inducing Schumpeterian bank.* Banker Paddock founded the Black River Bank in 1844 under the terms of New York's free banking law. By the early 1850s, the bank had grown into the second largest bank in Watertown. Using 2 discount books for the period of 1844 to 1859, Bodenhorn matches the borrowers' names to city directories and manuscript censuses to provide insights into the banker's lending practice. He finds that merchants, who had good collateral and were favored borrowers of charter banks, were relatively underrepresented, whereas manufacturers, small businesses, and young entrepreneurs were overrepresented.

A notable example was the financing of Bradford, who invented the portable steam engine. In 1849 Bradford constructed a working model of a portable steam engine and formed a partnership with machinist Hoard. Hoard & Bradford turned to banker Paddock for financial assistance. With a number of notes from the bank, the partnership flourished in the 1850s, ultimately developing by 1857 into a firm with 150 machinists. The Black River Bank's support of Hoard & Bradford was not

[10]The free banking era was not a period of laissez-faire banking. Despite unrestricted entry, banks established under the free banking laws were subject to strict oversight intended to protect the noteholders. First, free banks had to deposit designated state and federal bonds as collateral for all notes issued. Second, they were required to pay specie for their notes on demand and at par value. Finally, free bank stockholders had double liability, that is, they were liable for bank losses in an amount up to the value of their stock. Most free banking laws provided additional protection for noteholders by giving them first lien on the assets of a bank (see, e.g., Rolnick and Weber (1983)).

atypical. There were several other instances of the bank offering financial assistance to fledging upstarts, including Remington, who established the Remington paper mill in 1853, and to Hotchkin, who established a tannery and harness manufactory in Watertown in 1854. These instances reflect well on Paddock's role as a Schumpeterian banker in financing innovative entrepreneurs.

C. Exploitative Labor Practices

Exploitative labor practices enabled by the institution of slavery were prevalent at the time. Relative to Europe, America was land abundant and labor scarce, with the bulk of the labor force working in agriculture (Rosenbloom (2018)). Labor markets were segmented across regions with considerable heterogeneity. The regional divergence in the practice of slavery gave rise to differences in the use of exploited labor.

In states with no enslaved population, workers had property rights in their own labor and were wage earners. Like in contemporary labor markets, workers entered into agreements to provide labor services for a limited time, and producers incurred a unit cost of labor comparable in magnitude to labor's marginal product. In the Northeast, agricultural labor had started to transition to industrial occupations. Despite a high population density, agricultural producers had incentives to reduce their reliance on labor because the rapid growth of the Northeast manufacturing sector was associated with wages adjusting upward in both the agricultural and manufacturing sectors (Goldin and Sokoloff (1982)). The Midwest was a major engine of agricultural growth: based on the census data of 1850 and 1860, the ratio of agricultural to manufacturing output averaged around 1.80, compared to that of 0.58 in the Northeast. Although the land was cheap to acquire, the supply of agricultural labor was scarce and unreliable. Demands for harvest labor occurred in a short window, which typically drove up wages (Rosenbloom (2018)). The high cost and difficulty of hiring farm labor were important considerations for the rapid adoption of new cultivating inventions such as steel plows and mechanical reapers (David (1975)).

In states with enslaved population, enslaved labor and wage-earning labor coexisted. Unlike wage earners, enslaved workers, who formed the major workforce in agriculture, faced *labor exploitation* (Ransom and Sutch (2001)). Enslavers had property rights in the labor of enslaved workers. This property rights regime meant relatively unrestricted control over labor's time and effort, ensuring that sufficient labor was available at crucial times in the agricultural cycle.[11] This observation accords with agricultural historians who argue that slavery relieved a labor constraint faced by those northern farmers (see, e.g., Fleisig (1976)).

Exploitative labor practices allowed enslavers, the "laborlords" as Wright (2006) puts it, to extract a large proportion of enslaved workers' marginal product while paying a low maintenance cost. As Adam Smith famously said of the enslaved labor in his condemnation of slavery, "Whatever work he does beyond

[11] Whereas wage earners might also have experienced some extent of labor exploitation, the nature of exploitation faced by an enslaved worker was institutionalized by the property rights system (Wright (2006)): Wage earners could have walked out or insisted on improved conditions or wages, but enslaved workers could not.

what is sufficient to purchase his own maintenance, can be squeezed out of him by violence only." Representative McDuffie of South Carolina spoke of "efficient agricultural labor operating at 12.5 cents a day and producing one of the most valuable staples on the earth" (Congress (1832)). This meant a cost of $3.75 a month, compared to the wage of $7.33 plus board paid to free agricultural labor in the South Atlantic area. Using data on costs and returns for slaveholding, Lebergott (1960) estimates that the cost excluding board ran merely to about $1.25 a month. A similar estimate was given by Conrad and Meyer (1958). Such differences in labor costs should not be interpreted as differences in productivity. Despite their low unit cost, enslaved field hands were on average harder working and more efficient than their white counterparts (Fogel and Engerman (1974)). In sum, slavery led to exploitative labor practices. The lower unit cost of labor relative to the product of labor potentially obviated the need for producers to pursue the invention and improvement of labor-saving technologies.

The enslaved population increased nearly fourfold from 1810 to 1860.[12] Meanwhile, markets for trade of enslaved people were well-developed. Trade was allocated by a system of regional specialization, with New Orleans serving as the site of the largest market (Calomiris and Pritchett (2016)). Throughout this time, banks were involved in the trade by underwriting the sales of enslaved people. As noted by Murphy ((2017a), p. 1), "The use of slaves as collateral, and the readiness of banks to foreclose on this property, placed southern banks at the heart of the buying and selling of slave property, one of the most reviled aspects of the slave system."

D. Hypothesis Development

In this section, we develop testable hypotheses motivated by theory and literature. We contend that both access to finance and labor practices are critical factors in shaping innovation outcomes. To articulate the theoretical motivation for our hypotheses, we provide a conceptual framework in Appendix B where we show that the equilibrium level of labor-saving innovation equates its marginal cost with its marginal benefit. The marginal cost, motivated by information frictions and transaction costs inherent in financing innovative activities, is inversely related to access to finance. The marginal benefit of labor-saving technology is positively associated with the marginal cost of labor. Consequently, two factors (access to finance and the marginal cost of labor) jointly determine innovation outcomes.

According to our first testable prediction of the model, all else equal, access to finance promotes innovation. The idea is that innovative projects by nature are difficult to evaluate, have skewed and uncertain returns, and require a long-term commitment of resources.[13] Access to finance mitigates information frictions and transaction costs, facilitates exchange, relaxes entrepreneurs' financing constraints,

[12]High birth rates and low mortality rates contributed to an exceptional rate of natural increase. In addition, Collins (1904) lists extensive evidence that at least 270,000 enslaved were introduced into the US from 1808 to 1860; the importation of enslaved workers from abroad had been prohibited by 1808, but the laws were not entirely effective.

[13]See, e.g., Kerr and Nanda (2015), Nanda and Rhodes-Kropf (2017), and Chemmanur and Tian (2018).

and diversifies risks associated with uncertainty and long-run capital commitments (King and Levine (1993b), Levine (1997)). Such benefits are consistent with the literature that suggests a positive, first-order relationship between finance and growth. Schumpeter ((1934), Ch. 3) argued that well-functioning banks stimulated innovation by identifying and funding entrepreneurs with the best chances of successfully implementing innovative products and production processes. In their cross-country study, King and Levine (1993a) find empirical support for the finance-growth nexus. Evidence from the US shows that state-level banking deregulation accelerated economic growth (Jayaratne and Strahan (1996)), fostered entrepreneurship (Black and Strahan (2002)), and spurred corporate innovation (Amore et al. (2013), Chava et al. (2013), and Cornaggia et al. (2015)). Meanwhile, Nanda and Nicholas (2014) show that bank distress in the Great Depression reduced patenting, suggesting a positive relation between credit markets and innovation.[14]

In the pre-Civil War era, the widespread use of capital markets was uncommon, and bank services were local; hence, we expect to see an overall positive response of innovation to bank entry. Local bankers could help entrepreneurs and inventors in several ways. First, local bankers provided more accessible financial support for the adoption of new technologies. McKinnon ((1973), p. 13) emphasizes "the virtual impossibility of a poor farmer's financing from his current savings the whole of the balanced investment needed to adopt the new technology. Access to external financial resources is likely to be necessary." Second, as the example of Black River Bank described in Section II.B demonstrates, local bankers acted as Schumpeterian financiers to identify and endorse promising entrepreneurs, much like the role played by today's venture capitalists. Finally, banks helped expand the market size by promoting exchange and made it profitable for entrepreneurs to commercialize new inventions. This is consistent with the observation of Lamoreaux and Sokoloff ((1996), p. 17) that "it was primarily the development of institutions that facilitated the exchange of technology in the market that enabled creative individuals to specialize in and become more productive at invention." The above discussion leads to our first hypothesis.

Hypothesis 1. Improved access to finance, all else equal, leads to more innovation.

Regarding labor-saving innovation, the conceptual framework described in Appendix B also predicts a negative cross-sectional relationship between the degree of labor exploitation and the sensitivity of innovation to financial development. Consistent with Habakkuk's (1962) hypothesis, economizing on labor costs poses a strong incentive for producers to adopt labor-saving technologies.[15] Hence, the marginal benefit of labor-saving innovation and its sensitivity to access to finance

[14]The positive role of finance in innovation is not confined to credit markets. Some studies, for example, emphasize the importance of equity markets (Brown et al. (2009), Hsu, Tian, and Xu (2014), and Celik, Tian, and Wang (2020)), while others highlight the role of venture capital (Chemmanur et al. (2014)) and foreign institutional investors (Luong, Moshirian, Nguyen, Tian, and Zhang (2017)).

[15]Similarly, Rosenberg (1969) contends that firms tried to invent labor-saving technologies when labor was scarce. Acemoglu (2010) further establishes conditions under which the high cost of labor encourages technological advances. Hornbeck and Naidu (2014) and Bena, Ortiz-Molina, and Simintzi (2020) provide empirical evidence supporting the theoretical prediction.

depends on the marginal cost of labor. In the context of pre-Civil War America, labor markets were segmented; there was considerable heterogeneity across regions in the degree of labor exploitation as reflected in the practice of slavery. In regions where exploitative labor practices were absent, producers incurred a unit cost of labor comparable in magnitude to labor's marginal product; we expect access to finance to impact technological innovation substantially. Conversely, in regions where exploitative labor practices were pervasive, planters used their property rights over enslaved workers to extract part of workers' marginal product, and thus had little incentive to shift away from labor-intensive production methods. In those regions, we expect access to finance to have a weaker impact on technological innovation. Together, this leads to our second hypothesis.

Hypothesis 2. Improved access to finance has a weaker impact on labor-saving innovation in regions that use exploitative labor practices.

So far, we have taken the unit cost of labor in a region as fixed, yet labor cost may respond to improved access to finance. If so, the link between labor cost and labor-saving innovation will provide an additional channel through which finance influences innovation. This second channel adds nuance to the sensitivity of innovation to finance. A rise in labor cost strengthens the finance-innovation nexus, whereas a concomitant decline in labor cost weakens (and can even break) the finance-innovation nexus. Take the Midwest region for an example. Better financing promoted the development of the manufacturing sector, which competed for labor supply and aggravated the scarcity of farm labor. Hence, we should expect more inventions and improvements in farm technology in those states. By contrast, in regions where slavery was prevalent, if banks further reduced the unit cost of labor by exacerbating the extent of labor exploitation (e.g., through facilitating enslaved trade and increasing the concentration of slaveholding), we might observe a negative relation between finance and innovation. We therefore test the following hypothesis.

Hypothesis 3. If improved access to finance exacerbates the extent of labor exploitation, the impact of finance on innovation is ambiguous and might be negative.

III. Data and Summary Statistics

To assess the effect of free banking on innovation and the role of labor practices in shaping this relation, we gather data on the passage of the free banking law, bank balance sheets, patents, proxies for labor exploitation, and control variables.

A. Measuring Access to Finance and Free Banking Events

We measure access to finance using detailed bank data from Weber ((2006), (2008)), which are complemented with hand-collected records. While the former provides comprehensive documentation for the charter banks before the Civil War, the presence of free banks in Southern states appears underestimated in Louisiana and Tennessee. Therefore, we enhance the data set by hand collecting information

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

from a set of secondary sources.[16] For example, the *Merchant's and Banker's Almanac* documented that 7 out of a total of 11 Louisiana banks in 1859 were free banks; similarly, 16 out of a total of 36 Tennessee banks in 1855 were free banks. See Figures A.1 and A.2 in the Supplementary Material for the *Merchant's and Banker's Almanac* records.

We assemble bank-level data which consist of the name of the bank, its charter type, the location of operation, entry and exit dates, and detailed balance sheet items by year, including total assets, loans, and discounts (all in thousands of dollars). The balance sheet size of an average free bank was slightly smaller than that of an average charter bank. For example, an average free bank had a total asset of 0.57 million dollars, compared to an average charter bank's asset of 0.77 million dollars. The largest free bank was the Bank of Commerce in New York with an asset size of 18 million dollars, and the largest charter bank was Citizens Bank of Louisiana with an asset size of 16 million dollars.

The passage of the free banking law is represented by an indicator variable, FREE_BANKING. For the 18 states that adopted free banking, we set the FREE_BANKING indicator equal to 0 in all the years preceding the law's passage and equal to 1 starting from the passage year onward. For Michigan, we allow the indicator to revert to 0 starting from 1840 when the state abolished free banking and change it back to 1 beginning in 1857, when the state reinstated the law. For the 21 states that did not pass the law, we set the indicator equal to 0 for all years.

B. Measuring Innovation

To measure technological innovation outcomes, we rely on the number of patents granted every year at the state and county levels. The source is digitized patent filings from the United States Patent and Trademark Office (USPTO). From the original patent documents, we obtain the patent number, the year in which the patent was granted, and the state and county where the inventor resided. We link this data set with the USPTO's historical patent files using the patent number to obtain the technology class to which the patent belonged.

To test the hypothesis that labor practices affect the marginal impact of finance on labor-saving innovation, we focus our analysis on agricultural patents for two reasons. First, as discussed in Section II.A, the labor-saving incentive for technology adoption in the pre-Civil War era was especially relevant in agriculture. Second, our empirical strategy leverages the spatial variation in exploitative labor practices in agricultural production. To identify patented technologies used in agriculture, we map the USPTO technology classes into 36 2-digit technological categories following Hall, Jaffe, and Trajtenberg (2001). Agricultural patents consist of those that fall into category 61 (Agriculture, Husbandry, Food).[17] Graph A

[16]The secondary sources include the *Merchant's and Banker's Almanac* (1856, 1860), Economopoulous and O'Neill (1995), the *Bankers' Magazine and Statistical Register*, and the Comptroller of Currency Report (OCC 1876).

[17]This technological category corresponds to the USPTO patent classes 43 (Fishing, Trapping, and Vermin Destroying), 47 (Plant Husbandry), 56 (Harvesters), 99 (Foods and Beverages: Apparatus), 111 (Planting), 119 (Animal Husbandry), 131 (Tobacco), 426 (Food or Edible Material: Processes, Compositions, and Products), 449 (Bee Culture), 452 (Butchering), and 460 (Crop Threshing or

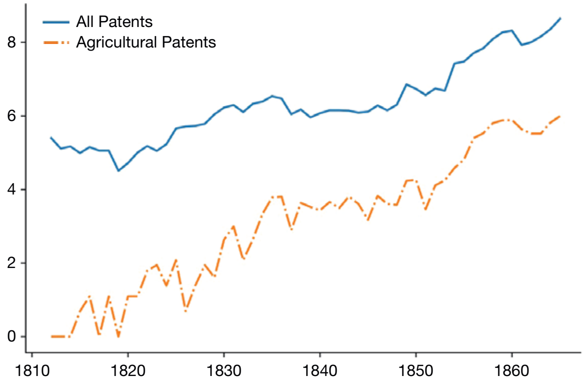
https://doi.org/10.1017/S0022050722000795 Published online by Cambridge University Press

FIGURE 2

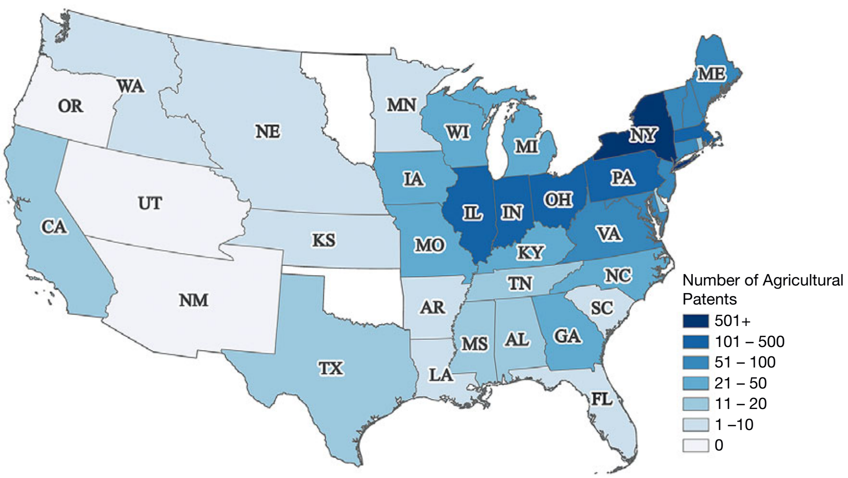
Patent Data

Figure 2 illustrates the patent data. Graph A plots the natural logarithm of 1 plus the total number of patents (the blue solid curve) and of agricultural patents (the orange dashed curve) for 1812–1860. Graph B visualizes the cross-sectional variation in agricultural patenting across states based on the total agricultural patents in each state for 1812–1860.

Graph A. Number of Patents per Year



Graph B. Spatial Variation in Agricultural Patents



of Figure 2 plots the natural logarithm of 1 plus the total number of patents and of agricultural patents over time. Graph B of Figure 2 visualizes the total number of agricultural patents in each state on the map; Figure A.3 in the Supplementary Material provides a similar map for the total number of agricultural patents per capita. Both figures demonstrate significant spatial variation in agricultural

Separating). Most patented technologies in agricultural mechanization fall into one of these classes. For instance, McCormick's mechanical reaper (Patent No. 5335) and Knowles and Bevington's mower (Patent No. 7475) both belonged to patent class 56; Urmy's seed planter (Patent No. 8866) belonged to patent class 111; Murdock's tobacco cutter (Patent No. 11330) belonged to patent class 131; Dozier's threshing machine (Patent No. 5050) belonged to patent class 460.

patenting, whereas the geographical distribution of agricultural patents per capita appears less skewed.

Patents could miss certain valuable inventions and technologies. Nonetheless, while imperfect, patent data are often the best available and the most widely used measure of inventive activity before the Civil War, particularly since the alternative economic census data were available only at the decennial frequency. Studies have shown a strong correlation between patenting and the resources consumed in inventive activity (see Griliches (1990) for a survey). Sokoloff (1992) uses census data and shows that patenting was a major driver of state-level total factor productivity in the pre-Civil War era. Nanda and Nicholas (2014) examine the quantity and quality of patenting to measure innovation during the Great Depression.

In using geographical information on patents, we assume that the place where the patent was granted proxies for the place where the technology was adopted, at least at the initial marketing stage. Indeed, with high transportation costs, the technology market was fractional and segmented at that time. Lamoreaux and Sokoloff (2000) use industry directories to map the location of the firms that adopted the most advanced technologies. They also use trade journal accounts to track the geographic origins of the most important inventions in an industry. They find that both sources correspond closely with the distribution of patents, suggesting that the location of inventions was largely consistent with that of technology adoption.

C. Measuring Labor Exploitation

The practice of slavery led to exploitative labor practices. The pervasiveness of labor exploitation differed across states and shaped the local cost of labor in agricultural production. To measure the extent of labor exploitation, we construct the variable, LABOR_EXPLOITATION, as the fraction of a state's (county's) population that was enslaved when the state entered the pre-Civil War era. We use the time-invariant fraction of the initial enslaved population to isolate it from changes in the enslaved population in response to local financial development. If a state or territory did not have population data reported in the 1810 census, we instead use the first year when the demographic data are available.[18] Among the 39 states in our sample, 28 states had positive LABOR_EXPLOITATION; see Table A.1 in the Supplementary Material. Of these 28 states, 17 had legal systems that sanctioned slavery. The top 5 states with the highest LABOR_EXPLOITATION were South Carolina, Louisiana, Florida, Mississippi, and Georgia, which remained among the states with the highest fractions of enslaved population in 1860. The other 11 states, including New York, New Jersey, and Illinois, abolished slavery with gradual emancipation, and the existing enslaved population had to remain with their former owners as indentured servants. The enslaved population in these areas was generally small.

[18]Our results are robust to using the contemporaneous measures of the fraction enslaved; see Table A.6 of the Supplementary Material. In Section V.A, we will examine plausibly exogenous variations in LABOR_EXPLOITATION.

TABLE 2

Summary Statistics

Table 2 reports the summary statistics for the state-year observations of our main sample. For bank variables, we report the summary statistics for the whole sample period, as well as for the state-year observations conditional on passing the free banking law. The definitions of all variables are provided in Appendix A.

	No. of Obs.	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile
PATENTS	1,449	25.48	75.23	1	5	19
AGRICULTURAL_PATENTS	1,449	1.827	6.179	0	0	1
POPULATION (thousands)	1,449	567.1	579.1	158.4	409.7	738.0
URBAN_RATIO	1,449	0.127	0.185	0.019	0.057	0.159
WHITE_RATIO	1,449	0.818	0.189	0.648	0.919	0.988
LABOR_EXPLOITATION	1,449	0.148	0.171	0.001	0.044	0.304
Bank variables for the whole sample period						
FREE_BANKS	1,449	3.658	23.29	0	0	0
FREE_BANK_ASSETS (thousands)	1,449	2,070	18,112	0	0	0
FREE_BANK_LOANS (thousands)	1,449	1,472	14,182	0	0	0
CHARTER_BANKS	1,449	17.16	25.53	2	6	23
CHARTER_BANK_ASSETS (thousands)	1,449	13,105	19,083	1,758	6,073	16,197
CHARTER_BANK_LOANS (thousands)	1,449	8,909	13,990	1,092	3,709	11,271
Bank variables conditional on passing the free banking law						
FREE_BANKS	175	30.28	60.86	0	6	25
FREE_BANK_ASSETS (thousands)	175	17,140	49,699	0	2,364	8,130
FREE_BANK_LOANS (thousands)	175	12,190	39,274	0	524.3	2,954
CHARTER_BANKS	175	34.06	41.34	4	20	48
CHARTER_BANK_ASSETS (thousands)	175	28,496	32,557	7,411	17,682	35,710
CHARTER_BANK_LOANS (thousands)	175	18,839	25,715	1,501	8,716	18,998

D. Sample Construction and Summary Statistics

Our sample spans from 1812 through 1860. States established after 1812 enter our sample starting from the year of establishment as a territory or statehood, whichever is earlier.[19] To control for demographic and socioeconomic conditions at the state and county level, we obtain information from the decennial censuses of 1810–1860 and the Census of Agriculture in 1840, 1850, and 1860. We use the following baseline control variables: ln(POPULATION) defined as the natural logarithm of a state's (county's) population, URBAN_RATIO as the fraction of population that was urban, and WHITE_RATIO as the fraction of population that was white. The definitions of all variables are provided in Appendix A. In robustness analyses, we also include characteristics related to industry composition, educational attainment, foreign-born fraction of the population, and access to railroads. Since the control variables are decennial, we interpolate them linearly to the intervening individual years. Our sample consists of 1,449 state-year observations and covers 39 states.

Table 2 reports the descriptive statistics for our sample. An average state had 25.48 total patents and 1.83 agricultural patents granted per year. Since both total patents and agricultural patents are right skewed, we take the log transformation to reduce the effects of outliers. The average population in a state was 0.57 million, of which 12.7% were urban population and 81.8% were white population. LABOR_EXPLOITATION for the state-year sample has a mean of 14.8%, a median of 4.4%,

[19]Table A.1 of the Supplementary Material provides the list of states and the year of territory/statehood. The date of statehood information is obtained from www.history.com/topics/us-states.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

and a standard deviation of 17.1%, suggesting substantial differences in the fractions of populations enslaved across states.

In an average state, there were 3.66 free banks, $2.07 million in free bank assets, and $1.47 million in loans issued by all free banks per year. Of those state-years that adopted free banking, there were an average of 30.28 free banks, which together had assets valued at $17.14 million and issued a statewide average of $12.19 million in loans each year. For those same observations, there were an average of 34.06 charter banks, which together had assets valued at $28.50 million and issued a statewide average of $18.84 million in loans each year.

IV. Free Banking and Innovation

A. Identification Strategy

We use a difference-in-differences approach to assess the extent to which improved access to finance affected innovation. Our identification strategy requires that the enactment of the free banking laws imparted a positive shock to a state's access to finance. We begin by empirically testing how the timing of free banking in a state was related to potential determinants of innovation. Using a hazard model, we predict the "time until the law's passage" with a diverse set of variables. Besides state-level demographic characteristics and wage rates, we also include variables to measure the pre-event conditions of innovation and banking development in a state, which could potentially confound the causal impact of free banking on innovation.[20] Another factor possibly related to both innovation and banking is the alternation of state political parties in power. For example, the Whig Party favored modernization, banking, and economic protectionism to stimulate manufacturing.[21] We additionally include measures of industry composition, educational attainment, and access to railroads. Estimations of the hazard model, reported in Table A.2 in the Supplementary Material, show that none of the variables significantly predict the likelihood of the law's passage in a specific year.

We provide evidence that the adoption of free banking indeed accelerated bank entry and improved access to finance. Panel A of Table 3 reports the entry of free banks within 3 years following the law's passage in the free banking states. We observe substantial free bank entry reflected in bank counts and assets, as well as in loans and discounts. On average, there were 19 free bank entries per state within 3 years following the law's passage, accounting for more than three times the number of banks operating in years before free banking. While the southern banking sector was considered smaller and had higher barriers to entry due to the preexisting bank branch networks serving plantation owners, we observe entry in those states as well. For example, Tennessee had 16 free banks adding to its 5

[20]We include the variable LABOR_EXPLOITATION to alleviate the concern that the practice of slavery might have affected the adoption of free banking. Results are unchanged if we use WHITE_RATIO instead of LABOR_EXPLOITATION.

[21]The Whig Party, consisting of former members of the National Republican and Anti-Masonic Parties, emerged in the 1830s as the leading opponent of Jacksonians (supporters of President Jackson and his Democratic Party).

TABLE 3

Free Banking Law and Access to Finance

Table 3 summarizes evidence that the adoption of free banking led to better access to finance. Panel A reports the status of free banks as of 3 years following the adoption of free banking law for the 18 states. The amounts of bank assets and loans are in thousands. The percentages represent a comparison of levels 3 years after with levels 3 years prior to the law's passage. When the value prior to passage was 0, the percentage is denoted as "N/A." Panel B reports, for both free banks and charter banks, the OLS regression estimates for the response of access-to-finance measures to free banking. The dependent variables are the natural logarithm of 1 plus bank counts, assets, and loans of, respectively, free banks and charter banks in a state in a given year. The dependent variables lead the independent variables by 1 year. Robust standard errors clustered at the state level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

Panel A. Status of Free Banks as of 3 Years Following the Passage of the Free Banking Law

	FREE_BANKS		FREE_BANK_ASSETS		FREE_BANK_LOANS	
	Amount	Percentage	Amount	Percentage	Amount	Percentage
Michigan	40	333	3,448	59	1,904	57
New York	74	75	26,286	21	21,367	26
Georgia	1	5	145	0	95	1
Alabama	1	100	536	10	313	25
New Jersey	22	85	5,945	65	3,784	58
Vermont	1	4	222	4	152	3
Ohio	13	22	3,505	12	1,463	8
Massachusetts	0	0	0	0	0	0
Illinois	32	N/A	7,655	N/A	1,794	N/A
Connecticut	14	27	6,827	27	5,315	26
Indiana	83	638	19,813	259	7,950	397
Wisconsin	32	3,200	6,612	875	3,689	1,221
Tennessee	16	320	8,130	47	3,398	29
Louisiana	4	67	11,688	30	763	7
Florida	0	N/A	0	N/A	0	N/A
Minnesota	16	N/A	1,197	N/A	417	N/A
Iowa	0	N/A	0	N/A	0	N/A
Pennsylvania	0	0	0	0	0	0%

Panel B. Free Banking and the Access to Free Banks and Charter Banks

	ln(1 + BANKS)		ln(1 + BANK_ASSETS)		ln(1 + BANK_LOANS)	
	Free	Charter	Free	Charter	Free	Charter
FREE_BANKING	1.863***	0.126	10.173***	0.575	9.658***	0.048
	(0.461)	(0.128)	(1.596)	(0.657)	(1.529)	(0.777)
ln(POPULATION)	0.149	−0.103	0.348	1.216*	0.261	0.809
	(0.114)	(0.129)	(0.409)	(0.707)	(0.357)	(0.784)
URBAN_RATIO	2.537	0.063	4.553	2.053	6.145	3.369
	(2.551)	(1.453)	(9.333)	(4.945)	(8.875)	(4.976)
WHITE_RATIO	0.547	0.154	0.671	12.055	−2.222	10.708
	(1.679)	(2.605)	(7.746)	(12.214)	(5.998)	(12.064)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,410	1,410	1,410	1,410	1,410	1,410
R^2	0.673	0.900	0.700	0.741	0.706	0.751

existing charter banks, Louisiana had 4 banks adding to its 6 existing charter banks, and Alabama had 1 bank adding to its sole existing charter bank.

The notion of improved access to finance was particularly relevant as banking markets were local. Examining the county locations of the entrants, we find that the new banks entered rural, previously unbanked areas, and had broader geographical coverage than the existing charter banks. After the onset of free banking, 21.7% of previously unbanked counties had bank entry, and 18.5% of previously unbanked counties had free bank entry by 1860.

To rule out the possibility of capital reallocation from charter banks to free banks, we assess how free banking affected a state's access to finance in Panel B of

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

Table 3. As expected, the free banking laws allowed sizable free bank entry. More importantly, charter banks did not exit the market or become smaller. These results confirm that the banking sector as a whole expanded, and that access to finance improved following the adoption of free banking laws.

B. Baseline Analysis

We test the first hypothesis (improved access to finance leads to more innovation) using the following ordinary least squares (OLS) specification:

$$(1) \quad \ln(1+\text{PATENTS})_{i,t+s} = \alpha + \beta\text{FREE\_BANKING}_{i,t} + \gamma Z_{i,t} + \text{STATE}_i + \text{YEAR}_t + \epsilon_{i,t},$$

where i indexes state, t indexes year, and s is equal to 1, 2, or 3 years. The dependent variable is the natural logarithm of 1 plus the total number of patents granted in a state in the following 1, 2, and 3 years. The dummy variable $\text{FREE\_BANKING}_{i,t}$ captures the status of the law's passage in state i and year t. Z is the vector of state-level control variables (ln(POPULATION), URBAN_RATIO, and WHITE_RATIO). STATE_i and YEAR_t are state and year fixed effects, respectively. We cluster standard errors by state to account for serial correlation within states.[22]

The state-level control variables help absorb the time-varying socioeconomic conditions that were possibly associated with a state's inventive opportunities. We include population size and urbanization following Higgs (1971) who shows that, in the absence of a mass communications system, the number of inventions per capita was closely associated with the proportion of population in urban areas. The white population ratio largely reflected the local social class structure,

TABLE 4

Free Banking and Innovation: Baseline Results

Table 4 reports the OLS regression estimates of equation (1). The dependent variables in columns 1–2, 3–4, and 5–6 are the natural logarithm of 1 plus the total number of patents granted in a state in year $t+1$, $t+2$, and $t+3$, respectively. Robust standard errors clustered at the state level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

	ln(1 + PATENTS)					
	$t+1$		$t+2$		$t+3$	
	1	2	3	4	5	6
FREE_BANKING	0.471*** (0.165)	0.403*** (0.120)	0.550*** (0.180)	0.468*** (0.127)	0.570*** (0.199)	0.476*** (0.138)
ln(POPULATION)		0.453*** (0.093)		0.517*** (0.095)		0.583*** (0.099)
URBAN_RATIO		1.536* (0.871)		2.373** (0.941)		3.069*** (1.056)
WHITE_RATIO		1.648 (2.106)		1.931 (2.129)		2.631 (2.183)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,449	1,449	1,449	1,449	1,449	1,449
R^2	0.877	0.892	0.866	0.887	0.856	0.882

[22]To investigate potential bias in these standard errors due to the small number of clusters, we perform the wild bootstrap procedure following Cameron, Gelbach, and Miller (2008) and find robust results.

educational attainment, and division of labor. The state fixed effects allow us to strip out unobservable differences that persist across states; the year fixed effects enable us to control for economy-wide shocks and trends.

The estimation results are presented in Table 4. The coefficient estimates of FREE_BANKING are positive and significant at the 1% level across all columns. Consistent with Hypothesis 1, the results indicate that the passage of free banking law led to an increase in the number of patents in the subsequent 3 years. For instance, based on the coefficient estimate in column 6, those states that passed the free banking law experienced a growth rate of 47.6% in total patents in the third year, compared to states that did not pass the law. This estimate translates to an increase of 12.13 (=25.48 × 47.6%) patents, given an average of 25.48 patents granted in a state each year. This increase in patent quantity is economically sizable, accounting for 16.1% (=12.13/75.23) of the state-level patent variability.

The estimated sizable effect of free banking on innovation might work through both *direct* and *indirect* channels. Through direct channels, free banks entered areas that previously lacked access to financial services, made loans to "noninsiders" who did not have connections to charter banks, and encouraged manufacturing and small businesses (Bodenhorn (2000)). As noted in Section II.B, Bodenhorn (1999) provides microlevel evidence of the Black River Bank and shows that this free bank operated as an innovation-inducing Schumpeterian bank by directly supporting young, local innovators and entrepreneurs.

Also, free banks might have promoted innovation through indirect channels. The lower barrier to entry by free banks made incumbent charter banks more efficient and competitive (see, e.g., Bodenhorn (1990), Carlson et al. (2020)), improving the allocation of bank capital. Consistent with the view that banks generated a virtuous cycle of economic development through the transportation revolution, we find (in untabulated results) that free banking increased money supply and promoted the diffusion of railroad transportation networks, which likely enlarged market access and boosted incentives to innovate.

Whereas Table 4 shows that the effect on innovation started to be significant after 1 year, we believe this immediate effect is plausible for the pre-Civil War era for several reasons. First, innovations before the Civil War typically did not take too long to invent. For instance, Singer developed the first commercially practical sewing machine 11 days after being given a sewing machine to repair. Second, unlike today, examining and granting a patent took only several months. Finally, it was likely that the manufacturers of new tools and technologies were more sensitive to access to finance than inventors; when manufacturers had better financing, inventors had stronger incentives to patent existing ideas and inventions.

C. Robustness of the Baseline Results

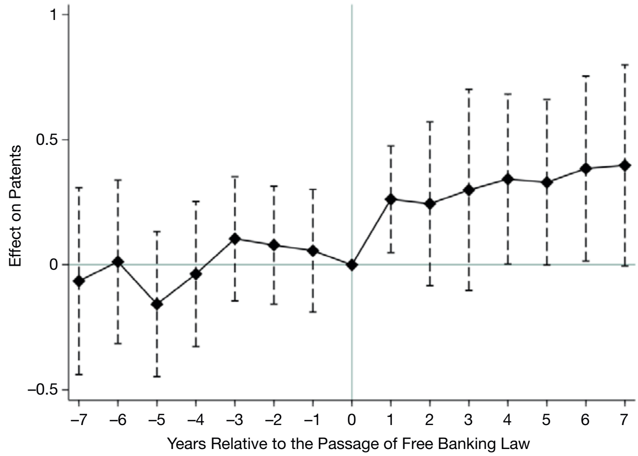
1. Temporal Dynamics

A relevant concern is reverse causality if states differed in their innovation intensity and if such differences triggered the passage of free banking laws. To alleviate this concern, we examine the dynamics of innovation surrounding the adoption of free banking. Specifically, we estimate an augmented version of equation (1) where we decompose FREE_BANKING into 4 dummy variables

FIGURE 3

Temporal Dynamics of Innovation

Figure 3 shows the temporal dynamics of innovation around the free banking year. The specification is the same as equation (1) except that the dummy variable FREE_BANKING is replaced by a collection of variables $\text{BEFORE}_{i,t}^{p}$ and $\text{AFTER}_{i,t}^{p}$, where $\text{BEFORE}_{i,t}^{p}$ is a dummy equal to 1 p years prior to free banking and $\text{AFTER}_{i,t}^{p}$ is a dummy equal to 1 p years after free banking. The solid line plots the point estimates of BEFORE^{p} and AFTER^{p} for $p = 1, 2, \ldots, 7$, using the free banking year as the reference year. The vertical bars correspond to 95% confidence intervals with state-clustered standard errors.



associated with four periods around the enactment: all years up to and including 1 year prior to free banking, 1–2 years after free banking, 3–4 years after free banking, and 5 years or more after free banking. The year in which the free banking law was passed is the reference year.

As reported in column 1 of Table A.3 in the Supplementary Material, our estimates suggest that the change in innovation did not occur before the enactment of the free banking law. After the enactment year, the estimate becomes positive and significant, consistent with our baseline findings that the effect of free banking began to manifest 1 year after. In column 2, we decompose the period of 5 years or more after free banking into 5–6 years after free banking and 7 years or more after free banking, and find the coefficient estimates virtually unchanged. To ensure that the results are not capturing a trend, we plot the temporal dynamics of patents around the free banking year; see Figure 3. We estimate a variation of equation (1) by replacing the dummy variable FREE_BANKING with dummy variables for each year from 7 years before to 7 years after the passage year. Reassuringly, the figure corroborates a key message: effects on innovation did not precede free banking but persisted over the years following the law's passage.[23]

2. Placebo Test Using Randomized Free Banking Years

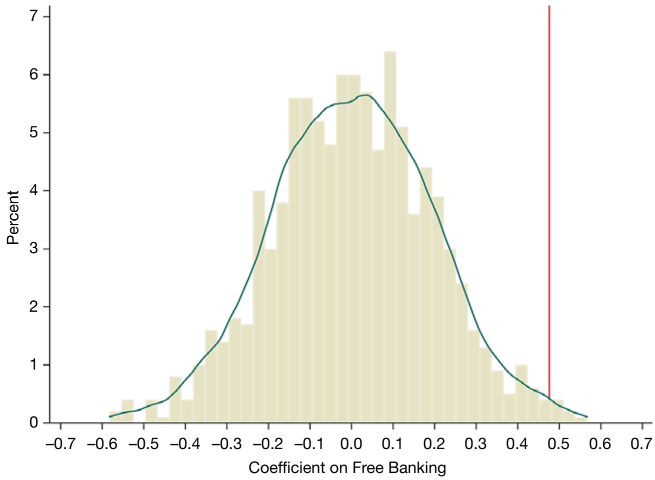
To further assess the reliability of our identification strategy, we perform a placebo test. We randomly assign a false free banking passage year to each state by maintaining the true distribution of the free banking years and reestimate column

[23]This finding is robust in the county-level regressions where the standard errors are clustered by county.

FIGURE 4

Placebo Test

Figure 4 plots the empirical distribution of the coefficient estimate on FREE_BANKING when we reestimate column 6 in Table 4 for 1,000 times using the bootstrapped sample. The 95th percentile of the distribution is 0.321 and the 99th percentile 0.460. We draw a vertical line to indicate the actual coefficient of 0.476 in column 6 in Table 4.



6 in Table 4. We repeat this procedure 1,000 times and plot the empirical distribution of the coefficient estimate on FREE_BANKING in Figure 4. This placebo test gives confidence that our estimated effect on innovation is not a statistical artifact or driven by unobservable shocks that coincided with the cluster of the free banking events.

3. Patent Skewness and Poisson Regression

Since the patent data are right skewed, we follow the common practice in the literature and take the log of 1 plus the patent count to reduce the effects of outliers. We evaluate the robustness of our results by estimating a Poisson regression model. The results, reported in columns 1–2 of Panel A of Table A.4 in the Supplementary Material, show that the coefficient estimate on FREE_BANKING remains positive and significant for both the baseline specification and the specification when controlling for state-specific pre-trends. In addition, to allay concerns that relatively small variations in patenting might have an outsized effect, we conduct two robustness checks. Columns 3–4 of the panel show that our results are robust to excluding the state-year observations with zero patents, and to excluding states ranked in the bottom quintile of total patents granted over the sample period.

4. Subsample Analyses

We assess the robustness of our baseline results in subsamples. First, the Second Bank of the United States, which operated from 1816 to 1836, had 25 branches scattered around the country and provided banking services to several states. To ensure that our results are not driven by the Second Bank's exit, we restrict to

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

the post-Second Bank period. Second, a wave of passage of free banking laws occurred in the 1850s. We thus drop the states that had earlier adoption of free banking and start our sample from 1850. Third, studies have shown that free banks might have experienced a higher probability of failure than charter banks, especially in Michigan, Indiana, Illinois, Wisconsin, Minnesota, and New Jersey. We therefore exclude these so-called "wildcat banking" states (Rockoff (1974)). Finally, we exclude states in the west because their establishment of territory/statehood was in the later part of the pre-Civil War era. The results, reported in Panel B of Table A.4 in the Supplementary Material, show that the coefficient estimate on FREE_BANKING remains significant for these subsamples.

5. Controlling for Contemporaneous Laws

Another concern is that our estimates may capture the effect of other state laws instituted at the same time as free banking laws. For example, states used usury laws to limit the maximum interest rate banks could charge on loans. Benmelech and Moskowitz (2010) show that usury laws in the nineteenth century reduced credit and economic activity when they were binding. If the states that passed the free banking law concurrently relaxed the maximum interest rate, our results might be biased because a higher ceiling might allow banks to lend with lower restrictions to high-risk entrepreneurs. In addition, some states adopted general incorporation statutes for manufacturing firms, which might have had an impact on innovation. In Panel B of Table A.4 in the Supplementary Material, we find that controlling for these contemporaneous law changes does not subsume the estimated impact of free banking on innovation.

6. Placebo Test Using the Intensity of Free Banking Activities

Among the 18 states that passed the free banking law, 11 (including New York and Louisiana) had significant free banking activities, whereas few free banking activities materialized in Massachusetts, Pennsylvania, Alabama, Florida, Iowa, Georgia, and Vermont (Rolnick and Weber (1983)). This observation provides us with a natural spectrum of the intensity of free banking activities. If the estimated effect of free banking indeed comes through its impact on access to finance, it should be more pronounced in the 11 states with significant free banking activities, and less pronounced in the 7 states with fewer free banking activities. This is indeed what we find in Table A.5 in the Supplementary Material.

D. County-Level Identification

Banking markets before the Civil War were local due to the high transportation cost; hence, we expect that the entry of free banks had a significant impact on local innovation outcomes. To estimate the relation between local access to free banks and innovation outcomes, we next turn to our county-level sample, which consists of 51,585 county-year observations and covers 2,007 unique counties. Specifically, we regress the patenting outcomes on the FREE_BANKING dummy, the counts, assets, and loans of free banks located in a county, and use the same set of county-level control variables as in Table 4, including county and year fixed effects. The results, reported in columns 1–4 of Panel A of Table 5, suggest that the degree of access to free banks in a county was significantly associated with patent counts 3

TABLE 5

Free Banking and Innovation: County-Level Identification

Table 5 reports the regression estimates on the relation between access to free banks and future innovation outcomes at the county level. The dependent variable for all columns is the natural logarithm of 1 plus the total number of patents granted in a county in year $t + 3$. Panel A reports the results based on the full county-year sample; Panel B reports the results when we restrict to the sample of contiguous border counties. Robust standard errors clustered at the county level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

Panel A. Full County-Year Sample

	ln(1 + PATENTS)						
	1	2	3	4	5	6	7
FREE_BANKING	0.147*** (0.016)						
ln(1 + FREE_BANKS)		0.361*** (0.030)			0.224*** (0.041)		
ln(1 + FREE_BANK_ASSETS)			0.028*** (0.003)			0.014*** (0.004)	
ln(1 + FREE_BANK_LOANS)				0.030*** (0.003)			0.013*** (0.004)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	No	No	No
State-by-year FE	No	No	No	No	Yes	Yes	Yes
No. of obs.	51,585	51,585	51,585	51,585	51,585	51,585	51,585
R^2	0.647	0.655	0.652	0.651	0.714	0.713	0.713

Panel B. Contiguous Border Counties

	ln(1 + PATENTS)						
FREE_BANKING	0.079*** (0.030)						
ln(1 + FREE_BANKS)		0.280*** (0.052)			0.167*** (0.059)		
ln(1 + FREE_BANK_ASSETS)			0.023*** (0.005)			0.015*** (0.005)	
ln(1 + FREE_BANK_LOANS)				0.025*** (0.005)			0.015*** (0.006)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	No	No	No
State-by-year FE	No	No	No	No	Yes	Yes	Yes
No. of obs.	16,526	16,526	16,526	16,526	16,526	16,526	16,526
R^2	0.671	0.676	0.675	0.675	0.740	0.741	0.740

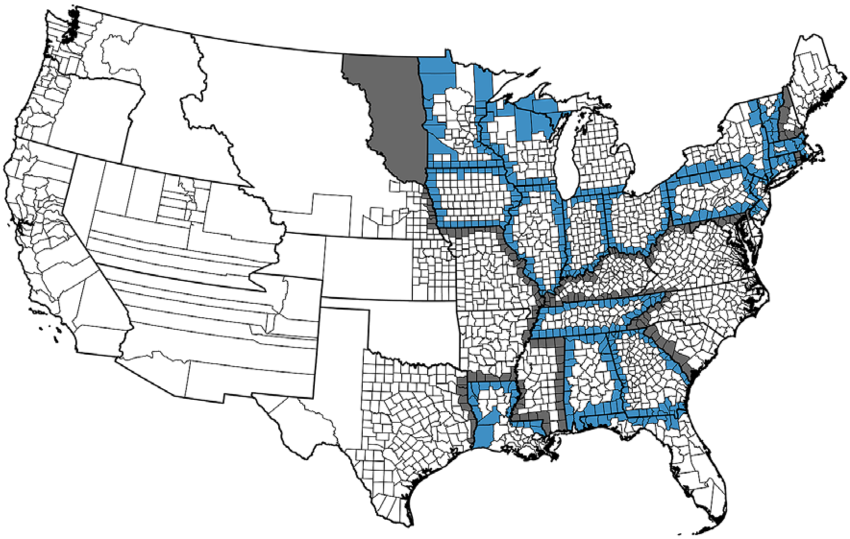
years ahead. For instance, the coefficient estimate of column 2 implies that for a 1% increase in the number of free banks in a county, the number of patents increased by 0.36% in the third year. In addition, to absorb the potential effect of unobserved time-varying heterogeneity across states, we include a full set of state-by-year fixed effects in columns 5–7 for the regressions on the counts, assets, and loans of free banks (We do not include the FREE_BANKING dummy because it would be absorbed by the state-by-year fixed effects). Our results are robust to this specification, suggesting that state-specific business cycles are unlikely to drive our results.

The entry of free banks in a county, however, might be endogenous to local economic conditions. To address the potential endogeneity bias, we employ an identification strategy that compares contiguous counties separated by state borders

FIGURE 5

Contiguous Border Counties of the Free Banking States in 1860

Figure 5 illustrates the contiguous border counties for the identification test reported in Panel B of Table 5. The "treated" counties inside the free banking state border are illustrated in blue, and the "control" border counties are illustrated in gray. As the county and state boundaries are time-varying, we demonstrate the sample using the GIS files based on the 1860 census.



(see, e.g., Huang (2008), Heider and Ljungqvist (2015)). Specifically, we include counties along a shared state border, where the free banking law was passed on one side. By restricting the control group to contiguous counties in close geographical proximity on the other side of the state border, we can effectively remove the biasing influence of otherwise unobservable variation in local economic conditions. We rely on the GIS files provided by the National Historical Geographic Information System to identify the contiguous border counties based on the time-varying county and state boundaries. The contiguous border county sample consists of 16,526 county-year observations and 574 unique counties. Figure 5 illustrates the "treated" counties inside the free banking state border and their "control" border counties based on the 1860 census.

In Panel B of Table 5, we reestimate the regressions using the contiguous border county sample. Besides the various fixed effects in Panel A, our specification also includes border fixed effects in order to focus the comparison between contiguous counties around a specific state-pair border instead of between those that were not located in neighboring states. The coefficient estimates on the county-level access-to-bank measures continue to be positive and statistically significant at the 1% level. This test provides confidence that localized unobserved dimensions do not confound the positive relation between innovation and access to finance. Overall, our county-level results are potent evidence that free banks entered counties that previously lacked access to finance and positively influenced local innovation outcomes.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

V. Labor Practices and the Finance-Innovation Nexus

Our evidence so far shows a robust and positive effect on technological innovation from improved access to finance. This section extends our analysis and shows that both access to finance and labor practices are critical factors that drive innovation outcomes. Whereas improved access to finance in general fosters innovation, its extent varies in predictable ways with local labor practices.

A. Exploitative Labor Practices and Agricultural Innovation

1. Cross-Sectional Variation in Labor Exploitation

Pre-Civil War America provides a suitable empirical context to study the role of labor practices. The labor markets were more geographically segmented than today's markets, and there was considerable divergence in the practice of slavery across regions. As discussed in Section II, such spatial variation in the practice of slavery represents a natural heterogeneity in the intensity of labor exploitation, which shaped the cost of agricultural labor and affected producers' demand for agricultural machinery. To the extent that economizing on labor costs posed a major concern, producers facing a higher cost of labor would be more inclined to switch to machines. Improved access to finance made investments in agricultural machinery more feasible and thereby increased the demand for labor-saving technologies. However, producers using exploitative labor practices faced a marginal cost of labor lower than the marginal product and had little incentive to shift away from labor-intensive production methods. Accordingly, our Hypothesis 2 predicts that the passage of the free banking law had a weaker impact on agricultural innovation in regions where exploitative labor practices were more pervasive.

We test Hypothesis 2 by augmenting equation (1) with the variable LABOR_EXPLOITATION, which measures the pervasiveness of exploitative labor practices in a state (county). The model is as follows:

$$(2)\qquad \begin{aligned}&\ln(1+\text{AGRICULTURAL\_PATENTS})_{i,t+s}\\ &= \begin{aligned}&\alpha+\beta_1\text{FREE\_BANKING}_{i,t}\times\text{LABOR\_EXPLOITATION}_i\\ &+\beta_2\text{FREE\_BANKING}_{i,t}+\gamma Z_{i,t}+\text{STATE}_i+\text{YEAR}_t+\epsilon_{i,t},\end{aligned}\end{aligned}$$

where i indexes state, t indexes year, and s is equal to 1, 2, or 3 years. The dependent variable is the natural logarithm of 1 plus the total number of agricultural patents granted in a state in the following 1, 2, and 3 years. We focus on agricultural patents because, as noted in Section III.C, the labor-saving incentive and the spatial variation in labor exploitation were manifested primarily in agriculture. The dummy variable, $\text{FREE\_BANKING}_{i,t}$, captures the status of the law's passage in state i and year t. To interact with FREE_BANKING, we introduce the variable $\text{LABOR\_EXPLOITATION}_i$, defined as the fraction of state i's population that was enslaved when the state entered the pre-Civil War era.[24] The coefficient on the interaction term β_1 reflects the correlation between labor exploitation and the

[24]We do not include $\text{LABOR\_EXPLOITATION}_i$ separately in the model because it is not time-varying and thus is subsumed by the state fixed effects.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

TABLE 6

Free Banking and Agricultural Innovation: The Role of Exploitative Labor Practices

Table 6 examines the impact of free banking on agricultural innovation across states (counties) with different levels of labor exploitation. LABOR_EXPLOITATION is the fraction of a state's (county's) population that was enslaved at the beginning of the pre-Civil War era. Columns 1–3 report state-level regression results that estimate equation (2); the dependent variable is the natural logarithm of 1 plus the total number of agricultural patents granted in a state in year $t+1$, $t+2$, and $t+3$, respectively. Columns 4–6 report county-level regression results when the dummy variable FREE_BANKING is replaced with county-level ln(1 + FREE_BANKS); the dependent variable is the natural logarithm of 1 plus the total number of agricultural patents granted in a county in year $t+1$, $t+2$, and $t+3$, respectively. For the state-level analysis, robust standard errors clustered at the state level are reported in parentheses below each point estimate; for the county-level analysis, robust standard errors clustered at the county level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

	ln(1 + AGRICULTURAL_PATENTS)					
	State-Level Regressions			County-Level Regressions		
	$t+1$	$t+2$	$t+3$	$t+1$	$t+2$	$t+3$
	1	2	3	4	5	6
FREE_BANKING × LABOR_EXPLOITATION	−3.088***	−3.281***	−3.480***			
	(0.586)	(0.586)	(0.579)			
FREE_BANKING	0.860***	0.952***	1.024***			
	(0.189)	(0.185)	(0.190)			
ln(1 + FREE_BANKS) × LABOR_EXPLOITATION				−0.461***	−0.466**	−0.514**
				(0.159)	(0.185)	(0.200)
ln(1 + FREE_BANKS)				0.154***	0.168***	0.182***
				(0.023)	(0.024)	(0.025)
ln(POPULATION)	0.044	0.079	0.120	0.003	0.007	0.013**
	(0.071)	(0.075)	(0.077)	(0.005)	(0.005)	(0.005)
URBAN_RATIO	1.734	2.020*	2.172*	0.409***	0.418***	0.420***
	(1.223)	(1.166)	(1.133)	(0.067)	(0.070)	(0.073)
WHITE_RATIO	2.862**	2.842**	3.045**	0.188***	0.192***	0.204***
	(1.244)	(1.218)	(1.294)	(0.036)	(0.038)	(0.040)
State FE	Yes	Yes	Yes	No	No	No
County FE	No	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,449	1,449	1,449	51,585	51,585	51,585
R^2	0.712	0.723	0.733	0.274	0.286	0.300

sensitivity of agricultural innovation to free banking. If labor exploitation is negatively associated with the impact of free banking on agricultural innovation, we expect β_1 to be negative.

Columns 1–3 of Table 6 summarize the results of estimating equation (2). The coefficient estimates of FREE_BANKING are positive and significant at the 1% level, suggesting that free banking spurred agricultural innovation in states with no enslaved population. Consistent with Hypothesis 2, the estimates for β_1 in all columns are negative and statistically significant at the 1% level. Based on the estimate in column 3, states with a median LABOR_EXPLOITATION of 4.4% had 87.1% (=102.4% − 3.48 × 4.4%) more agricultural patents 3 years after the law's passage, and as LABOR_EXPLOITATION increases by 1-standard-deviation (17.1%) from the median, states with LABOR_EXPLOITATION of 21.5% had 27.6% more agricultural patents 3 years after free banking.

One possibility is that the observed negative relation between labor exploitation and the finance-innovation nexus might merely reflect the modest entry by free banks in areas with more severe labor exploitation (the Southern states). However, if the results are driven solely by the limited bank entry in those areas, we should not expect a differential impact on innovation across regions conditional on the same level of bank entry. Hence, instead of using a dummy variable that captures the extensive margin of free banking at the state level, we perform county-level regressions using the number of free banks in a county to capture the intensive margin. Columns 4–6 of Table 6 summarize our county-level regression results.[25] The coefficient estimates on the interaction term remain negative and statistically significant, suggesting that the marginal value of an additional bank decreased with the intensity of labor exploitation. This finding bolsters confidence that exploitative labor practices negatively correlated with the impact of finance on agricultural innovation, controlling for the level of entry by free banks in a county.

2. Robustness Tests

A valid concern is that areas with different degrees of labor exploitation also differed in economic conditions and industry composition, and that these factors, rather than differences in exploitative labor practices, could drive our results. For example, states in the South dominated in agricultural production but fell behind in innovation growth, the supply of immigrants, and access to railway transportation. Accordingly, we control for a diverse set of state-level characteristics in estimating equation (2), including industry composition, educational attainment, the foreign-born fraction of the population, innovation growth, and access to railroads, and their interactions with the FREE_BANKING dummy. The results, as reported in Panel A of Table 7, confirm that our findings continue to hold when controlling for these potential confounding factors.

We next isolate common sources of heterogeneity by examining subsamples of similar attributes. First, we remove states with no enslaved population (LABOR_EXPLOITATION = 0) from the analysis because their unobservable characteristics may differ from those of regions with exploitative labor practices. Second, as discussed in Section II.C, in the Northeast, manufacturing rather than agriculture experienced rapid growth and became a significant employer. In light of the disparities in sectoral development between the Northeast and Midwest states, we assess whether free banking had any differential impact on patenting in the two regions. The estimated effects in the Northeast are comparable relative to the Midwest for both total patents and agricultural patents (reported in Table A.7 of the Supplementary Material), suggesting that despite sectoral differences, agricultural producers in both regions shared the incentive to reduce their reliance on labor. Our findings thus rationalize including both regions in the regressions in Table 6. Nonetheless, we also perform a robustness test by excluding states in the Northeast. Third, since the majority of enslaved laborers worked in the cotton fields, we restrict the sample to the states with positive cotton output using data from the Census of Agriculture.

[25]We use the ex ante time-invariant LABOR_EXPLOITATION to isolate it from changes in the enslaved population in response to local finance, thereby alleviating concerns of reverse causality. Nonetheless, this specification does not generate sufficient variation for the inclusion of state-by-year fixed effects. As shown in Table A.6 of the Supplementary Material, our results are robust to measuring LABOR_EXPLOITATION alternatively as the contemporaneous fraction of a state's population that was enslaved in a given year. The specification using the time-varying LABOR_EXPLOITATION is robustly significant (at the 1% level) to including the state-by-year fixed effects.

The results, reported in columns 1–3 in Panel B of Table 7, show that the coefficient estimates on FREE_BANKING × LABOR_EXPLOITATION remain negative and statistically significant at the 1% level. Similarly in columns 5–7, we repeat the subsample analyses using county-level observations and by replacing the statewide banking shock, FREE_BANKING, with the county-level access to free banks, ln(1 + FREE_BANKS). The results suggest a robust negative relation between LABOR_EXPLOITATION and the sensitivity of patenting to access to local free banks, which is not a byproduct of heterogeneity bias. Finally, to alleviate

TABLE 7

The Role of Exploitative Labor Practices: Robustness Results

Table 7 presents robustness checks for the results in Table 6. In Panel A, we include additional state-level characteristics (AGRICULTURAL_OUTPUT_RATIO, EDUCATION, FOREIGN-BORN_RATIO, INNOVATION_GROWTH, RAILWAY) and their interactions with the FREE_BANKING dummy to the estimation of equation (2). The dependent variable for all columns is the natural logarithm of 1 plus the total number of agricultural patents granted in year $t+3$. We include the same set of controls (ln (POPULATION), URBAN_RATIO, and WHITE_RATIO) as in Table 6. In Panel B, we estimate equation (2) using subsamples of relatively similar states and counties. The dependent variable for all columns is the natural logarithm of 1 plus the total number of agricultural patents granted in year $t+3$. Column 1 restricts the sample to the states with LABOR_EXPLOITATION > 0. Column 2 excludes states in the Northeast. Column 3 restricts the sample to the states with positive cotton output. Column 4 excludes states ranked in the bottom quintile of the number of total agricultural patents granted over the sample period. Columns 5–8 repeat the regressions in columns 1–4 using county-level observations and by replacing the dummy variable FREE_BANKING with ln(1 + FREE_BANKS). We include the same set of controls (ln(POPULATION), URBAN_RATIO, and WHITE_RATIO) as in Table 6. For the state-level analysis, robust standard errors clustered at the state level are reported in parentheses below each point estimate; for the county-level analysis, robust standard errors clustered at the county level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

Panel A. Additional Controls

	ln(1 + AGRICULTURAL_PATENTS)					
	1	2	3	4	5	6
FREE_BANKING × LABOR_EXPLOITATION	−3.482***	−2.602***	−2.480***	−3.477***	−2.982***	−3.255***
	(0.663)	(0.390)	(0.617)	(0.578)	(0.603)	(0.917)
FREE_BANKING × AGRICULTURAL_OUTPUT_RATIO	1.060					1.037
	(0.931)					(1.313)
AGRICULTURAL_OUTPUT_RATIO	0.796					2.151
	(1.232)					(1.360)
FREE_BANKING × EDUCATION		−36.137**				11.419
		(14.485)				(22.117)
EDUCATION		9.526				18.818
		(6.303)				(16.468)
FREE_BANKING × FOREIGN-BORN_RATIO			0.654			0.645
			(0.983)			(1.481)
FOREIGN-BORN_RATIO			4.508			3.953
			(3.690)			(5.817)
FREE_BANKING × INNOVATION_GROWTH				−0.039		−0.024
				(0.099)		(0.116)
INNOVATION_GROWTH				0.018		−0.088
				(0.016)		(0.070)
FREE_BANKING × RAILWAY					−0.390	0.024
					(0.515)	(0.802)
RAILWAY					1.118	0.864
					(0.777)	(0.787)
FREE_BANKING	0.376	1.280***	0.822**	1.029***	1.102***	0.043
	(0.561)	(0.243)	(0.313)	(0.189)	(0.254)	(1.256)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	399	699	399	1,445	389	386
R^2	0.864	0.820	0.863	0.734	0.867	0.871

(continued on next page)

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

TABLE 7 (continued)

The Role of Exploitative Labor Practices: Robustness Results

Panel B. Subsample Analyses

	ln(1 + AGRICULTURAL_PATENTS)							
	State-Level Regressions				County-Level Regressions			
	1	2	3	4	5	6	7	8
FREE_BANKING × LABOR_EXPLOITATION	−3.576*** (0.637)	−3.727*** (0.601)	−4.566*** (0.846)	−3.492*** (0.597)				
FREE_BANKING	1.072*** (0.230)	1.252*** (0.228)	1.618*** (0.350)	0.987*** (0.193)				
ln(1 + FREE_BANKS) × LABOR_EXPLOITATION					−0.562*** (0.191)	−0.533*** (0.094)	−0.461*** (0.088)	−0.518*** (0.199)
ln(1 + FREE_BANKS)					0.218*** (0.034)	0.143*** (0.029)	0.130*** (0.030)	0.181*** (0.025)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	No	No	No	No
County FE	No	No	No	No	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,159	861	784	1,361	37,608	41,522	36,317	49,877
R^2	0.738	0.733	0.684	0.736	0.307	0.238	0.223	0.299

concerns due to the abundance of zeros in the outcome variable, we exclude from our analyses the states that patented the least. Specifically, we drop observations in states ranked in the bottom quintile of total agricultural patents granted over the sample period in both the state- and county-level regressions. As summarized in columns 4 and 8 of the panel, our findings are robust in both cases.

Together, our results in Tables 6 and 7 show that the impact of greater access to finance on innovation varied in a theoretically predictable manner. When focusing on the agricultural sector where the marginal cost of labor differed across states with different labor practices, we find a significantly weaker impact of free banking on agricultural patents in areas with more severe labor exploitation. Exploitative labor practices reduce labor's marginal cost relative to its marginal product and discourage producers from adopting labor-saving technologies, thus weakening the finance-innovation nexus.

3. Shock to Labor Exploitation: The 1850s Cholera Pandemic

To establish a causal role of the exploitative labor practices, we need to address the endogeneity of the variable LABOR_EXPLOITATION. Measuring LABOR_EXPLOITATION as the time-invariant fraction of the initial enslaved population alleviates concerns with reverse causality. In addition, our robustness tests in Table 7 mitigate concerns with omitted variable bias. Still, to provide further causal evidence on the effect of labor practices on the marginal impact of free banking on innovation, next we examine a plausibly exogenous shock to the supply of exploited workers in the context of the 1850s cholera pandemic.

The 1850s cholera pandemic entered the United States in 1849 through New York and New Orleans, spreading across much of the country until 1854. Claiming hundreds of thousands of lives, this pandemic is among the largest loss-of-life events in US history.[26] Death could happen within a day, sometimes within a few hours of the abrupt onset of symptoms (Rosenberg (2009)). Deemed the "poor man's plague," cholera was confined mostly to the lower classes living in filth and poverty. Primitive sanitation practices, warm weather, and proximity to waterways by which ships carried the disease exacerbated the spread of disease, and the epidemic disproportionately affected enslaved field hands, causing sudden reductions in the enslaved population in affected regions (Hays (2005)). It has been calculated that the Southern states alone lost about 10,000 enslaved people in 1849 (Rosenberg (2009)). The 1850s cholera pandemic thus generated a negative shock to the extent of labor exploitation by planters.

Our goal is to examine whether access to free banks had a differential impact on local agricultural patenting in counties that were differentially exposed to the cholera epidemic in their enslaved population. To measure the county-level exposure to the cholera shock, we hand-collect novel data from the 1850 Census Mortality Schedules via ancestry.com on the number of cholera-caused deaths among the enslaved population in a county in 1850.[27] The data are available for 722 counties in 12 Southern states. We limit the sample period to 1850–1860 since 1850 is the only pre-Civil War year for which the mortality schedule is available. Because the pandemic lasted for about 5 years in the United States until 1854 (Rosenberg (2009)), we construct the variable ENSLAVED_CHOLERA_DEATHS as the fraction of a county's enslaved population that died of cholera in 1850 for the years 1850–1854, and as 0 for the years 1855–1860. For ease of interpretation, we further standardize the variable to have a mean of 0 and a standard deviation of 1.

We estimate the following model to gauge the effect of ENSLAVED_CHOLERA_DEATHS on the finance-innovation nexus:

$$\begin{aligned}(3)\quad & \ln(1+\text{AGRICULTURAL\_PATENTS})_{i,t+3} \\ & \quad \alpha+\beta_1 \ln(1+\text{FREE\_BANKS})_{i,t} \times \text{ENSLAVED\_CHOLERA\_DEATHS}_{i,t} \\ & = +\beta_2 \ln(1+\text{FREE\_BANKS})_{i,t} + \beta_3 \text{ENSLAVED\_CHOLERA\_DEATHS}_{i,t} \\ & \quad +\gamma Z_{i,t} + \text{COUNTY}_i + \text{YEAR}_t + \epsilon_{i,t},\end{aligned}$$

where i indexes county and t indexes year. The dependent variable is the natural logarithm of 1 plus the number of agricultural patents granted in a county 3 years after. To leverage the county-level granularity, we use $\ln(1 + \text{FREE\_BANKS})_{i,t}$ to measure local access to free banks in county i and year t. Our focus is on β_1, the coefficient of the interaction term, ln(1 + FREE_BANKS) × ENSLAVED_CHOLERA_DEATHS. As noted earlier, producers using fewer enslaved workers would be more inclined to switch to machines when finance became more

[26]See the Deadliest American Disasters and Large-Loss-of-Life Events website maintained by Wayne Blanchard.

[27]Taken concurrently with the 1850 Census, the 1850 Mortality Schedule presents a unique opportunity to observe the mortality among the enslaved population. The Mortality Schedule enumerated the individuals who died during the 12 months prior to the census day. It listed the deceased persons' name, gender, age, race, marital status (if white), place of birth, month of death, occupation, and cause of death. The data are available at www.ancestry.com/search/collections/8756.

TABLE 8

Shock to Labor Exploitation: The 1850s Cholera Pandemic

Table 8 provides evidence on the causal effect of labor practices on the impact of free banking on innovation by exploiting a plausibly exogenous shock to the supply of exploited workers caused by the 1850s cholera pandemic. The dependent variable is the natural logarithm of 1 plus the total number of agricultural patents granted in a county in year $t+3$. In column 1, ENSLAVED_CHOLERA_DEATHS equals the fraction of a county's enslaved population that died of cholera in 1850 for the years 1850–1854, and 0 for the years 1855–1860. In column 2, ENSLAVED_CHOLERA_DEATHS equals the fraction of a county's enslaved population that died of cholera in 1850 for the years 1850–1855, and 0 for the years 1856–1860. In column 3, ENSLAVED_CHOLERA_DEATHS equals the fraction of a county's total enslaved deaths that were caused by cholera in 1850 for the years 1850–1854, and 0 for the years 1855–1860. In column 4, ENSLAVED_CHOLERA_DEATHS equals the fraction of a county's enslaved population that died in 1850 from one of the eight major deadly and contagious diseases (including cholera) for the years 1850–1854, and 0 for the years 1855–1860. For ease of interpretation, all measures of ENSLAVED_CHOLERA_DEATHS are standardized to have a mean of 0 and a standard deviation of 1. We include the same set of controls (ln(POPULATION), URBAN_RATIO, and WHITE_RATIO) as in Table 6. The sample consists of 722 unique counties in the period 1850–1860. Robust standard errors clustered at the county level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

	ln(1 + AGRICULTURAL_PATENTS)			
	1	2	3	4
ln(1 + FREE_BANKS) × ENSLAVED_CHOLERA_DEATHS	0.018***	0.012***	0.027***	0.018***
	(0.003)	(0.002)	(0.004)	(0.005)
ln(1 + FREE_BANKS)	−0.001	0.000	−0.003	−0.002
	(0.023)	(0.023)	(0.024)	(0.023)
ENSLAVED_CHOLERA_DEATHS	−0.003	0.000	−0.006	−0.003
	(0.004)	(0.003)	(0.005)	(0.005)
Controls	Yes	Yes	Yes	Yes
County FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
No. of obs.	7,942	7,942	7,942	7,942
R^2	0.251	0.247	0.251	0.251

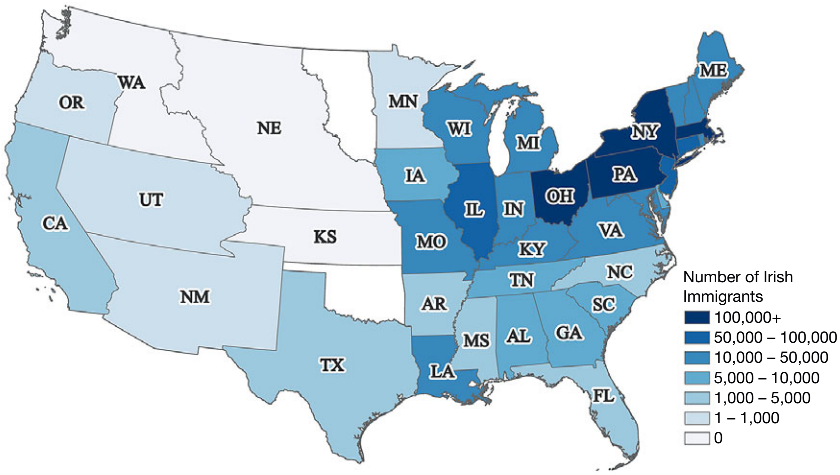
accessible. Hence, if the effect of exploitative labor practices was indeed causal, we expect a greater increase in labor-saving technologies in areas harder hit by cholera, that is, we expect β_1 to be positive.

Table 8 summarizes the results. Consistent with our prediction, estimates of the baseline regression in column 1 show that local agricultural innovation responded more positively to access to free banks in areas where planters faced larger ENSLAVED_CHOLERA_DEATHS. A 1-standard-deviation increase in ENSLAVED_CHOLERA_DEATHS is associated with a 0.018 increase in the elasticity of agricultural patents to access to free banks. In columns 2–4, we consider alternative measures of ENSLAVED_CHOLERA_DEATHS (all standardized) as robustness checks. Since the pandemic subsided after 1854, we report results by also including 1855 in the cholera years in column 2. To control for the mortality rate among enslaved workers, we alternatively calculate ENSLAVED_CHOLERA_DEATHS as the fraction of a county's total enslaved deaths that were caused by cholera in column 3. Finally, cholera was not the only disease bringing death to America. We thus obtain another alternative measure for ENSLAVED_CHOLERA_DEATHS in column 4 as the fraction of the enslaved population who died in 1850 from one of the eight major deadly and contagious diseases ubiquitous at the time: cholera, measles, smallpox, tuberculosis, pneumonia, typhus, typhoid, and yellow fever. Our results are robust for all alternative measures. Overall, our evidence based on the 1850s cholera pandemic supports

FIGURE 6

Spatial Variation in the Influx of Irish Immigrants

Figure 6 visualizes the variation in the influx of Irish immigrants across states based on the estimated total Irish immigrants that arrived in each state during 1820–1860.



a causal interpretation of the relation between labor exploitation and the sensitivity of innovation to financial development.

4. Shock to Labor Exploitation: The Influx of Irish Immigrants

Our tests regarding the effect of labor exploitation focus on agricultural innovation because our strategy leverages the spatial variation in slavery, under which highly exploited enslaved people worked primarily in agriculture. To assess the external validity and to shed light on technological innovation and exploitable labor more broadly, we extend our analysis to another group of exploited workers at the time, Irish immigrants.

Around 2 million Irish migrated to America from 1820 to 1860, constituting the largest share of pre-Civil War immigrants (Willcox (1929)). Unlike other immigrants, the Irish came with no capital as they fled their homeland to escape famine and religious persecution. These Irish immigrants often took any jobs they could find, at meager pay, and were largely exposed to exploitation by employers (Laxton (1997)). Newspapers reported that those who were employed in canals and railroad construction projects were treated "like slaves" (Wittke (1939)). As such, the arrival of Irish immigrants provided a positive shock to the supply of exploitable labor for local producers.

To measure the influx of Irish immigrants into each state, we take two steps to construct a state-year variable, IRISH_IMMIGRANTS. First, we use data from Willcox (1929) on the annual aggregate inflow of Irish immigrants to the US from 1820 to 1860. The aggregates of immigrants by sending country were compiled from passenger lists provided by the masters of arriving vessels. Second, to estimate the arrival of Irish immigrants in each state, we employ a modified version of the shift-share instrument (Card (2001)) using the shares of persons born in Ireland that settled in each state.[28] Figure 6 visualizes the total influx of Irish immigrants across states; Figure A.4 in the Supplementary Material provides a similar map for the total influx of Irish immigrants per capita in each state. As illustrated by these heat maps, Irish immigrants gravitated disproportionately toward the northern part of the country.

If an increase in the supply of workers vulnerable to exploitation weakened producers' incentive to shift away from labor-intensive production techniques, we expect free banking to have a weaker impact on innovation in states with a bigger influx of Irish immigrants. To test this prediction, we explore the cross-state variation in the influx of Irish immigrants and examine how states with varying levels of IRISH_IMMIGRANTS responded to free banking in their patenting outcome, measured by ln(1 + PATENTS).[29] For ease of interpretation, we standardize IRISH_IMMIGRANTS to have a mean of 0 and a standard deviation of 1. Panel A of Table 9 summarizes the results based on the full state-year sample for 1820–1860. Consistent with our prediction, the number of patents responded less positively to free banking and access to free banks in states where a greater number of Irish immigrants arrived.

Since a majority of Irish immigrants settled in the northern states, we also focus on a subsample of states that abolished slavery (in the North). This test allows us to assess the external validity of our earlier findings based on the 1850s cholera pandemic which mainly affected enslaved workers in the South. The results, reported in columns 1–3 of Panel B, are similar to those in Panel A based on the full sample. These findings suggest that our results are not specific to slavery (and the potentially unobserved features of slavery versus other forms of exploitative labor practices) but generally apply to shocks to labor exploitation.

Unlike the cholera-caused deaths among the enslaved population that imparted a negative shock to the supply of exploitable labor, the influx of Irish immigrants provided a positive shock. To assess whether the effect was symmetric between positive and negative shocks to labor exploitation and whether the effect differed between the North and the South, we compare the estimated economic significance with that from the county-level cholera-based test in Table 8. To this end, in columns 4–6 of Panel B, we run county-level regressions by restricting the sample to Northern counties. We also restrict the time horizon to 1850–1860 to be consistent with the specification in Table 8. To measure the density of Irish immigrants that arrived in a county-year, we construct IRISH_IMMIGRANTS by scaling the number of state-level Irish immigrants arriving with the total foreign-born population and then standardize the variable.[30] Based on the coefficient estimate in column 6, a 1-standard-deviation increase in IRISH_IMMIGRANTS in a Northern county is associated with a 0.041 decrease in the elasticity of patents to access to

[28]This approach exploits the observation that immigrants locate close to settled immigrants from the same country of origin. It generates variation at the state level from changes in national inflows, which are arguably less endogenous to local conditions.

[29]Unlike enslaved laborers who worked primarily in agriculture, Irish immigrants took a broad range of occupations; hence, we use total patents to capture the corresponding innovation.

[30]We adopt a scaled variable for the county-level regressions because i) ENSLAVED_CHOLERA_DEATHS in Table 8 is a scaled variable, and ii) the estimated number of Irish immigrants' arriving is only available at the state level.

TABLE 9

Shock to Labor Exploitation: The Influx of Irish Immigrants

Table 9 provides evidence on the causal effect of labor practices on the impact of free banking on innovation by exploiting a plausibly exogenous shock to the supply of exploited workers caused by the influx of Irish immigrants. The dependent variable is the natural logarithm of 1 plus the total number of patents granted in year $t+1$, $t+2$, and $t+3$, respectively. Panel A presents estimation results for the full state-year sample for 1820–1860; Panel B restricts the sample to Northern states for 1820–1860 in columns 1–3 and Northern counties for 1850–1860 in columns 4–6. IRISH_IMMIGRANTS is the estimated number of Irish immigrants that arrived in a state in a given year for the state-level regressions, and the estimated number of Irish immigrants that arrived in a state in a given year scaled by the total foreign-born population for the county-level regressions, with both measures standardized to have a mean of 0 and a standard deviation of 1. Robust standard errors clustered at the state (county) level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

	ln(1 + PATENTS)					
	$t+1$	$t+2$	$t+3$	$t+1$	$t+2$	$t+3$
	1	2	3	4	5	6
Panel A. All States						
FREE_BANKING × IRISH_IMMIGRANTS	−0.123***	−0.116***	−0.114***			
	(0.041)	(0.040)	(0.040)			
FREE_BANKING	0.392***	0.471***	0.481***			
	(0.130)	(0.132)	(0.142)			
ln(1 + FREE_BANKS) ×IRISH_IMMIGRANTS				−0.035***	−0.031***	−0.030***
				(0.009)	(0.009)	(0.009)
ln(1 + FREE_BANKS)				0.161**	0.170**	0.175**
				(0.062)	(0.062)	(0.066)
IRISH_IMMIGRANTS	0.113***	0.090**	0.077**	0.124***	0.096**	0.077**
	(0.039)	(0.038)	(0.035)	(0.042)	(0.039)	(0.035)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,246	1,246	1,246	1,246	1,246	1,246
R^2	0.900	0.894	0.890	0.901	0.894	0.889
Panel B. Northern States and Counties						
ln(1 + FREE_BANKS) ×IRISH_IMMIGRANTS	−0.033**	−0.030**	−0.030**	−0.059***	−0.052***	−0.041***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.013)	(0.014)
ln(1 + FREE_BANKS)	0.127**	0.127**	0.118**	0.063*	0.090***	0.116***
	(0.048)	(0.045)	(0.043)	(0.035)	(0.034)	(0.033)
IRISH_IMMIGRANTS	0.102	0.083	0.095	−0.118***	−0.091***	−0.005
	(0.081)	(0.081)	(0.084)	(0.021)	(0.021)	(0.020)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	No	No	No
County FE	No	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	608	608	608	7,282	7,282	7,282
R^2	0.930	0.931	0.934	0.814	0.818	0.821

free banks. This estimate is on the same order of magnitude compared with the point estimate of 0.018 in column 1 of Table 8, thus reinforcing the external validity. The slightly larger magnitude estimated from Irish immigrants suggests that the effect might be asymmetric between positive and negative shocks to the supply of exploitable labor; it may also reflect a greater sensitivity of total patents to free banking in the North than that of agricultural patents to free banking in the South.

In sum, our results based on Irish immigrants in the North indicate a significant and negative relation between the quantity of Irish immigrants arriving and the sensitivity of innovation to the adoption of free banking. By providing external validity to our earlier evidence from the 1850s cholera pandemic in the South, these findings reinforce the notion that both access to finance and labor practices are critical factors shaping innovation outcomes.

B. Economic Mechanism: Changes in the Marginal Cost of Labor

Estimates in Table 6 imply that free banking might have depressed agricultural innovation in states where slavery was widespread. Take a state from the 75th percentile of LABOR_EXPLOITATION, where the enslaved population ratio was 30.4% in 1810. Our estimate shows that agricultural patenting fell by 3.4% (= 102.4% − 3.48 × 30.4%) in the third year after the law's passage relative to states that did not pass the law. Next, we show that this result is consistent with our Hypothesis 3, namely, the impact of finance on innovation might be negative if access to finance exacerbates the extent of labor exploitation.

The proposed mechanism is that finance may shift the marginal cost of labor and affect innovation through producers' demand for labor-saving technologies. The finance-innovation nexus strengthens with an increase in marginal labor cost but weakens (and can even break) with a decline in marginal labor cost. In the context of pre-Civil War America, the use of available finance after free banking differed across regions depending on sectoral specialization and labor practices; consequently, the effect of free banking on marginal labor cost also differed across regions. For example, in states where labor exploitation was absent, banks led to more accessible financing for merchants and manufacturers; the industrial development drove up local labor demand and wage rates (Goldin and Sokoloff (1982)). Conversely, in states where exploitative labor practices were pervasive, planters' major investment and wealth were in the enslaved people (see, e.g., Wright ((2006), p. 60)). Bankers participated in enslaved mortgages, which facilitated the investment and trade of enslaved persons. Hence, access to finance likely aggravated the use of exploited workers and reduced the marginal cost of labor, discouraging the adoption of labor-saving technologies. We thus test Hypothesis 3 by first examining how labor costs in states with different degrees of labor exploitation responded to free banking. Then, we focus on states that sanctioned slavery in discussing potential channels.

We draw from several sources for measures of daily cost of labor. The wage measures are from Margo and Villaflor (1987), who provide annual estimates of nominal daily wage rates for common laborers (COMMON_LABORER_WAGE) and artisans (ARTISAN_WAGE) at the census region level from 1820 to 1856.[31] To proxy for the daily cost of using an exploited worker, we use the nominal daily hire rate for an enslaved laborer (SLAVE_HIRE_RATE) from Fogel and Engerman (1976a).[32] Motivated by the conceptual framework in Appendix B, we proxy for the

[31]Pre-Civil War wage records are scarce (e.g., wage rates from the censuses are decennial). The estimates from Margo and Villaflor (1987) are at an annual frequency and cover all parts of the country, providing the most comprehensive wage data for the pre-Civil War labor markets.

[32]Ideally, one would like to directly measure the subsistence cost (food, clothing, medical care, housing, insurance, and supervision). Since detailed data on subsistence costs are not available, we measure the opportunity cost using data on the rate when enslavers hired out enslaved workers. As Wright explains, "it makes no essential difference whether the slave was owned or rented; the opportunity cost of labor was the same in either case" (Wright ((2006), p. 71)). Data on the hire rate are available for 8 Southern states, so we use observations for the 8 states to fill in their bordering states

TABLE 10

Free Banking and the Marginal Cost of Labor: The Role of Exploitative Labor Practices

Table 10 examines the impact of free banking on local marginal cost of labor across states with different levels of labor exploitation. The dependent variable is COMMON_LABORER_WAGE in column 1, WEIGHTED_LABORER_COST in column 2, ARTISAN_WAGE in column 3, WEIGHTED_ARTISAN_COST in column 4, and SLAVE_SALE_VALUE in column 5. All dependent variables are deflated into real values using the CPI with 1860 as the base year, and lead the independent variables by 1 year. Robust standard errors clustered at the state level are reported in parentheses below each point estimate. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

	COMMON LABORER_WAGE	WEIGHTED LABORER_COST	ARTISAN WAGE	WEIGHTED ARTISAN_COST	SLAVE SALE_VALUE
	1	2	3	4	5
FREE_BANKING × LABOR_EXPLOITATION	−0.169***	−0.249**	−0.211**	−0.443*	0.302**
	(0.059)	(0.121)	(0.083)	(0.223)	(0.099)
FREE_BANKING	0.045***	0.056**	0.029	0.053	−0.128**
	(0.016)	(0.023)	(0.026)	(0.041)	(0.049)
ln(POPULATION)	0.025*	0.017	0.048**	0.020	0.036
	(0.012)	(0.023)	(0.018)	(0.033)	(0.022)
URBAN_RATIO	0.673***	1.099***	0.016	0.999*	−0.048
	(0.166)	(0.336)	(0.108)	(0.521)	(0.269)
WHITE_RATIO	−0.253	−0.105	−0.504*	−0.409	−0.201
	(0.290)	(0.696)	(0.253)	(1.274)	(0.369)
State FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
No. of obs.	1,023	1,023	1,036	1,036	311
R^2	0.853	0.834	0.838	0.793	0.883

average cost of labor in a state by constructing WEIGHTED_LABORER_COST (WEIGHTED_ARTISAN_COST) as the average of COMMON_LABORER_WAGE (ARTISAN_WAGE) weighted by the fraction of population that was free and SLAVE_HIRE_RATE weighted by the fraction of population that was enslaved. We use the historical Consumer Price Index (CPI) by Officer and Williamson (2018) to convert the nominal values to real terms.

Table 10 presents the results on whether free banking had a differential impact on the cost of labor that is predictably determined by a state's labor practices. Columns 1 and 2 report results for COMMON_LABORER_WAGE and WEIGHTED_LABORER_COST. The coefficient estimates are positive for FREE_BANKING and negative for FREE_BANKING × LABOR_EXPLOITATION. Based on the estimates, in a state from the 25th percentile of LABOR_EXPLOITATION (0.1%), COMMON_LABORER_WAGE increased by 4.5 cents (= 0.045 − 0.169 × 0.1%) the year after free banking relative to the nonfree-banking states, which is 5.5% of the sample mean (81.7 cents). In a state from the 75th percentile of LABOR_EXPLOITATION (30.4%), COMMON_LABORER_WAGE dropped by 0.8% of the sample mean and WEIGHTED_LABORER_COST dropped by 2.5% of the sample mean the year after free banking relative to the nonfree-banking states. The larger decline in the latter variable indicates that the negative impact of free banking on labor cost is driven primarily by the exacerbation of slavery. Results are similar in columns 3–4 where we replace

within the same economic census division. When a state has multiple bordering states, we take the average across the neighboring states. For the few years with missing observations, we interpolate the data linearly.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

TABLE 11

Free Banking, the Spread of Enslavement, and the Concentration of Slaveholding

Table 11 examines the impact of free banking on exploitative labor practices reflected in the spread of enslavement and the concentration of slaveholding. We restrict our sample to the observations for which data on the distribution of slaveholding are available from the decennial census. The dependent variable in column 1 is FRACTION_ENSLAVED, that is, the fraction of a state's population that was enslaved in that year. The dependent variable in column 2 is PERCENTAGE_OF_SLAVEHOLDERS, that is, the number of slaveholders divided by the white population. The dependent variable in column 3 is GINI_COEFFICIENT, which is calculated based on the distribution of slaveholding among slaveholders. The dependent variables in columns 4–7 are, respectively, the percentages of slaveholders with 100 or more, with 50 or more, with fewer than 10, and with fewer than 5, enslaved workers. Since the data on the distribution of slaveholding are only available in the 1850 and 1860 censuses, we present results with and without interpolating the sample in Panel A and Panel B. The number of observations in column 1 is larger than those in the other columns because the 1850 census provides data for Utah on the enslaved population but not on slaveholding. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The definitions of all variables are provided in Appendix A.

				Distribution of Slaveholding Among Slaveholders			
	FRACTION ENSLAVED	PERCENTAGE_OF SLAVEHOLDERS	GINI COEFFICIENT	100+	50+	1–9	1–4
	1	2	3	4	5	6	7
Panel A. Interpolated Sample: 1850–1860							
FREE_BANKING	0.162***	0.016***	0.059***	0.005***	0.018***	−0.094***	−0.106***
	(0.027)	(0.004)	(0.011)	(0.001)	(0.003)	(0.017)	(0.022)
No. of obs.	187	177	177	177	177	177	177
R^2	0.162	0.103	0.150	0.108	0.140	0.149	0.115
Panel B. Only the Years 1850 and 1860							
FREE_BANKING	0.164**	0.017	0.055*	0.005*	0.019**	−0.109**	−0.123**
	(0.071)	(0.010)	(0.028)	(0.003)	(0.009)	(0.044)	(0.059)
No. of obs.	34	33	33	33	33	33	33
R^2	0.143	0.083	0.113	0.105	0.142	0.165	0.122

the dependent variable in columns 1–2 with ARTISAN_WAGE and WEIGHTED_ARTISAN_COST. These results suggest that free banking increased wage rates in areas without labor exploitation, and decreased the cost of labor in areas where exploitation was pervasive.

A decline in the daily cost of using an enslaved worker after free banking meant the enslaver could extract a larger share of the labor's marginal product, which drove up the value of an enslaved worker.[33] To test this prediction, we using data on SLAVE_SALE_VALUE from Fogel and Engerman (1976b) as the dependent variable in column 5 of Table 10. Consistent with our prediction, the coefficient estimate on FREE_BANKING × LABOR_EXPLOITATION is positive, suggesting that free banking increased the financial value of owning enslaved labor in regions with pervasive slavery.

We offer two channels for the decline in marginal labor cost after the free banking reforms in states with exploited workers. One channel is that free banking led to more widespread slavery in terms of both the numbers of people enslaved and the spread of enslavement. Consistent with this channel, column 1 of Table 11 shows an increase of 16.2 percentage points in the fraction of population enslaved after free banking. Moreover, column 2 shows that the percentage of those listed

[33]Although many factors, such as market conditions and political uncertainty (Calomiris and Pritchett (2016)), might have affected the valuation of an enslaved person, a central determinant is the expected stream of cash flows generated from the marginal product of the enslaved labor net of the operating cost (Wright (2006)).

(out of the white population) as holding enslaved workers increased by 1.6 percentage points in the free banking states from 1850 to 1860. These findings are in line with studies documenting the interregional trade in enslaved people (Conrad and Meyer (1958)). Banks played a central role in assisting this trade throughout the pre-Civil War era (Murphy (2017b)). Profit-seeking banks participated in underwriting the sale of enslaved persons, accepting them as collateral for mortgage loans and equity loans; banks also assisted in selling enslaved persons as part of foreclosure proceedings against those who failed to fulfill a debt contract. Alternatively, finance might have encouraged migration by more planters (Fogel and Engerman (1974)), who then took enslaved workers with them to states that adopted free banking.

A second channel is the increased concentration of enslaved workers following the free banking law. Using data on the distribution of slaveholding from the 1850 and 1860 censuses, we show in columns 3–7 of Table 11 that slaveholding appears more concentrated after the adoption of free banking. The Gini coefficient, which is a measure of concentration based on the distribution of slaveholding, increased after free banking, suggesting that larger plantations accounted for a higher proportion of the total enslaved population. A detailed breakdown of the distribution of slaveholding confirms a rise in the percentage of large plantations (e.g., with 100 or more enslaved persons) and a decline in the percentage of small plantations (e.g., with fewer than 5 enslaved persons). In other words, large plantations grew larger by the eve of the Civil War. Due to their economies of scale, larger plantations were associated with more efficient allocation of labor, more intense monitoring, and likely lower daily operating cost. Accordingly, those who owned larger plantations extracted a higher profit (marginal product of labor minus operating cost) and had less incentive to switch to labor-saving technologies. In fact, they probably had a disincentive toward producing such innovations, as the new technology would likely have reduced the value of their major asset (enslaved labor). These findings support the mechanism that free banking aggravated labor exploitation and reduced technical progress in agriculture.

We conclude this subsection by validating that the negative impact of free banking was limited to agricultural patents in states heavily reliant on exploited labor. We focus on these states where labor exploitation was severe (LABOR_EXPLOITATION above the sample median) and estimate free banking's impact on agricultural patents relative to other patents in Table A.8 of the Supplementary Material. The coefficient estimate on FREE_BANKING captures the effect of free banking on nonagricultural patents, and the coefficient estimate on FREE_BANKING × AGRICULTURE_DUMMY captures the incremental effect of free banking on agricultural patents. Estimates in column 3 show that, relative to the nonfree-banking states, nonagricultural patents increased by 37.5% in year $t+3$ after free banking, but agricultural patents decreased by 29% (= −66.5% + 37.5%). Consistent with Hypothesis 3, these estimates suggest that in states where labor exploitation was severe, the positive effect of finance was isolated to innovations not substituting for exploited workers, and agricultural innovations actually reduced.[34]

Overall, the evidence in Tables 6–11 indicates that improved access to finance, on average, stimulated technological innovation, but its extent declined with the use of exploited workers. In response to easier bank entry under the free banking laws, states rife with labor exploitation were associated with exacerbated exploitation, a drop in the marginal cost of labor, and a reduction in agricultural patenting. When geared to aiding slavery, the additional finance weakened planters' incentives to adopt labor-saving technologies.

VI. Conclusion

In this article, we provide causal evidence of the finance-innovation nexus and of the role of labor practices in shaping this relation. Our testing ground is pre-Civil War America from 1812 to 1860. This historical episode witnessed the staggered passage of free banking laws across 18 states, which offers us an opportunity to identify exogenous variations in local access to finance. In addition, the use of enslaved labor, which is widely and rightly condemned on moral and ethical grounds, provides a window through which to study the impact of exploitative labor practices on agricultural producers' incentives to adopt labor-saving innovations.

We show that greater access to finance, as identified by the staggered passage of free banking laws, stimulated innovation on average. However, access to finance alone was no guarantee of innovation. The finance-growth nexus was more pronounced in areas where producers faced strong incentives to substitute innovative technologies for labor. In areas where producers relied extensively on exploitative labor practices, more accessible banking might have slowed agricultural innovation by exacerbating the exploitation and further dampening producers' incentives to cut labor costs. Our findings therefore contribute to existing studies by illuminating an important adverse effect of slavery on economic development.

This study advances our understanding of the factors that drive innovation. Although existing studies have explored the separate roles of finance and labor costs, little is known about how the two factors interact and jointly determine innovation outcomes. Our evidence suggests a novel mechanism through which finance can, directly and indirectly, impact innovation by influencing producers' incentives to replace labor with technology. While access to finance, in general, fosters innovation, our mechanism highlights scenarios in which finance may stifle innovation. For example, if firms respond to a relaxation of financial constraints by expanding production and adopting more exploitative labor practices, innovation might decrease.

[34]This heterogeneous response across patent types also helps to rule out alternative explanations for the negative relationship between labor exploitation and the sensitivity of patenting to free banking. For example, states associated with exploitative labor practices might be less inventive because of intrinsic characteristics, such as conservative culture, social norms, lack of economic diversity, climate, major crops, or alternative credit sources. These factors alone, however, cannot rationalize the joint results of the negative effect on agricultural patents and the positive effect on nonagricultural patents.

https://doi.org/10.1017/S0022109022000795 Published online by Cambridge University Press

Appendix A. Variable Definitions

Measures of Innovation

ln(1 + PATENTS): The natural logarithm of 1 plus the total number of patents granted in a state (county) in a given year.

ln(1 + AGRICULTURAL_PATENTS): The natural logarithm of 1 plus the total number of agricultural patents granted in a state (county) in a given year. Agricultural patents consist of those that fall into technological category 61 (Agriculture, Husbandry, Food).

AGRICULTURAL_DUMMY: An indicator variable that takes the value of 1 if the patent count in a state, ln(1 + PATENTS: agricultural or nonagricultural), is for agricultural patents and 0 if it is for nonagricultural patents.

Free Banking Events

FREE_BANKING: An indicator variable that takes the value of 0 prior to the passage of the free banking law and 1 otherwise. For Michigan, the variable was 0 prior to 1837, 1 for 1837–1839, 0 for 1840 through 1856, and 1 for 1857 and later years. For states that did not pass a free banking law, the variable takes the value of 0 for the entire sample period.

BEFORE^{m-}: An indicator variable that takes the value of 1 in all years up to and including m years prior to the free banking law's passage, and 0 otherwise.

BEFORE$^{p\&q}$: An indicator variable that takes the value of 1 in p to q years prior to the free banking law's passage, and 0 otherwise.

AFTER$^{p\&q}$: An indicator variable that takes the value of 1 in p to q years after the free banking law's passage and 0 otherwise.

AFTER^{n+}: An indicator variable that takes the value of 1 in n or more years after the free banking law's passage and 0 otherwise.

LITTLE (LARGE)_FREE_BANKING: An indicator variable that takes the value of 1 if FREE_BANKING equals 1 and the state had little (significant) free banking activities, and 0 otherwise. Of the 18 states that adopted free banking, 7 had only little activity by free banks, and 11 had significant or "large" levels of activity by free banks.

Baseline Control Variables

ln(POPULATION): The natural logarithm of the total population in a state (county) in a given year, from the decennial census.

URBAN_RATIO: The ratio of urban population to total population in a state (county) in a given year, from the decennial census.

WHITE_RATIO: The ratio of white population to total population in a state (county) in a given year, from the decennial census.

Measures of Access to Finance

ln(1 + BANKS): The natural logarithm of 1 plus the total number of banks in operation in a state in a given year.

ln(1 + BANK_ASSETS): The natural logarithm of 1 plus the total dollar value of bank assets in a state in a given year. The value is obtained by summing over the total assets on individual bank's balance sheets.

ln(1 + BANK_LOANS): The natural logarithm of 1 plus the total dollar value of bank loans and discounts in a state in a given year. The value is obtained by summing over the loans and discounts on individual bank's balance sheets.

ln(1 + FREE_BANKS): The natural logarithm of 1 plus the total number of free banks in operation in a state (county) in a given year.

ln(1 + FREE_BANK_ASSETS): The natural logarithm of 1 plus the total dollar value of free bank assets in a state (county) in a given year. The value is obtained by summing over the total assets on individual bank's balance sheets.

ln(1 + FREE_BANK_LOANS): The natural logarithm of 1 plus the total dollar value of free bank loans and discounts in a state (county) in a given year. The value is obtained by summing over the loans and discounts on individual bank's balance sheets.

Measures of Labor Exploitation and the Cost of Labor

LABOR_EXPLOITATION: The fraction of a state's (county's) population that was enslaved at the beginning of the pre-Civil War era. We use the ratio of enslaved population to total population in the 1810 census; if a state or territory did not have population data reported in the 1810 census, we instead use the first year when the demographic data are available.

COMMON_LABORER_WAGE: The real daily wage rate for a common laborer in a state in a given year. The data are from Margo and Villaflor (1987), who construct nominal daily wage rates at the census region level from 1820 to 1856 using payroll records of the US military that report wages paid to civilian workers at forts located throughout the country. We convert nominal values to real terms using historical CPI (Officer and Williamson (2018)).

ARTISAN_WAGE: The real daily wage rate for an artisan in a state in a given year. The data are from Margo and Villaflor (1987). We convert nominal values to real terms using historical CPI (Officer and Williamson (2018)).

SLAVE_HIRE_RATE: The real daily hire rate for an enslaved laborer in a state in a given year. The source is Fogel and Engerman (1976a), who provide data pertaining to slave hiring transactions that occurred from 1775 to 1865 in 8 Southern states: Virginia, Maryland, North Carolina, South Carolina, Louisiana, Tennessee, Georgia, and Mississippi. We convert nominal values to real terms using historical CPI (Officer and Williamson (2018)).

WEIGHTED_LABORER (ARTISAN)_COST: The average of COMMON_LABORER_WAGE (ARTISAN_WAGE) weighted by the fraction of population that was free and SLAVE_HIRE_RATE weighted by the fraction of population that was enslaved.

SLAVE_SALE_VALUE: The real sale value for an enslaved person in a state in a given year (in thousand dollars). The source is Fogel and Engerman (1976b), who provide data pertaining to slave sales and appraisals that occurred from 1775 to 1865 in 8 Southern states: Virginia, Maryland, North Carolina, South Carolina, Louisiana, Tennessee, Georgia, and Mississippi. We convert nominal values to real terms using historical CPI by Officer and Williamson (2018).

FRACTION_ENSLAVED: The fraction of a state's (county's) population that was enslaved in a given year, from the decennial census.

PERCENTAGE_OF_SLAVEHOLDERS: The number of slaveholders divided by the white population in a state in a given year, from the decennial census.

GINI_COEFFICIENT: The number of slaveholders are distributed across the following size bins (in the number of enslaved persons): 0–1; 2–4; 5–9; 10–19; 20–49; 50–99; 100–199; 200–299; 300–499; 500–999; 1,000 and above. We use the midpoint of each bin to construct the Gini coefficient; slaveholders with more than 1,000 enslaved persons are assumed to hold 1,000 enslaved persons.

ENSLAVED_CHOLERA_DEATHS: A variable that equals the fraction of a county's enslaved population that died of cholera in 1850 for the years 1850–1854, and 0 for the years 1855–1860. This variable is standardized to have a mean of 0 and a standard deviation of 1. We consider three alternative measures of this variable in Table 8.

IRISH_IMMIGRANTS: The number of Irish immigrants that arrived in a state in a given year for 1820–1860. We construct the variable following a modified shift-share instrument approach by interacting the annual total inflow of immigrants into the US, and the shares of Irish persons that settled in each state reported in the 1850 census (the first year when such information is available). This variable is standardized to have a mean of 0 and a standard deviation of 1.

Additional State-Level Characteristics

INNOVATION_GROWTH: The annual growth rate of the number of patents.

POLITICAL_ PARTY: An indicator variable that takes the value of 1 if the presiding party in a state was Whig or Republican and 0 otherwise. The data are from the record of the governors of the states in *The Tribune Almanac and Political Register.*

AGRICULTURAL_ LABOR_ RATIO: The ratio of agricultural labor to the sum of agricultural and manufacturing labor in a state in a given year, from the decennial census.

AGRICULTURAL_OUTPUT: The value of total agricultural output in a state in a given year, from the decennial census.

MANUFACTURING_OUTPUT: The value of total manufacturing output in a state in a given year, from the decennial census.

AGRICULTURAL_OUTPUT_RATIO: The ratio of agricultural output value to the sum of agricultural and manufacturing output value, from the decennial census.

EDUCATION: The number of students in academies, grammar schools, and universities or colleges, scaled by the total population in a state in a given year, from the decennial census.

FOREIGN-BORN_RATIO: The ratio of foreign-born population to total population in a state in a given year, from the decennial census.

RAILWAY: The fraction of counties that had railway access in a state in a given year, from the decennial census.

MAX_RATE: The maximum interest rate limit in a state imposed by usury laws, from Holmes (1892).

INCORPORATION_LAW: An indicator variable that takes the value of 0 prior to the passage of the general incorporation statutes for manufacturing firms and 1 otherwise. The variable resets to 0 for states that repealed the laws and returns to 1 when the state reinstated the law. For states that did not pass the general incorporation laws, the variable takes the value of 0 for the entire sample period. The chronology is from Hilt (2017).

Appendix B: A Conceptual Framework

To articulate the theoretical motivation for our hypotheses, we build a conceptual framework to understand how access to finance as well as labor practices shape innovation outcomes.

B.1. Environment

The economy has a monopoly entrepreneur and a representative final goods producer. The entrepreneur innovates and patents new technology, $\theta \in (0,1)$, and manufactures tools or machines, q, that embody the patented technology. To fix ideas, suppose θ is the technology to automate the task of reaping crops; then q is the quantity of mechanical reapers.

The representative final goods producer combines labor $L \in (0,1)$, technology θ, and machines q in production. The production function is given by $\alpha^{-\alpha}(1-\alpha)^{-1}F(L,\theta)^{\alpha}q^{1-\alpha}$, where $\alpha \in (0,1)$ and the scalar, $\alpha^{-\alpha}(1-\alpha)^{-1}$, is included for convenient normalization following Acemoglu (2010). Function $F(L,\theta)$ is increasing in both arguments and concave with labor; technology and labor satisfy $\partial^2 F/\partial L \partial \theta < 0$, that is, technology and labor are substitutes, reflecting a choice between labor-intensive production and capital-intensive production. For analytical convenience, let us take the functional form $F(L,\theta) = \theta + (1-\theta)L^{\beta}$, with $\beta \in (0,1)$, such that $\partial F/\partial \theta = 1 - L^{\beta}$, and $\partial F/\partial L = (1-\theta)\beta L^{\beta-1}$. Whereas better technology boosts the productivity of machines, the marginal benefit decreases with the amount of labor input. Intuitively, θ is a labor-saving technology that shifts tasks from labor to machines.

The producer faces a unit cost of machine, χ, set by the monopoly entrepreneur. The unit cost of labor, w, depends on the local labor practices. In a region without exploitative labor practices, a competitive wage, $\overline{w}$, is paid to workers for each unit of labor input. By contrast, in a region where exploitative labor practices prevail, for example, through producers' property rights over labor, producers can extract part of labor's marginal product. Denoting the exploitation rate by e, the unit cost of exploited labor is $\overline{w} - e$.[35] Let the fraction of labor subject to exploitation in a region be d, the weighted unit cost of labor is $w = (1-d)\overline{w} + d(\overline{w} - e) = \overline{w} - de$. All else equal, the weighted unit cost of labor w decreases with the fraction of labor subject to exploitation d, and the exploitation rate e.

[35]Consistent with Ransom and Sutch (2001), in exploitative labor practices (such as slavery), a large part of labor's marginal product goes to the owner, giving rise to the exploitation rate. The unit cost of exploited labor to an owner, $\overline{w} - e$, includes providing basic necessities (food, clothing, and shelter).

With monopoly power, the entrepreneur manufactures machines that embody the patented technology.[36] Due to information frictions and transaction costs inherent in financing innovative activities, the entrepreneur incurs a cost, $C(\theta,\gamma)$, for example, for research and development (R&D), constructing prototypes, marketing, and gathering information for demand. The parameter γ summarizes the entrepreneur's access to local finance. $C(\theta,\gamma)$ is increasing and convex with θ, decreasing with γ, and satisfies $\partial^2 C/\partial\theta\partial\gamma < 0$. To simplify the analysis, let $C(\theta,\gamma)=\theta^2/(2\gamma)$, so $\partial C/\partial\theta=\theta/\gamma$. This is a reduced-form approach to capture the idea that greater access to local finance reduces the marginal cost of innovation by relaxing the entrepreneur's financing constraint and lowering financing cost. Besides potentially relaxing the constraint to finance R&D or patent application, improved access to local finance may benefit an entrepreneur in several other ways. For instance, with a banker in town, the entrepreneur may face lower financing cost for manufacturing the new machines; she may also find it easier to acquire information and to market the new technology. Once the technology is patented, the entrepreneur has monopoly power and charges a monopoly price, χ, for each machine. To capture the nonrivalrous character of the technology, we assume that the machines can be produced at a low per-unit cost, normalized to $1-\alpha$.

B.2. Optimization

Given the unit cost of machine χ and the unit cost of labor w, the final goods producer chooses factor demands to maximize profit, that is,

$$\max_{q,L} \alpha^{-\alpha}(1-\alpha)^{-1}F(L,\theta)^{\alpha}q^{1-\alpha}-wL-\chi q. \tag{B-1}$$

Taking the first-order conditions with respect to q and L, we obtain that the demand for machines satisfies $q^*=\alpha^{-1}F\chi^{-\frac{1}{\alpha}}$, and the demand for labor satisfies $(1-\alpha)^{-1}\chi^{1-\frac{1}{\alpha}}\frac{\partial F}{\partial L}=w$. Since F is increasing and concave with L, we have $\partial L^*/\partial w<0$, that is, the demand for labor decreases with its cost.

Given the demand for machines and the cost of manufacturing the new technology, the monopoly entrepreneur chooses the level of technology θ and the monopoly unit price χ:

$$\max_{\theta,\chi}(\chi-(1-\alpha))q-C(\theta,\gamma). \tag{B-2}$$

B.3. Equilibrium Definition

For given labor practices and labor cost of a local region, $(\overline{w},d,e)$, an equilibrium consists of the factor demands of the final goods producer (q^*,L^*) and the entrepreneur's decisions (θ^*,χ^*), such that q^* and L^* solve the producer's problem (B-1) given w, θ^*, and χ^*, and θ^* and χ^* solve the entrepreneur's problem (B-2) given the demand for machine q^*.

[36]We assume the entrepreneur files the patent application and manufactures the machines. In practice, the innovator and the manufacturer could be different persons; nonetheless, the two activities are closely connected. For patent filing to be profitable, there must be a corresponding product market and an interested manufacturer for the technology. If greater access to finance makes the manufacturers more willing to invest, patenting promises greater profits, and innovators would become more willing to file patents and earn a royalty. One example is Walter Hunt, discussed in Section II.A. Hunt sold the patent for the safety pin to W. R. Grace and Company, who mass-produced the safety pin and made millions.

B.4. Factors Driving Innovation

We start by substituting the demand for machines $q^* = \alpha^{-1} F \chi^{-\frac{1}{\alpha}}$ into the entrepreneur's problem (B-2). A first-order condition with respect to χ gives the profit-maximizing price of the entrepreneur, $\chi^* = 1$. Substituting χ^* and q^* into (B-2), we reduce the entrepreneur's problem to $\max_{\{\theta\}} F(L^*, \theta) - C(\theta, \gamma)$. The equilibrium innovation θ^* satisfies

$$\theta^* = \gamma\left(1 - L^{*\beta}\right). \tag{B-3}$$

B.5. Testable Predictions

The equilibrium θ^* equates the marginal cost of innovation with its marginal benefit. The marginal cost, θ^*/γ, is inversely related to access to finance. The marginal benefit, $1 - L^{*\beta}$, is negatively related to the equilibrium labor input, which in turn depends on the local labor practices. Accordingly, two factors (access to finance and local labor practices) jointly determine the equilibrium innovation outcomes. This stylized model delivers several testable predictions which provide theoretical motivation for our hypotheses.

Prediction 1. $\partial\theta^*/\partial\gamma > 0$.

Prediction 1 establishes the positive impact of access to finance on innovation outcomes. Since $L^* \in (0, 1)$, equation (B-3) implies that θ^* increases with γ, all else equal. Greater access to finance shifts the marginal cost of innovation downward, leading to more innovation.

Prediction 2. $\partial\theta^*/\partial\gamma$ increases with the competitive labor cost $\overline{w}$, decreases with the fraction of labor subject to exploitation d, and decreases with the exploitation rate e.

Prediction 2 shows that the marginal impact of access to finance on innovation depends on local labor practices. Equation (B-3) suggests that the impact of finance on innovation, $\partial\theta^*/\partial\gamma$, is negatively related to labor input L^*. From the producer's optimization problem, labor input decreases with labor cost w. Accordingly, the sensitivity of innovation to finance increases with labor cost w. Intuitively, in regions where higher unit cost of labor creates stronger incentives to replace labor, greater access to finance has a more substantial impact on labor-saving innovation. In our framework, the unit cost of labor depends on three terms: the competitive labor cost $\overline{w}$, the fraction of labor subject to exploitation d, and the exploitation rate e. For instance, we expect that in the cross section, the effect of finance on innovation is the greatest in areas where exploitative labor practices are absent, and the effect is weaker in areas with a larger fraction of exploited labor.

Prediction 3. In areas where $d'(\gamma) > 0$ holds, the sign of $\partial\theta^*/\partial\gamma$ is ambiguous.

Our baseline framework takes the labor practices of a region as fixed. Instead, Prediction 3 considers a scenario when labor practices (thus the unit cost of labor) change with access to finance. The additional assumption, $d'(\gamma) > 0$, states that access to finance, besides reducing the marginal cost of innovation, also increases the fraction of labor under exploitation. This additional force, if significant enough, will break the positive link between finance and innovation. To see this, note that $d\theta^*/d\gamma = (1 - L^{*\beta}) + \partial\theta^*/\partial L \times \partial L^*/\partial d \times d'(\gamma)$. Equation (B-3) suggests that $\partial\theta^*/\partial L < 0$, because an increase in labor input lowers the marginal value of labor-saving technology. From our earlier results, the demand for labor decreases with the cost w (recall that $w = \overline{w} - de$) and increases with the fraction of labor under exploitation d, that is, $\partial L^*/\partial d > 0$. Under the assumption that $d'(\gamma) > 0$, the last term above in $d\theta^*/d\gamma$ is negative. Especially if $d'(\gamma)$ is sufficiently large, it is possible that $d\theta^*/d\gamma < 0$. A similar prediction follows if $e'(\gamma) > 0$ holds. Prediction 3 highlights that the relation between finance and innovation becomes subtle when labor relations interact with access to finance.

Supplementary Material

Supplementary Material for this article is available at https://doi.org/10.1017/S0022109022000795.

References

Acemoglu, D. "Technical Change, Inequality, and the Labor Market." *Journal of Economic Literature*, 40 (2002), 7–72.

Acemoglu, D. "When Does Labor Scarcity Encourage Innovation?" *Journal of Political Economy*, 118 (2010), 1037–1078.

Amore, M. D.; C. Schneider; and A. Žaldokas. "Credit Supply and Corporate Innovation." *Journal of Financial Economics*, 109 (2013), 835–855.

Beck, T.; R. Levine; and N. Loayza. "Finance and the Sources of Growth." *Journal of Financial Economics*, 58 (2000), 261–300.

Bena, J.; H. Ortiz-Molina; and E. Simintzi. "Shielding Firm Value: Employment Protection and Process Innovation." *Journal of Financial Economics*, 146 (2022), 637–664.

Benmelech, E., and T. J. Moskowitz. "The Political Economy of Financial Regulation: Evidence from U.S. State Usury Laws in the 19th Century." *Journal of Finance*, 65 (2010), 1029–1073.

Black, S. E., and P. E. Strahan. "Entrepreneurship and Bank Credit Availability." *Journal of Finance*, 57 (2002), 2807–2833.

Bodenhorn, H. "Entry, Rivalry and Free Banking in Antebellum America." *Review of Economics and Statistics*, 72 (1990), 682–686.

Bodenhorn, H. "An Engine of Growth: Real Bills and Schumpeterian Banking in Antebellum New York." *Explorations in Economic History*, 36 (1999), 278–302.

Bodenhorn, H. *A History of Banking in Antebellum America: Markets and Economic Development in an Era of Nation-Building*. Cambridge: Cambridge University Press (2000).

Bodenhorn, H. "Bank Chartering and Political Corruption in Antebellum New York: Free Banking as Reform." In *Corruption and Reform: Lessons from America's Economic History*. Chicago, IL: University of Chicago Press (2006), 231–257.

Brown, J. R.; S. M. Fazzari; and B. C. Petersen. "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom." *Journal of Finance*, 64 (2009), 151–185.

Calomiris, C., and J. Pritchett. "Betting on Secession: Quantifying Political Events Surrounding Slavery and the Civil War." *American Economic Review*, 106 (2016), 1–23.

Cameron, A. C.; J. B. Gelbach; and D. L. Miller. "Bootstrap-Based Improvements for Inference with Clustered Errors." *Review of Economics and Statistics*, 90 (2008), 414–427.

Card, D. "Immigrant Inflows, Native Outflows, and the Local Labor Market Impacts of Higher Immigration." *Journal of Labor Economics*, 19 (2001), 22–64.

Carlson, M.; S. Correia; and S. Luck. "The Effects of Banking Competition on Growth and Financial Stability: Evidence From the National Banking Era." *Journal of Political Economy*, 130 (2022), 462–520.

Celik, M. A.; X. Tian; and W. Wang. "Acquiring Innovation Under Information Frictions." Working Paper, available at https://papers.ssrn.com/sol3/Papers.cfm?abstract_id=3475698 (2020).

Chava, S.; A. Oettl; A. Subramanian; and K. V. Subramanian. "Banking Deregulation and Innovation." *Journal of Financial Economics*, 109 (2013), 759–774.

Chemmanur, T. J.; E. Loutskina; and X. Tian. "Corporate Venture Capital, Value Creation, and Innovation." *Review of Financial Studies*, 27 (2014), 2434–2473.

Chemmanur, T. J., and X. Tian. "Do Antitakeover Provisions Spur Corporate Innovation? A Regression Discontinuity Analysis." *Journal of Financial and Quantitative Analysis*, 53 (2018), 1163–1194.

Collins, W. H. *The Domestic Slave Trade of the Southern States*. New York: Broadway Publishing Company (1904).

Congress. *United States Congressional Register*, Vol. 3137–3140. Washington, DC: U.S. Government Printing Office (1832).

Congress. *United States Congressional Serial Set*. Vol. 302. Washington, DC: U.S. Government Printing Office (1837).

Conrad, A. H., and J. R. Meyer. "The Economics of Slavery in the Ante Bellum South." *Journal of Political Economy*, 66 (1958), 95–130.

Cornaggia, J.; Y. Mao; X. Tian; and B. Wolfe. "Does Banking Competition Affect Innovation?" *Journal of Financial Economics*, 115 (2015), 95–130.

D'Acunto, F. "From Financial History to History & Finance." Working Paper, Georgetown University (2018).

D'Acunto, F.; M. Prokopczuk; and M. Weber. "Historical Antisemitism, Ethnic Specialization, and Financial Development." *Review of Economic Studies*, 86 (2018), 1170–1206.

David, P. A. *Technical Choice, Innovation and Economic Growth: Essays on American and British Experience in the Nineteenth Century*. Cambridge: Cambridge University Press (1975).

Economopoulous, A., and H. O'Neill. "Bank Entry during the Antebellum Period." *Journal of Money, Credit and Banking*, 27 (1995), 1071–1085.

Fleisig, H. "Slavery, the Supply of Agricultural Labor, and the Industrialization of the South." *Journal of Economic History*, 36 (1976), 572–597.

Fogel, R. W., and S. L. Engerman. *Time on the Cross: The Economics of American Negro Slavery*. Boston, MA: Little, Brown and Company (1974).

Fogel, R. W., and S. L. Engerman. *Slave Hires, 1775–1865*. Ann Arbor, MI: Inter-University Consortium for Political and Social Research (1976a).

Fogel, R. W., and S. L. Engerman. *Slave Sales and Appraisals, 1775–1865*. Ann Arbor, MI: Inter-University Consortium for Political and Social Research (1976b).

Goldin, C., and L. F. Katz. "The Origins of Technology-Skill Complementarity." *Quarterly Journal of Economics*, 113 (1998), 693–732.

Goldin, C., and K. L. Sokoloff. "Women, Children, and Industrialization in the Early Republic: Evidence from the Manufacturing Censuses." *Journal of Economic History*, 42 (1982), 741–774.

Goldin, C., and K. L. Sokoloff. "The Relative Productivity Hypothesis of Industrialization: The American Case, 1820 to 1850." *Quarterly Journal of Economics*, 99 (1984), 461–487.

Griliches, Z. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature*, 28 (1990), 1661–1707.

Habakkuk, H. *American and British Technology in the Nineteenth Century: The Search for Labour Saving Inventions*. Cambridge: Cambridge University Press (1962).

Hall, B. H.; A. B. Jaffe; and M. Trajtenberg. "The NBER Patent Citations Data File: Lessons, Insights, and Methodological Tools" (2001).

Hall, B. H., and J. Lerner. "The Financing of R&D and Innovation." In *Handbook of the Economics of Innovation*, Vol. 1, B. Hall, and N. Rosenberg, eds. Amsterdam: North Holland (2010), 609–639.

Hammond, B. *Banks and Politics in America: From the Revolution to the Civil War*. Princeton: Princeton University Press (1957).

Hays, J. N. *Epidemics and Pandemics: Their Impacts on Human History*. Santa Barbara, CA: ABC-CLIO (2005).

Heider, F., and A. Ljungqvist. "As Certain as Debt and Taxes: Estimating the Tax Sensitivity of Leverage from State Tax Changes." *Journal of Financial Economics*, 118 (2015), 684–712.

Higgs, R. "American Inventiveness, 1870–1920." *Journal of Political Economy*, 79 (1971), 661–667.

Hilt, E. "Corporation Law and the Shift toward Open Access in the Antebellum United States." In *Organizations, Civil Society, and the Roots of Development*. Chicago: University of Chicago Press (2017), 147–177.

Holmes, G. K. "Usury in Law, in Practice and in Psychology." *Political Science Quarterly*, 7 (1892), 431–467.

Hornbeck, R., and S. Naidu. "When the Levee Breaks: Black Migration and Economic Development in the American South." *American Economic Review*, 104 (2014), 963–990.

Hsu, P.-H.; X. Tian; and Y. Xu. "Financial Development and Innovation: Cross-Country Evidence." *Journal of Financial Economics*, 112 (2014), 116–135.

Huang, R. R. "Evaluating the Real Effect of Bank Branching Deregulation: Comparing Contiguous Counties across US State Borders." *Journal of Financial Economics*, 87 (2008), 678–705.

International Labour Organization. "Global Estimates of Modern Slavery: Forced Labour and Forced Marriage" (2017).

Jaremski, M., and P. Rousseau. "Banks, Free Banks, and U.S. Economic Growth." *Economic Inquiry*, 51 (2013), 1603–1621.

Jayaratne, J., and P. E. Strahan. "The Finance-Growth Nexus: Evidence from Bank Branch Deregulation." *Quarterly Journal of Economics*, 111 (1996), 639–670.

Kerr, W. R., and R. Nanda. "Democratizing Entry: Banking Deregulations, Financing Constraints, and Entrepreneurship." *Journal of Financial Economics*, 94 (2009), 124–149.

Kerr, W. R., and R. Nanda. "Financing Innovation." *Annual Review of Financial Economics*, 7 (2015), 445–462.

King, R. G., and R. Levine. "Finance and Growth: Schumpeter Might be Right." *Quarterly Journal of Economics*, 108 (1993a), 717–737.

King, R. G., and R. Levine. "Finance, Entrepreneurship and Growth." *Journal of Monetary Economics*, 32 (1993b), 513–542.

Lamoreaux, N. R. *Insider Lending: Banks, Personal Connections, and Economic Development in Industrial New England*. Cambridge: Cambridge University Press (1996).

Lamoreaux, N. R., and K. L. Sokoloff. "Long-Term Change in the Organization of Inventive Activity." *Proceedings of the National Academy of Sciences of the United States of America*, 93 (1996), 12686–12692.

Lamoreaux, N. R., and K. L. Sokoloff. "The Geography of Invention in the American Glass Industry, 1870–1925." *Journal of Economic History*, 60 (2000), 700–729.

Laxton, E. *The Famine Ships: The Irish Exodus to America, 1846–51*. London: Bloomsbury (1997).

Lebergott, S. "Wage Trends, 1800–1900." In *Trends in the American Economy in the Nineteenth Century*. Princeton: Princeton University Press (1960), 449–500.

Levine, R. "Financial Development and Economic Growth: Views and Agenda." *Journal of Economic Literature*, 35 (1997), 688–726.

Luong, H.; F. Moshirian; L. Nguyen; X. Tian; and B. Zhang. "How Do Foreign Institutional Investors Enhance Firm Innovation?" *Journal of Financial and Quantitative Analysis*, 52 (2017), 1449–1490.

Margo, R. A., and G. C. Villaflor. "The Growth of Wages in Antebellum America: New Evidence." *Journal of Economic History*, 47 (1987), 873–895.

Martin, B. "Slavery's Invisible Engine: Mortgaging Human Property." *Journal of Southern History*, 76 (2010), 817–866.

McKinnon, R. *Money and Capital in Economic Development*. Washington, DC: Brookings Institution (1973).

Murphy, S. A. "Banking on Slavery in the Antebellum South." Yale University Economic History Workshop Working Paper (2017a).

Murphy, S. A. Free Banking in Louisiana. Tobin Project Conference on Democracy Working Paper (2017b).

Murphy, S. A. *Other People's Money: How Banking Worked in the Early American Republic. How Things Worked*. Baltimore, MD: Johns Hopkins University Press (2017c).

Nanda, R., and T. Nicholas. "Did Bank Distress Stifle Innovation During the Great Depression?" *Journal of Financial Economics*, 114 (2014), 273–292.

Nanda, R., and M. Rhodes-Kropf. "Financing Risk and Innovation." *Management Science*, 63 (2017), 901–918.

Nunn, N. "The Long Term Effects of Africa's Slave Trades." *Quarterly Journal of Economics*, 123 (2008), 139–176.

OCC. *Annual Report of the Comptroller of the Currency*. Washington, DC: Washington Government Printing Office (1876).

Officer, L. H., and S. H. Williamson. *"The Annual Consumer Price Index for the United States, 1774–Present."* Measuring Worth (2018).

Pierce, L., and J. A. Snyder. "The Historical Slave Trade and Firm Access to Finance in Africa." *Review of Financial Studies*, 31 (2017), 142–174.

Ransom, R. L., and R. Sutch. *One Kind of Freedom: The Economic Consequences of Emancipation*. Cambridge: Cambridge University Press (2001).

Rasmussen, W. D. "The Mechanization of Agriculture." *Scientific American*, 247 (1982), 76–89.

Rockoff, H. "The Free Banking Era: A Reexamination." *Journal of Money, Credit and Banking*, 6 (1974), 141–167.

Rolnick, A. J., and W. E. Weber. "New Evidence on the Free Banking Era." *American Economic Review*, 73 (1983), 1080–1091.

Rosenberg, N. "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices." *Economic Development and Cultural Change*, 18 (1969), 1–24.

Rosenberg, C. E. *The Cholera Years: The United States in 1832, 1849, and 1866*. Chicago: University of Chicago Press (2009).

Rosenbloom, J. L. "Antebellum Labor Markets." In *Oxford Research Encyclopedia of American History*. Oxford: Oxford University Press (2018).

Schumpeter, J. A. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, MA: Harvard University Press (1934).

Sokoloff, K. L. "Invention, Innovation, and Manufacturing Productivity Growth in the Antebellum Northeast." In *American Economic Growth and Standards of Living before the Civil War*. Chicago: University of Chicago Press (1992), 345–384.

Temin, P. "Labor Scarcity in America." *Journal of Interdisciplinary History*, 1 (1971), 251–264.

Weber, W. E. "Early State Banks in the United States: How Many Were There and When Did They Exist?" *Journal of Economic History*, 66 (2006), 433–455.

Weber, W. E. "Balance Sheets for U.S. Antebellum State Banks." Minneapolis Fed Working Paper (2008).

Willcox, W. F. *International Migrations, Volume I: Statistics*. New York: National Bureau of Economic Research (1929).

Wittke, C. F. *We Who Built America: the Saga of the Immigrant*. Cleveland, OH: Press of Western Reserve University (1939).

Wright, G. "Slavery and American Economic Development." Walter Lynwood Fleming Lectures in Southern History. Louisiana State University Press (2006).