Access to Finance and Technological Innovation: Evidence from Antebellum America*

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Abstract

This paper provides new evidence on how access to finance impacts technological innovation and establishes labor scarcity as a novel economic mechanism. We exploit antebellum America, a unique setting with (1) staggered passage of free banking laws across states and (2) well-documented differences in labor scarcity between free and slave states. We find that access to finance spurred technological innovation as measured by patenting activities, especially in free states where labor was relatively scarcer. Notably, in slave states, access to finance encouraged technological innovation that substituted for free labor but discouraged technological innovation that substituted for slave labor.

Keywords: access to finance, innovation, labor scarcity, labor cost, free banking laws

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While technological innovation is key to economic growth (Romer, 1990), it is difficult to achieve. Pioneered by Schumpeter, a large literature has established a well-functioning financial market as a driver of technological innovation (King and Levine, 1993; Brown et al., 2009; Hall and Lerner, 2010; Hsu et al., 2014; Kerr and Nanda, 2015). Yet, the role of finance is rarely examined in connection with the fundamental incentive of innovation—reducing production costs. As argued by Rosenberg (1969) and Spence (1984), a major incentive for firms to develop new technology is to gain competitive advantage by spending less on production.[1] While financial market development contributes to better credit supply, the degree to which firms utilize credit to innovate remains a question.

In this paper, we make two contributions to the understanding of forces driving innovation. First, using a novel bank deregulation shock, we provide new evidence that access to finance elicits innovation. Second, we fill a gap in the literature by examining the marginal effect of finance on innovation under cost reduction incentives. In particular, we focus on *labor scarcity*, a term we use to measure local shortages of labor. Labor scarcity leads to high labor costs and hence to strong incentives to adopt labor-saving technologies.

Our testing ground is antebellum America. This fascinating period from just after the War of 1812 until 1860 (prior to the beginning of the Civil War), provides a unique laboratory for our test. First, this period witnessed the staggered passage of the free banking laws across 18 states, a novel setting in which to identify banking shocks. In the early 1800s, banks were mainly local businesses, owing to information frictions, costs in transportation, and the dearth of interstate branching. Access to banks was difficult because the chartering process was corrupted. Between 1837 and 1860, 18 states passed the free banking laws. The laws replaced individual charters with *free entry* upon a bank's satisfaction of standard requirements. The passage of the free banking laws encouraged bank entry and was a positive shock to a state's access to local finance.

Second, 19th century America has long been considered labor scarce (Rothbarth, 1946; Habakkuk, 1962; Temin, 1971)—a high land-labor ratio and moving costs contributed to local shortages of labor. Across regions, labor scarcity differed between the free states in the North and the slave states in the South. While the practice of slavery has been widely

[1]From Rosenberg (1969), firms tried to invent labor-saving technology when labor was dear, and likewise when capital was dear. Spence (1984) establishes the importance of cost-reducing R&D by showing that firms compete by spending resources with the purpose of reducing costs. Mokyr (2010) documents that many goods, such as fuel, steel, energy consumption, and transportation, have experienced a reduction in costs due to technological innovation for 1750–1914. Schaller (1997) illustrates the role of innovation in computer technology in reducing computational and labor cost, as documented and predicted by Moore's law.

and rightly condemned on moral and ethical grounds, the resulting distortions of local labor markets nevertheless provide a window by which to study the role of labor scarcity. We document that, especially owing to the institution of slavery in the South, labor costs at the margin for the same occupation were higher in the North. In other words, labor scarcity was more severe in the free states than in the slave states. The difference in labor scarcity was reinforced by the immobility of labor across regions—another feature of antebellum America distinct from today's world.

To guide empirical work, we build a model based on Acemoglu (2010) and show how access to finance and labor scarcity jointly affect innovation. The entrepreneur patents new technology; she earns monopoly profit from manufacturing machines that embody the technology but also incurs a setup cost. The final goods producers combine labor and technology in production. Given producers' demand for machines, the entrepreneur decides the level of innovation and monopoly price for machines. Importantly, labor scarcity drives producers' demand for labor-saving technology;[2] greater access to finance reduces the entrepreneur's cost of manufacturing. We show that the equilibrium innovation is jointly determined by labor scarcity and access to finance. This stylized model has several predictions. First, access to finance spurs innovation. Second, access to finance has a more substantial impact on innovation when labor is scarcer. Finally, if access to finance exacerbates labor scarcity, we would expect an even greater increase in innovation; however, if access to finance relaxes labor scarcity, the equilibrium innovation can decrease.

In the baseline analysis, we examine whether access to finance spurred innovation. Our difference-in-differences tests use the staggered passage of the free banking laws. Historical records seem to suggest that the timing of the laws' passage across states was plausibly exogenous.[3] Our test shows that the likelihood of a state passing the law was not affected by state-level determinants of innovation or trends in innovation prior to the law's passage. Fur-

[2]We focus on labor-saving technologies which are substitutes of labor in production. While generally speaking, technologies can also be labor complementary (e.g., as may be the case with computers complementing college graduates), antebellum America was mostly concerned with labor-saving technologies. The well-known *Habakkuk hypothesis* in economic history argues that rapid technological progress in 19th century US was owed to labor scarcity, which acted as a powerful inducement for the adoption of labor-saving technologies, and more broadly for innovation. Similar arguments and empirical evidence are also in e.g., Rothbarth (1946), Stewart (1977), James (1981), and James and Skinner (1985). In comparing labor-saving and labor-complementary technologies, Acemoglu argues: "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..." (Acemoglu, 2010, p. 1040).

[3]For example, the case of New York State was triggered by a kidnapping incident and was referred to as having a "serendipitous nature." For more discussions, see Section IV.A and online Appendix A.2.

thermore, we find that following the law's passage, free banks entered significantly, whereas charter banks did not exit or become smaller. The evidence confirms that the passage of free banking laws did improve access to finance.

Our baseline result confirms that finance spurs innovation: After the passage of the free banking laws, the number of patents granted in a state increased significantly in the subsequent years. The economic magnitude was sizable. On average, a state that passed the free banking law generated 11.1 more patents in the third year of free banking than states without free banking; this magnitude accounted for 14.7% of the state-level patent variability. The results are robust to controlling for state and year fixed effects, and time-varying state-level variables. In addition to free banks directly acting as Schumpeterian financiers, the estimated effect could also take place through indirect channels such as improved currency stability and advancement in transportation and commerce.

We then conduct a battery of tests to ensure that our baseline results indeed show a causal impact of free banking on innovation. First, following Bertrand and Mullainathan (2003), we examine the dynamics of innovation surrounding the laws' passage. The innovation output shows no prior trend, indicating that reverse causality is unlikely to explain our results. Second, we conduct a placebo test by generating pseudo treated groups and re-estimating our baseline model: We conclude that the baseline results cannot occur mechanically in the data.

Having established that access to finance spurred innovation, we next turn to the role of labor scarcity. From our theoretical model, labor scarcity drives producers' demand for labor-saving technology and strengthens the causal impact of finance on innovation. To test this hypothesis, we exploit differences in labor scarcity between the free and slave states. In free states where slavery was prohibited, production was carried out by wage labor; in slave states, slave labor and free labor coexisted.[4] Using a variety of records on labor costs—one indicator for labor scarcity—we document that the free states faced higher labor costs at the margin. Compared within free labor, wages in the North were about 21% higher than wages earned by laborers in the South; compared within agricultural farm labor, daily wage of a farm laborer in the North was 23% higher than that in the South, and three times as much as the daily slave hire price in the South. Evidence also suggests that the observed difference in costs is not a reflection of difference in productivity.

We find that the impact of free banking was higher in free states, where producers faced

[4]Free labor, as opposed to slave labor, refers to unforced labor. "Free labor" does not mean that the labor was free of charge; in fact, free labor was wage-earning.

higher labor costs and had stronger incentives to adopt labor-saving technologies. Granted, free states and slave states differed in many dimensions including economic conditions and industry composition. The purpose of this paper is not to eliminate other mechanisms that could generate differences in innovation but to establish labor scarcity as a new mechanism. To do so, we conduct robustness checks by controlling for industry concentration, educational achievement, innovation growth, and access to railway transportation. We also examine subsample tests using states that had predominantly agricultural economies with similar agricultural products. Our results are robust. We further discuss alternative mechanisms, but find little theoretical or empirical support. Overall, our findings indicate labor scarcity to be a salient mechanism.

To further pin down the labor scarcity mechanism, we take advantage of the differences in industry concentration between the free and slave states and introduce patent technology classification. The goal is to compare innovation changes within free states and slave states by exploiting the differences in labor scarcity across agriculture and manufacturing. We find that, following free banking, different types of innovation responded differently within the region. Manufacturing patents in the free states experienced the highest increase. What is perhaps less expected is the response of innovation in slave states. While manufacturing patents in the slave states increased with free banking, agricultural patents experienced a slight decline.

The findings are in line with our model's prediction that finance promotes innovation when labor becomes scarcer and may impede innovation when labor becomes more abundant. In the free states, free banking led to greater access to finance by merchants and manufacturers. The expansion of industries and labor demand likely caused a higher degree of labor scarcity, which amplified the positive impact of free banking on innovation. In contrast, the effect of free banking in the slave states was mixed depending on how labor scarcity reacted to free banking. One possible explanation for the decline of agricultural patents is that access to finance further increased the slave population as banking made slaver investment and trade more convenient. With a greater supply of slave labor into the free banking states, incentives for innovation were further weakened. Indeed, we find an increase in the slave population and a decrease in the marginal cost of labor in the slave states following the passage of free banking laws. These patterns stand in contrast to the positive response of wages to free banking in the free states.

Although wages directly measure labor scarcity conditions, they are endogenous. To further confirm causality, we exploit exogenous shocks to the local labor markets—the influx

of immigrants to the US ports—and show that these shocks had a *negative* impact on the effect of free banking on innovation outcomes. We collect novel data on immigrant arrivals from detailed records of immigrant ships. The staggered arrival of immigrants into 19 states serves as a plausibly exogenous shock that relaxed local labor scarcity. We find that free banking had a more substantial effect on innovation in a state where *fewer* immigrants arrived. Admittedly, immigration is endogenous; immigrants likely chose regions where labor was scarce and job prospects were strong. While this is a valid concern, it would only bias the estimates upward. The fact that we still find a significant negative impact corroborates our proposed mechanism: Finance has a more pronounced impact on innovation when labor becomes scarcer.

Our paper contributes to the finance-growth nexus literature which establishes a positive link between financial development and economic growth (King and Levine, 1993; Jayaratne and Strahan, 1996; Levine, 1997; Beck et al., 2000; Black and Strahan, 2002; Kerr and Nanda, 2009). In particular, several studies use banking deregulation in the 1970s to 1990s US to study the effect on innovation (Chava et al., 2013; Amore et al., 2013; Cornaggia et al., 2015; Hombert and Matray, 2016). In contrast to these studies on innovation, we take a historical approach and examine the antebellum setting using the staggered passage of the free banking laws as an exogenous shock to finance.[5] This unique testing ground provides us with new evidence on the impact of bank deregulation on technological innovation.

In addition, our paper provides empirical evidence linking labor scarcity and technology adoption. The idea dates back to Hicks (1932): "A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind directed to economizing the use of a factor which has become relatively expensive." Following this insight, Acemoglu (2002a, 2010) formalizes the role of factor price in directing innovation and technical change. Bena and Simintzi (2018) study the 1999 US-China bilateral agreement and find that cheap offshore labor crowds out labor-saving innovation. Neat historical settings also provide supporting evidence, such as the sudden drop in labor supply due to the Great Mississippi Flood of 1927 (Hornbeck and Naidu, 2014) and the reduction in cotton exports to Britain due to the US Civil War (Hanlon, 2015). Adding to this literature, we provide new evidence showing the role of labor scarcity in shaping innovation. Unlike earlier studies,

[5]We are among the first studies that exploit the staggered passage of the free banking laws. Jaremski and Rousseau (2013) study the effects of free banking on economic growth using decennial census data. Unlike economic growth measures that are only available at a decennial frequency, patenting activity can be measured annually, which provides a more granular reflection of growth via technological advances.

our analysis features the interaction between labor scarcity and access to finance.

This paper proceeds as follows. Section I presents the historical background. Section II sets up a stylized model to motivate our hypotheses. Section III describes the data. Section IV discusses identification, Section V presents the main empirical results on free banking and innovation, and Section VI highlights labor scarcity as a key economic channel. Section VII concludes.

I Historical Background

A Antebellum America

The antebellum era refers to the period from just after the War of 1812 until 1860, right before the beginning of the Civil War. During this period, the country experienced dramatic economic growth and innovation activity.

The North had abolished slavery and hence consisted of free states. The early industrialization promoted urbanization and manufacturing. Manufacturing advances occurred in many industries, e.g., textiles, machinery, and furniture. Industrialization also gave rise to a new concept of labor: The free (unforced) laborers became wage earners. For example, textile factories hired employees to run the looms; in such ways, wage earners overtook previous forms of labor, such as apprenticeship and family labor.

In the South, slave labor and free labor coexisted. Farmers obtained cheap land and used slave labor to grow and harvest the crops. Slaves were denied formal education and contributed primarily to the agricultural labor force. Compared to wage laborers, slaves had much lower rearing costs: They could not resign or demand higher wages, and their progeny ensured a supply of labor for generations. In describing slave labor, 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"(Congressional Register, 1832). This meant a wage of $3.25 a month, compared to the $7.33 plus board paid to free agricultural labor in the South Atlantic area. Using data on costs and returns for slave holding, Lebergott (1960) concludes that the cost other than board ran merely to about $1.25 a month. A similar estimation was given in Conrad and Meyer (1958). The documented difference in costs should not be interpreted as differences in productivity. Despite their low cost, slave field hands were not lazy, inept or unproductive; on average they were harder

working and more efficient than their white counterparts (Fogel and Engerman, 1974).[6]

The number of slaves in America grew from 700,000 in 1790 to 4 million in 1860. Even though by 1803 all the states and territories had laws in force prohibiting the importation of slaves from abroad, the laws were not effective.[7] Even within the country, slaves were mobile, being traded between slaveholders.[8] Far from stagnating, the economy of the antebellum South grew rapidly. From 1840 to 1860, per capita income in the South increased more rapidly than in the rest of the nation and attained a high level by the standards of the time (Fogel and Engerman, 1974).

B Antebellum Innovations

The antebellum era was a time of great technological change. Innovations, such as the mechanical reaper, steel plow, rotary printing press, dishwasher, and sewing machine, transformed the production process and living conditions of people. The boom in patenting was consistent with an emphasis on demand-induced advances in inventive activity; in particular, labor scarcity acted as a powerful inducement for the invention and diffusion of labor-saving technologies.[9] As hypothesized by Habakkuk, "the dearness and inelasticity of American labour gave the American entrepreneur[...]a greater inducement than his British counterpart to replace labour by machines" (Habakkuk, 1962, p. 17). For example, Singer patented the first practical and efficient sewing machine in 1851 (Patent No. 8294). The improvement

[6]One instance well-known to labor historians shows that contemporaneous free labor thought that urban slavery may even have worked too well: Workers at the Tredegar Iron Works in Richmond, Virginia, went out on their first strike in 1847 to protest the use of slave labor at the Works (Fogel, 1989).

[7]Collins (1904) lists extensive evidence of slave smuggling and provides a moderate estimate that at least 270,000 slaves were introduced into the United States from 1808 to 1860.

[8]New Orleans was the largest city in the South and the site of its largest slave market (Calomiris and Pritchett, 2016). The slave trade was allocated by a system of regional specialization that produced slaves on the worn-out land of the Old South and the border states for export to the high-yield cotton fields of the Mississippi and Red River Valleys (Collins, 1904; Conrad and Meyer, 1958)."...the selling states include Virginia, Maryland, Delaware, North Carolina, Kentucky, and the District of Columbia; the buying states include South Carolina, Georgia, Alabama, Mississippi, Tennessee, and Missouri. In 1830, Florida, and in 1850, Texas were added to the buying group. Tennessee, Missouri, and North Carolina are difficult to categorize; some parts of those states imported while other parts exported during the period" (Collins, 1904, Chapter III).

[9]Different from today, the antebellum technical change was unskill-biased and labor-saving rather than skilled-biased and labor-augmenting (Acemoglu, 2010, p. 1040). There are two explanations for the structural difference. First, in the early settlements, the high land-labor ratio made labor a most expensive factor at that time (Temin, 1971; Olmstead and Rhode, 1993). Second, the education and skill sets of workers shifted the nature of technical change: the rapid increase in the supply of skilled workers in the 20th century has induced the development of skill complementary technologies (Acemoglu, 2002b).

enabled a speed of 900 stitches per minute, greatly saved labor hours and revolutionized the textile industry. Similarly, a series of inventions on cleaning and winnowing grain were patented in New York, Pennsylvania, and Ohio, where farm labor was in scarcity.[10]

Behind the strong, innovative activity was a solid patenting system that transmitted knowledge of technological solutions and provided avenues for commercializing innovations.[11] The Patent Act of 1790 was the first federal US patent statute. The amendment of the act expedited the examining process: On average, it took several months for a patent to be examined and granted once a written application was submitted. At times the inventors would sell their patents to draftsmen and manufacturers who were better at marketing and producing.[12]

C The Free Banking Laws

In the early 19th century, access to banks was limited. New banks had to be chartered by a state legislature. There were usually only a few charter banks in each state. Unlike modern institutions, early charter banks operated only in major cities and rarely provided financial services to ordinary households in peripheral areas. Except in a few southern states with statewide branch bank networks, banking was both legally and economically a local affair.[13] In 1836, a legislative committee from Rhode Island reported that "by far 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 finance. First, the chartering system was a tedious and cumbersome process that severely limited the number of banks opened. Second, the approval of a charter often depended on political influence and was aimed at protecting the interests of incumbent banks. Once a bank was successfully chartered, its

[10]In contrast, in Southern plantations, winnowing was initially done by hand using winnowing baskets and then by winnowing barns, both relying intensively on slave labor.

[11]Cases of infringement were dealt with by a jury, which assessed the damages and determined the appropriate punishment. The person who infringed was made to hand over all of the infringing devices to the owner of the patent.

[12]For example, in 1849 Walter Hunt was granted a patent for the safety pin (Patent No. 6281). Hunt then sold rights of his patent to W. R. Grace and Company for about $10,000 (in today's dollars). W. R. Grace and Company mass-produced the safety pin and made millions.

[13]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 field 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).

Table 1. Passage of Free Banking Laws

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	1850	Florida	1853
Ohio	1850	Minnesota	1858
Massachusetts	1850	Iowa	1858
Illinois	1850	Pennsylvania	1860

Notes: Michigan passed the free banking law in 1837, abolished it in 1840, and reinstated it in 1857. The passage years are from Rockoff (1974).

supporters then lobbied heavily against the formation of new, competing banks. As a result, some parts of the country had only limited access to banking facilities, while banks in many other locations enjoyed a virtual monopoly in providing these financial services (Murphy, 2017). 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). Third, the early charter banks conducted extensive insider lending: they lent a large proportion of their funds to members of their own boards of directors or to others with close personal connections to the boards (Schweikart, 1987; Lamoreaux, 1996).

The free banking laws initiated banking system reforms by eliminating the legislative charter requirement for a bank to be established. Starting with Michigan in 1837 and continuing through Pennsylvania in 1860, the free banking laws were passed in a staggered fashion in 18 states. These states included seven states in the West, five states in the South, and six states in the Northeast: free banking spread through every region. Figure 1 shows a timeline of the staggered passage of the free banking laws, and Table 1 lists the passage years. The laws replaced individual legislative charters with "free entry" upon a bank's satisfaction of the stipulated requirements. The new laws allowed anyone who had the required paid-in capital to open a bank that could issue its own bank notes, take deposits, and make loans. The free banking era derived its name from this free entry provision of the general banking laws.[14] Importantly, there was no longer political influence involved,

[14]The free banking era was not a period of laissez-faire banking. The free banking laws attempted to protect the noteholders. While entry was unrestricted, banks established under the free banking laws were subject to strict oversight intended to insure the safely of free bank notes. First, free banks had to deposit designated state bonds as collateral for all notes issued. Second, they had to pay specie for notes on demand. Finally, free bank stockholders had double liability, i.e. they were liable for bank losses in an amount up to the value of their stock (Rolnick and Weber, 1983).

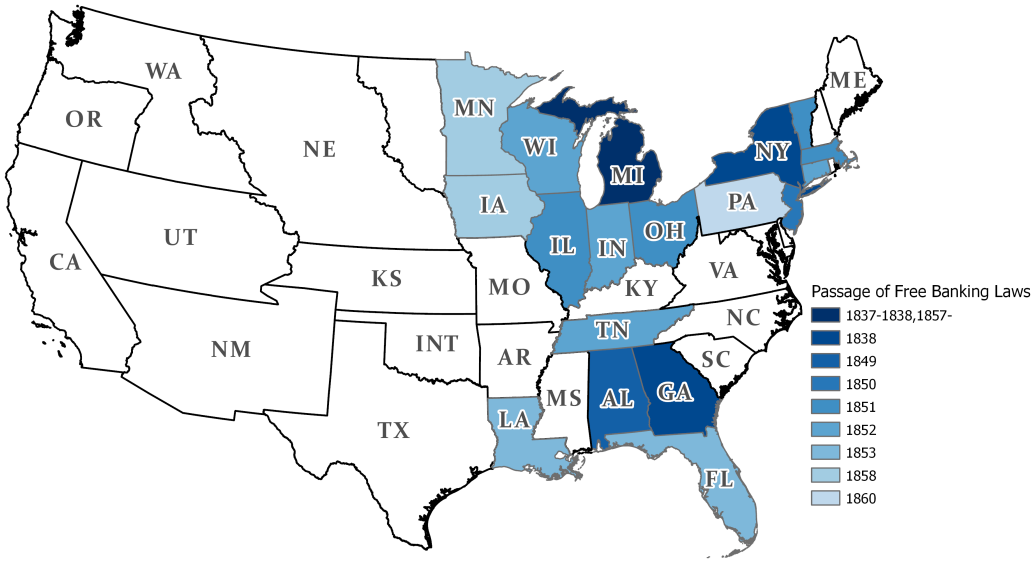


Figure 1. Passage of free banking laws. This figure shows a timeline of the staggered passage of free banking laws on the map. The state borders are drawn as in 1860, and states are labeled with their abbreviations.

allowing speedy bank entry with lower costs. This appealed both to Jacksonian Democrats, who believed the chartering process to be too monopolistic and aristocratic, as well as to the more commercially oriented Whig Party, who believed that the chartering process was too slow to address the financial needs of a rapidly expanding frontier region.

Microlevel data shows that some of these free banks acted as innovation-inducing Schumpeterian financier and engine of growth. While data on free banks' detailed lending was very limited, Bodenhorn (1999) uses surviving records of the Black River Bank of Watertown and shows that the bank operated as an innovation-inducing Schumpeterian bank. The Black River Bank was a free bank founded by banker Paddock in 1844 and had grown into the second largest bank in Watertown by the early 1850s. Bodenhorn uses two discount books for the period 1844 to 1859 and matches the borrowers' names to city directories and manuscript censuses. He finds that merchants (who had good collateral and were popular borrowers of charter banks) were relatively underrepresented, whereas manufacturers and entrepreneurs were quite a few. A notable example was the financing to Bradford who invented the portable steam engine. In 1849 Bradford constructed a working model for portable steam engine and formed a partnership with machinist Hoard. Hoard & Bradford turned to banker Paddock for financial assistance, and with a half-dozen notes from the bank over the next two years, the partnership flourished in the 1850s and developed into a firm with 150 machinists by

1857. The Black River Bank's support of Hoard & Bradford, while not typical, was not unusual. Several other instances of the bank's offering financial assistance to fledgling upstarts included Hotchkin, who established a tannery and harness manufactory in Watertown in late 1854, and Remington, who established the Remington paper mill in 1853.

Factors that determined where and when the laws were passed are clearly important. We defer the discussion to Section IV.A where we analyze the historical setting and formally test the exogenous nature of the law's passage across states.[15]

II Model and Implications

The model follows Acemoglu (2010). The goal of the model is to understand the impact of greater access to finance on innovation, especially in conjunction with labor scarcity.

A Model Setup

Environment The economy has a monopoly entrepreneur and a representative final goods producer. The entrepreneur innovates new technology, θ, and manufactures machines, q, that embody the patented technology (such as the mechanical reaper in agriculture and the sewing machine in the textile industry). The representative final goods producer combines labor L, 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 F is a function increasing and concave with both arguments. As discussed earlier, antebellum America was mostly concerned with demand-induced labor-saving technologies. Hence, we model technology θ as a labor-substitute such that $\partial^2 F/\partial L \partial \theta < 0$.[16] Without loss of generality, we take the functional form $F(L,\theta) = \theta^{\sigma} + (1-\theta)L^{1-\beta}$, $\sigma \in (0,1)$ and $\beta \in (0,1)$. We include the scalar, $\alpha^{-\alpha}(1-\alpha)^{-1}$, for convenient normalization.

With monopoly power, the entrepreneur manufactures machines that embody the patented

[15] We show that the law's passage cannot be explained by demographic and economic conditions, nor political factors. Online Appendix A.2 provides a brief legislative history of antebellum banking. The main lesson is that the early legislation was in its infancy, and the events leading up to the free banking laws were often quite dramatic and serendipitous.

[16] As in Acemoglu (2010), advances in the labor-saving technology θ reduce labor costs by lowering the marginal revenue product of labor (equilibrium wage), but not necessarily the marginal physical product of labor. For example, the invention of the sewing machine enabled a speed of 900 stitches per minute, which greatly saved labor hours but also put hand sewers out of work. In this case, the technology of industrial sewing reduced the marginal revenue product (and wages) for hand sewing.

technology.[17] She faces a one-time setup cost for manufacturing on, e.g., research and experimentation, installing new tools, constructing prototypes, marketing, and gathering information for demand. The setup cost is increasing and convex with θ, decreasing with γ, and satisfies $\partial^2 C/\partial\theta\partial\gamma < 0$. The parameter γ summarizes the entrepreneur's access to local finance. Greater access to local finance reduces the marginal setup cost for the entrepreneur. The benefit an entrepreneur receives from greater access to local finance comes from various channels. 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 for the new technology. Notice that the benefit does not require that the entrepreneur is financially constrained in research and development or patent application. Without loss of generality, we take the functional form $C(\theta, \gamma) = \theta^2/(2\gamma)$.

Once the technology is patented, the entrepreneur has monopoly power and charges a monopoly unit price, χ, for each machine. To capture the non-rivalrous character of the technology, we assume that the machines can be produced at a low per-unit cost, normalized to $1 - \alpha$ for analytical convenience. Finally, we assume a perfectly inelastic labor supply, $\bar{L}$.

Optimization Taking marginal labor cost w and the unit price of machine χ as given, the final goods producer chooses demand for labor and machines to maximize profits, i.e.,

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

A first-order condition with respect to q gives the optimal demand for machines, $q^* = \alpha^{-1}F\chi^{-\frac{1}{\alpha}}$.

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

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

[17] We assume the entrepreneur files the patent and manufactures the technology. In practice, the innovator and the manufacturer could be separate agents; 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, then the prospects of patenting are brighter, and innovators would become more willing to file patents and would earn a royalty. One example is Walter Hunt, discussed in Section I.B. Hunt sold the patent for the safety pin to W. R. Grace and Company, who then mass-produced the safety pin and made millions.

Equilibrium An equilibrium consists of: the final goods producer's decisions $\{L^*, q^*\}$, the entrepreneur's decisions $\{\theta^*, \chi^*\}$, and marginal labor cost w^*, such that L^* and q^* solve the producer's problem (1) given w, θ, and χ; θ^* and χ^* solve the entrepreneur's problem (2) given the demand for machine q^*; w^* satisfies labor market clearing such that $L^* = \bar{L}$.

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

$$\frac{\partial F(\bar{L}, \theta^*)}{\partial \theta} = \frac{\partial C(\theta^*, \gamma)}{\partial \theta}. \tag{3}$$

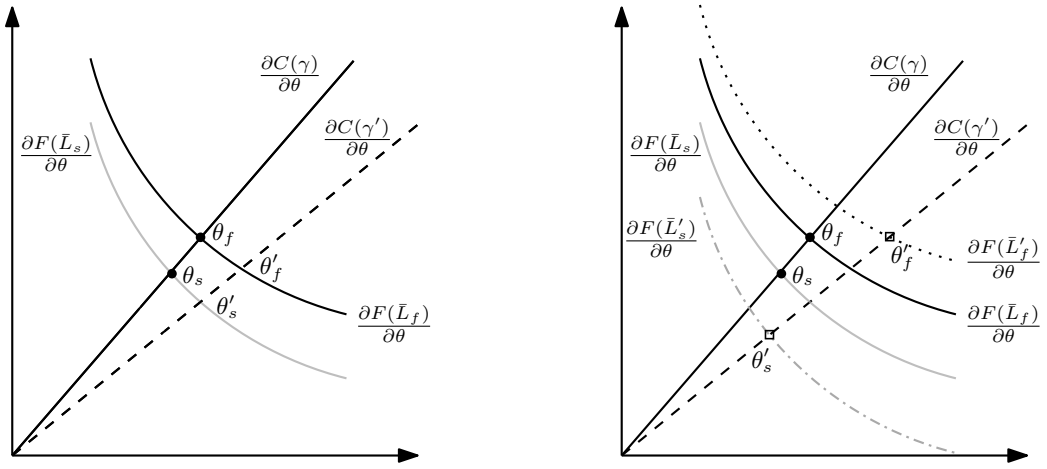
From Eq. (3), access to finance, γ, and labor supply, $\bar{L}$ (or equivalently, the marginal labor cost w), are two factors that jointly determine equilibrium innovation.

B Model Implications

This stylized model delivers several predictions that guide our hypothesis development. The first prediction is on the effect of greater access to finance. Eq. (3) implies that $\partial\theta^*/\partial\gamma > 0$. Other things equal, greater access to finance shifts the marginal setup cost downward, leading to higher innovation. We can also use the model to understand the role of labor scarcity. Given our perfectly inelastic labor supply, a decrease in labor supply $\bar{L}$ leads to a one-to-one increase in wage, thereby making labor more costly. From Eq. (3) and $\partial^2 F/\partial L \partial\theta < 0$, we have $\partial\theta^*/\partial\bar{L} < 0$. Scarcer labor vertically shifts up the marginal value of technology, which corresponds to a higher level of innovation.

We next apply this stylized model in the context of antebellum America.[18] Relative to the slave states, the free states had higher marginal labor costs and scarcer labor, and thus the labor-saving technology had higher marginal value. Let us first focus on the case when labor supply stays fixed for both the free and the slave states. Shown in Figure 2a, with

[18]This parsimonious model is by no means intended to analyze the economics of slavery. A slave economy is different from a competitive labor market. We have omitted many unique aspects of slavery, such as the fixed costs to acquire the coerced labor. For early influential works on slavery see, e.g., Fogel and Engerman (1974), Ransom and Sutch (2001), and Wright (2013). For formal models of a slave economy see, e.g., Barzel (1977) and Acemoglu and Wolitzky (2011). Here, the marginal labor cost in the slave states should be interpreted as the wage paid to free labor, cost of hiring slaves, or the maintaining cost faced by slaveholders. The marginal cost of slave labor could be lower than the marginal product, because a large part of the marginal product goes to the owner, giving rise to the exploitation rate.



(a) Labor scarcity is fixed.

(b) Labor scarcity changes.

Figure 2. Greater access to finance and labor scarcity. This figure shows changes in equilibrium innovation when labor scarcity conditions interact with access to finance. The horizontal axis represents θ. The downward sloping curve, $\partial F(\bar{L})/\partial\theta$, is the marginal product of the new technology. The upward sloping curve, $\partial C(\gamma)/\partial\theta$, is the marginal setup cost for the entrepreneur. The equilibrium level of innovation is achieved where the two curves cross. In Subfigure 2a, both labor supply $\bar{L}_f$ and $\bar{L}_s$ stay fixed. When γ increases to γ', the marginal cost curve shifts downward. Equilibrium innovation increases to θ'_f in the free states and θ'_s in the slave states. In Subfigure 2b, labor supply $\bar{L}_f$ drops in the free states but $\bar{L}_s$ increases in the slave states. Comparing this to Subfigure 2a, we observe a greater $\Delta\theta_f$ and a possibly negative $\Delta\theta_s$. The figure is prepared under the assumption that $F(L,\theta) = \theta^\sigma + (1-\theta)L^{1-\beta}$, $\sigma \in (0,1)$, $\beta \in (0,1)$, and $C(\theta,\gamma) = \theta^2/(2\gamma)$.

greater access to finance, the marginal cost curve shifts downward, leading to increases in innovation in both economies. Importantly, we can show that $\Delta\theta_f > \Delta\theta_s$.[19] This result suggests that greater access to finance has a more substantial impact on innovation when labor is scarcer.

The prediction becomes subtle when labor supply interacts with access to finance. In the industrial North, free banking led to greater access to finance by local merchants and manufacturers; the expansion of businesses and increased demand of labor likely posed a higher degree of labor scarcity. In this case, we would expect an even greater increase in

[19]Substituting the functional forms of $F(\bar{L},\theta)$ and $C(\gamma,\theta)$ into Eq. (3), we have that the equilibrium θ^* satisfies: $\theta = \gamma\sigma\theta^{\sigma-1} - \gamma\bar{L}^{1-\beta}$. When γ increases to γ', $\Delta\theta = \sigma\left(\gamma'\theta'^{\sigma-1} - \gamma\theta^{\sigma-1}\right) - (\gamma'-\gamma)\bar{L}^{1-\beta}$. Next we compare $\Delta\theta_f$ and $\Delta\theta_s$, the changes of innovation in the free and slave states. Assume for contradiction that $\Delta\theta_f \leq \Delta\theta_s$. Then $\gamma'\left(\theta'^{\sigma-1}_f - \theta'^{\sigma-1}_s\right) > \gamma\left(\theta^{\sigma-1}_f - \theta^{\sigma-1}_s\right)$, together with $\bar{L}^{1-\beta}_s > \bar{L}^{1-\beta}_f$, we have that $\Delta\theta_f > \Delta\theta_s$, a contradiction. Hence, it must be that $\Delta\theta_f > \Delta\theta_s$.

innovation, as $\theta_f^{'}$ shown in Figure 2b. An interesting case is when labor scarcity relaxes following greater access to finance. For example, if greater access to finance caused (or coincided with) an increase in slave labor, the effect on innovation would be ambiguous; particularly, we could expect a decrease in technologies that substituted for slave labor.

III Data and Summary Statistics

Our data span from 1812 to 1860. We use a combination of data sources to study how access to finance affects innovation and the role of labor scarcity in shaping this relation.

A Patents

We use historical patenting activity to proxy for technological innovation in the antebellum period. The source is digitalized historical patent filings from the United States Patent and Trademark Office (USPTO). The historical records describe the year in which the patent was granted, the state and county where the inventor resided, and the technology class to which the patent belonged. The blue dotted curve in Figure 3 shows the natural log of total patent counts by year from 1812 to 1860. Although the initial growth in patenting was slow, a later period of rapid growth coincided with the economic recovery of the early 1820s. As the upturn in the economy continued, patenting increased steadily until a change in the patent system in July 1836 introduced more stringent requirements. The number of patents awarded fell immediately and then stabilized at this lower level for nearly eight years. The economic contraction that began with the Panic of 1837 and persisted through the early 1840s played some role in accounting for the second spell of stagnation in patenting starting in the late 1830s. Notably, the growth rate of patent counts beginning in 1850 exceeds any modern-day growth.

Information on the technology class to which the patent belonged allows us to identify technologies used in the agriculture and manufacturing industry, separately. We begin by mapping the USPTO technology classes into six main technological categories and 36 two-digit sub-categories following Hall et al. (2001). Agricultural patents then consist of those that fall into sub-categories 11 (Agriculture, Food, Textiles) and 61 (Agriculture, Husbandry, Food). Manufacturing patents consist of those that fall into sub-categories 12 (Coating), 13 (Gas), main category 5 (Mechanical), sub-category 63 (Apparel & Textile), and sub-category

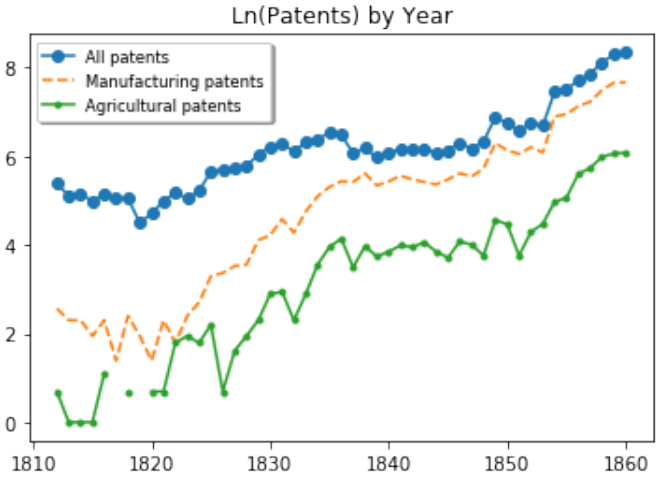


Figure 3. Total number of patents granted. The blue dotted curve shows the natural log of total patent counts by year for 1812–1860. The green dotted curve and the orange dashed curve show the natural log of agricultural patents and manufacturing patents.

65 (Furniture & House Fixtures).[20] The green dotted curve and the orange dashed curve in Figure 3 show the log of agricultural patents and manufacturing patents, respectively.

While we acknowledge that simply counting the number of patents could miss certain valuable inventions, it seems to be a reasonable approach and the best available measure of antebellum innovation. A large literature has shown that patenting, though an imperfect measure, should be qualitatively representative of the resources consumed in inventive activity (Griliches, 1990). In particular, economic historians studying pre-Civil War invention and productivity look primarily at patent counts. For example, using census data, Sokoloff (1992) shows that patenting was a major driver of antebellum total factor productivity at the state level.[21]

In using the location of the patents, we implicitly assume that the location where the patent was filed proxies for the location where the technology was adopted, at least at the initial marketing stage. Indeed, with high transportation costs, the technology market was fractional and segmented during that time. Lamoreaux and Sokoloff (2000) use industry

[20]Sub-categories 11 and 61 are the only ones that pertain to agriculture. The list of manufacturing sub-categories maps into manufacturing industries with SIC codes 20–39. In the absence of electricity, the antebellum patents classified into sub-category 13 were mainly about the manufacturing of heating and illuminating apparatuses.

[21]Although for modern-day patents, better metrics have been developed to capture the economic value of innovation, such as the citation measures by Hall et al. (2005) and the market value measures by Kogan et al. (2017), neither citation nor market value information is available for antebellum patents.

directories to map the location of the firms using the most advanced technologies. They also use trade journal accounts to track the geographic origins of the most important inventions in an industry. They confirm that both sources correspond closely with the distribution of patents, suggesting that the location of inventions was consistent with the location of technology adoption.

B Free Banking and Bank Records

We measure the passage of the free banking laws using an indicator variable, *Free banking*. For the 18 states that passed the free banking laws, we set the *Free banking* indicator equal to zero in all the years preceding the law's passage and equal to one starting from the passage year onward. Particularly for Michigan, we allow the indicator to revert to zero starting from 1840 when the state abolished the free banking law and before the year of 1857 when the state reinstated the law. For the 21 states that did not pass the free banking laws, we set the *Free banking* indicator equal to zero for all the years.

Our data for banks are from Weber (2006, 2008) complemented with historical bank records. While the former provides a comprehensive documentation for the antebellum state-chartered banks, the presence of free banks is underestimated in Southern states, specifically in Louisiana and Tennessee. We enhance the dataset by hand collecting information from a set of secondary sources.[22] For example, the Merchants and Bankers Almanac documented that seven 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.

We obtain information on the name of the bank, its charter type, the location of operation, entry and exit dates, and detailed balance sheets items by year, including total assets, loans and discounts (all in thousand dollars). When comparing the size of balance sheets, the average size of free banks was slightly smaller than that of the charter banks but was comparable. For example, an average free bank had a total asset of 0.57 million dollars whereas an average charter bank had an asset of 0.77 million dollars. The largest free bank in asset size was the Bank of Commerce in New York with an asset size of 18 million, and the largest charter bank was Citizens Bank of Louisiana with an asset size of 16 million.

[22]The secondary sources include the Merchants and Bankers Almanac (1856, 1860), statistics from Economopoulous and O'Neill (1995), the Bankers' Magazine and Statistical Register, as well as Comptroller of Currency Report (1876).

C Census Records

We obtain social, demographic and economic variables at the state level from the decennial censuses of 1810–1860 and the Census of Agriculture in 1840, 1850, and 1860. In particular, we use the following variables: population, urban population, slave population, white population. We also extract economic and industrial characteristics at the state level by using agricultural and manufacturing output. Because the variables are decennial, we interpolate them to the intervening individual years.

A state is included in our sample starting from its establishment as a territory or its statehood, whichever is earlier.[23] We also include a dummy variable on whether a state is a slave or a free state based on Wagner et al. (2009). Online Appendix Table A.1 provides the list of states, their slave/free characteristics, and the year of territory/statehood.

D Wages, Slave Hires, and Immigrants

To measure labor scarcity conditions, we rely on a variety of historical records and studies. Using payroll records of civilian employees of the US Army, Margo and Villaflor (1987) provide annual estimates of nominal daily wage rates for common laborers at the census region level from 1820 to 1856. The second source is the *Weeks Report* (1886), which provides average daily wages for common laborers based on the payroll records of 627 firms across the regions. The data is at the annual frequency starting from 1851 for six census regions. We also take the wage measures from the decennial census, including average wages to a day laborer, with and without board. They are available in the 1850 and 1860 census and are interpolated between the two years.

To ensure that the observed wage differences are not a mere reflection of different industries or different types of jobs, we also compare labor costs in agriculture. The source is Lebergott (1964) who provides estimates for average monthly earnings with board for farm laborers by geographic divisions. The data is available for selective years from 1818 to 1948 and we interpolate to obtain estimates in between. Monthly wages are divided by 26 days to convert to daily wages, a standard procedure adopted, e.g., in Margo and Villaflor (1987).

To measure the cost of slaves, we obtain the daily hiring price of a slave labor using the Slave Hires data by Fogel and Engerman (1976). Available is data pertaining to slave hiring transactions that occurred between 1775 and 1865 in eight southern states: Virginia,

[23] The date of statehood information is obtained from www.history.com/topics/us-states.

Maryland, North Carolina, South Carolina, Louisiana, Tennessee, Georgia, and Mississippi. Variables document the location of the hiring transaction, together with the period and rate of hire. We use the information to estimate the average daily slave hire price for a state in a given year. For the few years with missing slave hire prices, we interpolate the data. Finally, to estimate the real labor cost, we use the historical Consumer Price Index (CPI) by Officer and Williamson (2018).

Finally, we collect novel data on the immigrant arrivals in US ports from the Immigrant Ships Transcribers Guild (ISTG). The ISTG provides comprehensive records of immigrant ships, including detailed passenger lists with the dates and locations of the arrival port. For instance, the records show that on April 25, 1854, a ship named "Helicon" arrived at the Port of New York from Antwerp, Belgium, carrying 95 people. We collect all the ship records and calculate the total number of passengers arriving at each state in a given year. In total, there were 8,271 ships carrying 847,530 immigrants. The immigrants arrived at 19 states in a staggered fashion.[24] The states with positive immigrant arrivals are representative. Out of the 19 states, 10 were slave states, among which four passed the free banking laws; the other nine were free states, among which five passed the free banking laws.

E Summary Statistics

On average, a state in our sample had 25.14 patents granted per year. Among those patents, 2.27 are classified as agricultural patents, and 10.19 are classified as manufacturing patents. The average population in a state was 1.13 million, of which 12.7% was urban population, and 81.8% was white population. On average, there were 3.56 free banks in each state and $1.43 million in loans issued by all free banks each year in a state. In states that passed the free banking law, there were an average of 30.28 free banks, which together issued a statewide average of $12.19 million in loans each year. The definitions of variables are provided in online Appendix A.1.

[24]The 19 states are listed in descending order of arrival size: New York, Pennsylvania, Maryland, Louisiana, Massachusetts, Texas, Delaware, South Carolina, Virginia, Connecticut, Alabama, California, Maine, Rhode Island, New Jersey, Florida, District of Columbia, Georgia, New Hampshire.

Table 2. Summary Statistics

	P25	P50	Mean	P75	SD	N
Patents	1	5	25.14	18	75.39	1,491
Patents (agricultural)	0	0	2.272	2	7.205	1,491
Patents (manufacturing)	0	1	10.19	6	35.03	1,491
Population (thousands)	316.8	819.4	1,134	1,476	1,158	1,449
Urban ratio	0.019	0.057	0.127	0.159	0.185	1,449
White ratio	0.649	0.919	0.818	0.988	0.189	1,449
Bank variables for the whole sample period						
Free bank counts	0	0	3.555	0	22.97	1,491
Free bank assets (thousands)	0	0	2,012	0	17,858	1,491
Free bank loans (thousands)	0	0	1,431	0	13,983	1,491
Charter bank counts	1	6	16.70	22	25.32	1,491
Charter bank assets (thousands)	1,428	5,604	12,740	15,860	18,934	1,491
Charter bank loans (thousands)	863.1	3,433	8,661	10,882	13,868	1,491
Bank variables conditional on the passage of free banking laws						
Free bank counts	0	6	30.28	25	60.86	175
Free bank assets (thousands)	0	2,364	17,140	8,130	49,699	175
Free bank loans (thousands)	0	524.3	12,190	2,954	39,274	175
Charter bank counts	4	20	34.06	48	41.34	175
Charter bank assets (thousands)	7,411	17,682	28,496	35,710	32,557	175
Charter bank loans (thousands)	1,501	8,716	18,839	18,998	25,715	175

Notes: This table reports summary statistics for the state-year observations in the main sample. For bank variables, we report the summary statistics for the whole sample period, as well as for the state-year conditional on the passage of the free banking laws. Definitions of the variables are in online Appendix A.1.

IV Identification Strategy

A The Determinants of the Passage of Free Banking Laws

We use a difference-in-differences approach to examine how the passage of free banking laws affected innovation. The crucial assumption behind our identification strategy is that the passage of free banking laws provided an exogenous source of variation in a state's access to finance. In this section, we provide evidence that this assumption is likely to be valid.

Historians have not yet reached consensus on the factors that determined where and when the laws were passed. In some states, the free banking laws' passage seemed to be initiated by random events. We provide a brief legislative history of the free banking laws in online Appendix A.2. An interesting example is the state of New York. As discussed in Bodenhorn (2006), the laws' passage 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. Legislative debates on banking policy became anti-Masonic. When the Regency lost support, the law was passed. In this regard, economist Bodenhorn calls it the "serendipitous nature of economic reform."

Nonetheless, we empirically test how the timing of free banking was related to potential determinants of innovation. Using a hazard model, we predict the "time until the laws' passage" with a variety of state-level characteristics. First, we include state-level social and economic outcomes. These variables measure the pre-event conditions of innovation and banking development in a state and could potentially confound the causal impact of free banking on innovation. Another factor potentially related to both innovation and banking was the alternation of state political parties in power. For example, the Whig Party favored modernization, banking, and economic protectionism to stimulate manufacturing.[25] The Jacksonian Democrats on the other hand also believed that the chartering process was too monopolistic and aristocratic. Finally, we include measures for labor conditions, industry composition, economic and educational achievements. They include wages, agricultural labor ratio, output of agriculture and manufacturing, access to railway, the percentage of students in academies, grammar schools, and universities/colleges. We find none of the variables significantly predicted the likelihood that a state passed the free banking law. The evidence supports the notion that the passage of the free banking law by a state was plausibly an exogenous event. Online Appendix Table A.2 reports the results.

B Free Banking and Access to Finance

Key to our identification is that by allowing for free entry, the passage of the free banking laws led to better access to finance. We now show that the passage of the free banking laws accelerated bank entry. The new banks had wider geographic coverage and a larger customer base than the existing charter banks. They entered rural, previously unbanked areas. Following the passage of free banking laws, 15.2% of previously unbanked counties had bank entry, and 12.2% of previously unbanked counties had free bank entry by 1860.

Table 3 Panel A reports the entry of free banks three years following the law's passage in the 18 states. We observe substantial free bank entry reflected in bank counts, assets, as well as in loans and discounts. On average, across the 18 states that passed the free

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

Table 3. The Free Banking Laws and Access to Finance

Panel A: Entry of Free Banks

	Bank counts		Assets		Loans	
	Quantity	Percentage	Quantity	Percentage	Quantity	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	na	7,655	na	1,794	na
Connecticut	14	27%	6,827	27%	5,315	26%
Indiana	83	638%	19,813	259%	7,950	397%
Wisconsin	32	3200%	6,612	875%	3,689	1221%
Tennessee	16	320%	8,130	47%	3,398	29%
Louisiana	4	67%	11,688	30%	763	7%
Florida	0	na	0	na	0	na
Minnesota	16	na	1,197	na	417	na
Iowa	0	na	0	na	0	na
Pennsylvania	0	0%	0	0%	0	0%

Panel B: Free Banking and Access to Free Banks and Charter Banks

	Ln(Bank counts)		Ln(Assets)		Ln(Loans)	
	Free	Charter	Free	Charter	Free	Charter
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	1.863***	0.126	10.173***	0.575	9.658***	0.048
	(0.461)	(0.128)	(1.595)	(0.657)	(1.529)	(0.777)
Ln(Population)	0.150	-0.102	0.348	1.216*	0.261	0.809
	(0.114)	(0.128)	(0.409)	(0.707)	(0.357)	(0.784)
Urban ratio	2.537	0.063	4.553	2.053	6.145	3.368
	(2.551)	(1.454)	(9.333)	(4.945)	(8.875)	(4.976)
White ratio	0.546	0.163	0.656	12.030	-2.231	10.695
	(1.677)	(2.607)	(7.739)	(12.195)	(5.993)	(12.046)
Observations	1,410	1,410	1,410	1,410	1,410	1,410
R-squared	0.673	0.900	0.700	0.741	0.706	0.751
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Panel A reports the entry of free banks three years following the laws' passage in the 18 states. The quantity of bank assets and loans are in thousands. The percentages are taken over the banks operating prior to the years of entry. When the value prior to the passage was zero, the percentage is denoted as "na." Panel B reports the OLS regression estimates for how access-to-finance measures responded to free banking, for both free banks and charter banks. The dependent variables lead the independent variables by one year. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

banking law, there were 19 free bank entries within three years following the law's passage, accounting for 348% of the number of banks operating prior to the years of the entry. While the southern banking sector was considered smaller and had higher barriers to entry due to the pre-existing bank branch networks serving plantation owners (Calomiris and Schweikart, 1991), we observe significant bank entry in slave states as well. For example, Tennessee had 16 free banks adding to the five existing charter banks; Louisiana had four banks adding to the six existing charter banks.

To understand the impact on a state's banking sector as a whole and to rule out possibilities such as capital reallocation from charter to free banks, we examine how the passage of free banking laws affected access to finance in Panel B of Table 3. As expected, the free banking laws allowed sizable free bank entry. At the same time, charter banks did not exit or become smaller. The results confirm that the banking sector expanded after the law's passage and that the passage of free banking laws improved access to finance.

V Free Banking and Innovation

A Baseline Specification and Results

Our baseline results establish the impact of access to finance on innovation. We estimate the following model:

$$Ln(Patents)_{i,t+s} = \alpha + \beta Free\ banking_{i,t} + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \tag{4}$$

where i indexes state, t indexes time, and s is equal to one, two, or three. The dependent variable in Eq. (4) is the natural logarithm of one plus the total number of patents granted in a state in the following one, two, and three years, respectively. Dummy variable, $Free\ banking_{i,t}$, captures the status of the law's passage in state i and year t. $Z_{i,t}$ is a vector of controls that include total state population, white population ratio, and urban population ratio in state i and year t. $Year_t$ and $State_i$ capture year and state fixed effects, respectively. We cluster standard errors by state to account for serial correlation within states.

We include state-level controls to absorb the time-varying socioeconomic conditions which could be associated with the inventive opportunities of a state. We include population 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

Table 4. Baseline Regressions: Free Banking and Innovation

	Ln(Patents)					
	t+1		t+2		t+3	
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	0.440***	0.370***	0.518***	0.434***	0.531***	0.440***
	(0.160)	(0.117)	(0.173)	(0.121)	(0.188)	(0.125)
Ln(Population)		0.457***		0.522***		0.581***
		(0.093)		(0.096)		(0.099)
Urban ratio		1.455*		2.261**		2.917***
		(0.852)		(0.920)		(1.017)
White ratio		1.747		1.886		2.414
		(2.127)		(2.145)		(2.115)
Observations	1,491	1,449	1,491	1,449	1,491	1,449
R-squared	0.878	0.893	0.868	0.889	0.861	0.887
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports OLS regression estimates of Eq. (4). The dependent variables in columns (1)–(2), (3)–(4), and (5)–(6) are the natural logarithm of one plus the total number of patents granted in a state in year t+1, t+2, and t+3, respectively. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

of population in urban areas. The white population reveals, to a large extent, the local educational attainment, social class structure, and division of labor.

We also include state fixed effects. This helps to address the concern of omitted variables. Unobservable variables that generate variation in a state's openness to free banking laws might also correlate with innovativeness. For example, if states with vibrant economic activities and strong growth opportunities were more likely to pass free banking laws, then the unobservable state-level economic activity and growth opportunities could correlate with both *Ln(Patents)* and *Free banking*, which could bias our coefficient estimate of β upward. Including state fixed effects will strip out any persistent differences across states. In addition, we include year fixed effects to control for any economy-wide shocks and general trends.

We report the OLS regression results estimating Eq. (4) in Table 4. The coefficient estimates of *Free banking* are positive and significant at the 1% level. This finding suggests that the passage of free banking laws led to an increase in the number of patents in the first three subsequent years. For instance, based on the coefficient estimate of *Free banking* in column (6), states that passed the free banking laws generated a total of 44% more patents in the third year than states that did not pass the laws. The effect was economically sizable: The above estimate translates to an increase of 11.1 ($= 25.14 \times 44\%$) patents three years

after the passage of the free banking laws. (The average number of patents granted in a state was 25.14). This increase in patent quantity is economically sizable, accounting for 14.7% (=11.1/75.4) of the state-level patent variability.

The estimated sizable effect of free banking on innovation could take place through both *direct and indirect* channels. Through direct channels, the free banking laws led to the immediate and speedy entry of free banks in several states; the free banks entered previously unbanked areas, made loans to "non-insiders" who did not have connections to charter banks, and encouraged manufacturing and small businesses (Bodenhorn, 2000). As discussed in Section I.C, Bodenhorn (1999) provides micro-level evidence of a free bank (the Black River Bank) and shows that the bank operated as an innovation-inducing Schumpeterian bank by directly supporting young, local innovators and entrepreneurs. The free banking laws could also have improved access to finance through indirect channels. Free banking promoted currency stability as it increased currency circulation (Rockoff, 1974). The free entry improved the allocation of bank capital and encouraged the establishment of commercial businesses, manufacturing, and small businesses (Rockoff, 1974). Increasing competition further made existing charter banks more efficient and competitive.[26] An increase in the number of banks also promoted transportation and commerce (Atack et al., 2014).

Table 4 shows that the effect on innovation starts to be significant after one year. This is plausible for the antebellum era. First, antebellum innovations typically did not take too long to invent. For instance, Singer invented the first 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 technology were more sensitive to access to finance; when the manufacturers had more resources to invest, the innovators had stronger incentives to patent existing ideas.

B Robustness of the Free Banking-Innovation Result

Temporal dynamics A reverse causality concern may have arisen if the states differed in their innovation intensity and if such differences triggered the passage of the free banking laws. To rule out this concern, we follow Bertrand and Mullainathan (2003) to examine the

[26]Free banking advocates believed they had simultaneously addressed the issues of corruption, privilege, equality of opportunity, and protection of the public against incompetent bankers through the 100 percent note-collateral provision (Bodenhorn, 2006, p. 253). Bodenhorn (1990) examines the entry issue through interfirm rivalry and concluded that the free banking laws had a positive effect on competition through the "increasing possibility of entry and the number of potential entrants..."

Table 5. Temporal Dynamics and Falsification Test

Panel A: Dynamic Effects of Free Banking on Innovation	Ln(Patents)		*Panel B: Randomization of Free Banking*	Ln(Patents)	
	t+1	t+1	t+1	t+2	t+3
	(1)	(2)	(1)	(2)	(3)
$Before^{2-}$		-0.152			
		(0.155)			
$Before^{1}$		0.054			
		(0.124)			
$Before^{1-}$	-0.130				
	(0.144)				
$After^{1}$	0.246**	0.243**			
	(0.105)	(0.105)			
$After^{2+}$	0.319**	0.314**			
	(0.128)	(0.128)			
Free banking			0.060	0.017	0.008
			(0.196)	(0.197)	(0.198)
Ln(Population)	0.463***	0.459***	0.478***	0.542***	0.601***
	(0.091)	(0.090)	(0.104)	(0.108)	(0.111)
Urban ratio	1.420*	1.406*	1.615	2.472**	3.135**
	(0.830)	(0.816)	(1.093)	(1.165)	(1.251)
White ratio	1.844	1.865	1.542	1.592	2.106
	(2.097)	(2.077)	(2.391)	(2.435)	(2.395)
Observations	1,449	1,449	1,449	1,449	1,449
R-squared	0.894	0.894	0.890	0.885	0.883
State FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Panel A reports OLS regression estimates of Eq. (5). In column (1), we decompose *Free banking* into three dummy variables associated with three periods around the free banking laws: all years up to and including one year prior to free banking, one year after free banking, and two years or more after free banking. For Michigan which passed the law twice, we use 1857 as the free banking year for the dynamic effects. In column (2), we further decompose $Before^{1-}_{i,t}$ to $Before^{2-}_{i,t}$ and $Before^{1}_{i,t}$. Panel B reports OLS regression estimates of Eq. (4) with randomized free banking passage years across states. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

dynamics of innovation prior to the free banking laws. We decompose *Free banking* into three dummy variables associated with three periods around the free banking laws: all years up to and including one year prior to free banking, one year after free banking, and two years or more after free banking. The year in which the free banking law was passed was the reference year in this setting. We estimate the following model:

$$Ln(Patents)_{i,t+1} = \alpha + \beta_1 Before^{1-}_{i,t} + \beta_2 After^{1}_{i,t} + \beta_3 After^{2+}_{i,t} + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}. \quad (5)$$

In Panel A of Table 5 we report the regression results estimating Eq. (5) in column (1). The coefficient estimate of $Before_{i,t}^{1-}$ is not significant, suggesting that state-level innovation showed no significant change prior to the passage of the free banking laws. The coefficient estimates of $After^{1}$ and $After^{2+}$ are positive and significant, consistent with our baseline findings. In column (2), we further decompose $Before_{i,t}^{1-}$ to $Before_{i,t}^{2-}$ and $Before_{i,t}^{1}$ and find their coefficient estimates continue to be insignificant. These results alleviate concerns about reverse causality and suggest that the innovation only increased after free banking passage.

Falsification tests Another concern that could prevent us from drawing a causal interpretation of free banking laws on innovation is that an omitted variable coinciding with state-level free banking events could be driving our results. To resolve this concern, we conduct placebo tests. We obtain an empirical distribution of years when states passed the free banking laws. Then, following the empirical distribution, we randomly assign states without replacement to each of the passage years. This way, we maintain the distribution of free banking years from our baseline specification but reshuffle the assignment of free banking years to states. If an omitted shock occurred at the same time with the free banking laws, it should remain in the testing framework and thus is still able to drive the results. However, if no such shock exists, the incorrectly assigned years should weaken our results when we re-estimate Eq. (4). As shown in Panel B of Table 5, the coefficient estimates of *Free banking* are statistically insignificant and not different from zero, providing support that it was free banking, rather than other shocks, that impacted innovation.

Among the states that passed the free banking laws, some states such as New York and Louisiana had significant free banking activities, whereas little free banking was actually done 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 indeed comes through its impact on access to finance, it should be more pronounced in states with significant free banking activities, and less pronounced in states with little free banking activities. This is indeed what we find in online Appendix Table A.3.

Direct link between banking and innovation As an robustness check of the baseline result, we directly link the innovation outcomes with the expansion of free banks at both the state and county level. We find that free bank counts, assets, loans and discounts all

significantly related to the patent counts three years ahead. A 1% increase in free bank counts led to a 0.134% increase in innovation three years after at the state level. The economic magnitudes were sizable: An average increase in free bank counts of 63% translates to an 8.4% increase in patent counts three years after. The county-level finding is consistent with the idea that free banks entered previously unbanked counties. Online Appendix Table A.4 shows the result.

Subsample tests We examine whether our results hold in subsamples in online Appendix Table A.5. First, to rule out the concern that relatively small variations in patenting might have an outsized effect on the growth rate of innovation, we exclude all the year-by-state observations with zero patent in our sample, and reexamine the main results. Our main results still hold. Second, we restrict our sample period to post-1836. The Second Bank of the United States operated from 1816 to 1836.[27] This bank had 25 branches scattered around the country and provided banking services to several states. When its charter was not renewed, most states recognized a need to establish new banking facilities. We restrict to the post-Second Bank period and find that our main results still hold. Third, a wave of passage of the free banking laws occurred in the 1850s. We drop the states that had earlier passages of the free banking laws and start our sample from 1850. Again, our results are robust to this restriction. Finally, 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. These six states are also referred to as "wildcat banking" states (Rockoff, 1974). We exclude these states and the results still hold.

Controlling for contemporaneous laws Another concern is that our estimates could capture the effect of other state laws instituted at the same time with free banking laws. Notably, states used usury laws to limit the maximum interest rate banks could charge on loans.[28] If the states that passed free banking laws relaxed the maximum interest rate at the same time, our results might be biased because a higher ceiling might allow banks to lend with lower restrictions to high-risk entrepreneurs. In addition, states adopted the general incorporation statutes for manufacturing firms. While Hilt (2017) argues that the adoption of a general incorporation statute did not always represent a discrete transition to open access to the corporate form, it could still have an impact on innovation. We add these

[27] See Highfield et al. (1991) for a discussion on the Second Bank of the United Sates.

[28] Benmelech and Moskowitz (2010) show that usury laws in the 19th century reduced credit and economic activity when they were binding.

time-varying state laws as controls to our main specification and find that contemporaneous law changes did not absorb the impact of free banking on innovation.

VI The Role of Labor Scarcity

Our evidence so far shows a robust, positive effect of free banking laws on innovation. In this section, we establish an economic mechanism that shaped how free banking laws affected innovation outcome: labor scarcity.

A Comparing Free States and Slave States

As demonstrated in our theoretical model, labor scarcity is an important factor that determines how access to finance affects innovation. Empirical tests are challenging in today's world because labor is highly mobile geographically. The antebellum period, owing to the immobility of labor and the institution of slavery, provides a natural heterogeneity in labor scarcity across regions. We next document that the marginal labor costs were higher in the free states than in the slave states.

Table 6 compares labor conditions and innovation outcomes in the two regions. While the population size was similar, the composition of the population was very different. Free states had a higher urban to population ratio and a higher white to population ratio. We draw on several sources to compare the labor costs. We start by four measures for nominal daily wages of common laborers. *Common laborer wage 1* comes from Margo and Villaflor (1987) and runs from 1820 to 1856 annually. *Common laborer wage 2* is from the *Weeks Report* (1886), also an annual measure but one that started from 1851. We also use the available wage data from the decennial census: *Common laborer wage 3* is wage for day laborer with board, and *Common laborer wage 4* is wage for day laborer without board. In addition, to control for industry and occupational differences, we examine the nominal daily wage in agriculture using *Farm laborer wage* from Lebergott (1964).

All wage measures in Table 6 indicate that the free states faced a higher daily average wage relative to the slave states. For instance, the mean of *Common laborer wage 1* and *Common laborer wage 2* were \$0.88 and \$1.03 in the free states, which were higher than \$0.81 and \$0.80 in the slave states. Compared within agricultural farm labor, the daily *Farm laborer wage* was 23% higher in the North than in the South.

The vast majority of the plantation workforces consisted of slaves, who typically were

Table 6. Differences in Labor Conditions: Slave States vs. Free States

	P25	P50	Mean	P75	SD	N
Free states						
Population (thousands)	476.4	692.9	1,312	1,614	1,446	715
Urban ratio	0.030	0.091	0.131	0.177	0.137	715
White ratio	0.973	0.988	0.982	0.996	0.020	715
Common laborer wage 1	0.770	0.870	0.877	1	0.150	526
Common laborer wage 2	0.909	1	1.034	1.152	0.129	174
Common laborer wage 3	0.682	0.748	0.979	0.850	0.725	201
Common laborer wage 4	0.936	1.005	1.305	1.090	0.909	201
Farm laborer wage	0.383	0.450	0.438	0.484	0.064	633
Total patents	3	11	44.02	42	102.9	743
Manufacturing patents	0	3	18.21	14	48.11	743
Agricultural patents	0	0	3.808	3	9.800	743
Slave states						
Population (thousands)	199.2	917.5	960.7	1,435	743.3	734
Urban ratio	0.015	0.038	0.122	0.118	0.223	734
White ratio	0.556	0.651	0.659	0.766	0.138	734
Common laborer wage 1	0.740	0.790	0.813	0.890	0.109	526
Common laborer wage 2	0.677	0.770	0.796	0.827	0.157	130
Common laborer wage 3	0.535	0.604	0.665	0.736	0.206	198
Common laborer wage 4	0.752	0.847	0.940	1.040	0.305	198
Farm laborer wage	0.295	0.360	0.356	0.390	0.072	587
Slave hire price	0.092	0.127	0.145	0.185	0.067	232
Total patents	0.500	3	6.385	7	10.87	748
Manufacturing patents	0	0	2.227	2	4.607	748
Agricultural patents	0	0	0.746	1	1.865	748

Notes: This table presents summary statistics for labor and wage conditions in the free states and the slave states. Definitions of the variables are in online Appendix A.1.

judged to be cheaper than white farm hands (Genovese, 1976; Beckert, 2015). To slaveholders, slaves were considered as a durable asset and a profitable investment. The rising price of slaves reflected the expected value of this asset's future price but not necessarily the opportunity cost of labor in production.[29] Instead, we examine, *Slave hire price*, the daily hire price of a slave labor, which directly measures the opportunity cost. On average, the daily hire price for a slave was less than half of the daily farm laborer wage in the South and about a third of the daily farm laborer wage in the North.[30]

[29] "The net hire of a slave shows what is the value of his labor to his employer, and to his owner. The price for which he would sell shows what amount of capital is so vested[...]the price of hire marks the value of labor here, while the selling price is fixed by the demand of Alabama or Louisiana–and therefore the two may be quite disproportioned..." (Farmers' Register, 1835, p. 253).

[30] This estimate is in line with other sources of slave hire estimates. Starobin (1970) lists extensive evidence that "slave hirelings were more economical to employ than the free labor available." "Throughout the slave

Table 7. Labor Scarcity and Innovation

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking × *Free state*	0.448**	0.490***	0.593***
	(0.167)	(0.163)	(0.164)
Free banking	0.077	0.113	0.052
	(0.126)	(0.134)	(0.139)
Ln(Population)	0.442***	0.505***	0.562***
	(0.090)	(0.092)	(0.094)
Urban ratio	0.841	1.588*	2.104**
	(0.832)	(0.872)	(0.911)
White ratio	1.789	1.932	2.469
	(2.202)	(2.211)	(2.185)
Observations	1,449	1,449	1,449
R-squared	0.895	0.891	0.889
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table presents regression coefficient estimates of Eq. (6). Dependent variables in columns (1)–(3) are the natural logarithm of one plus the total number of patents granted in year t+1, t+2, and t+3, respectively. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

The lower price of slave labor relative to free labor should not be perceived as an indication of lower productivity of slave labor. In fact, coercion always increases effort (Starobin, 1970; Acemoglu and Wolitzky, 2011). Fogel and Engerman (1974) find that southern slave agriculture was 35% more efficient than the northern system of family farming. The difference in the cost of free labor and that of slave labor was imposed by the slavery system then, rather than being a market equilibrium measure of marginal labor productivity. This unique institutional setting allows us to disentangle labor scarcity from labor productivity.[31]

states during the period from 1833 to 1852, the average annual rent of slave hirelings was $100; from 1853 to 1861, it was $150...However, between 1800 and 1861, the annual average cost of employing free common laborers remained at about $310, not including supervision...slave hirelings remained between 25% and 40% cheaper to employ than wage laborers" (Starobin, 1970, p. 145). The estimates vary by year and location: for the Lower South around 1850, the annual hire rate was $168 (Fogel and Engerman, 1974, p. 73). Notice that slaves were not cheap in absolute terms: As emphasized in Olmstead and Rhode (2018), antebellum America was a land-abundant and labor-scarce economy after all.

[31]The observed contrast in labor costs between the free and slave states reflected the differences in labor scarcity caused by the slavery system; however, within the free or the slave states, cross-state variations in wage/slave hiring rate could be driven by multiple factors, such as measurement errors, labor market frictions, and skill composition. Hence, when testing the labor scarcity channel, we compare the free states vs. slave states rather than examine cross-state variations within the North and South.

We are interested in whether and how being a free state affected the marginal impact of free banking laws on innovation. To this end, we estimate the following model:

$$\begin{aligned} Ln(Patents)_{i,t+s} =& \alpha + \beta_1 \textit{Free banking}_{i,t} \times \textit{Free state}_i + \beta_2 \textit{Free banking}_{i,t} \\ &+ \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \end{aligned} \tag{6}$$

where i indexes state, t indexes time, and s is equal to one, two, or three. The dependent variable captures state-level innovation outcomes as measured by patent counts. We add the interaction term between $\textit{Free banking}_{i,t}$ and $\textit{Free state}_i$.[32] The coefficient estimate on the interaction term β_1 reflects the effects of the free banking laws on innovation in free states (relative to slave states). If the more pronounced labor scarcity in the free states posed a stronger incentive to innovate, we should expect β_1 to be positive and significant.

We report the results estimating Eq. (6) in Table 7. The coefficient estimates of $\textit{Free banking}_{i,t} \times \textit{Free state}_i$ are positive and significant at the 1% level. Based on the coefficient estimate in column (3), free states with free banking laws generated a total of 59.3% more patents than slave states with free banking in the third year following the law's passage. This finding shows that free banking enhanced innovation more significantly in free states than in slave states, confirming that access to finance has a larger impact on innovation under labor scarcity. The results continue to hold if we add controls interacted with $\textit{Free banking}_{i,t}$.

Controlling for economic conditions and industry composition One potential concern is that the North and South differed in economic conditions and industry composition, and these factors, rather than differences in labor scarcity, could drive our results. Relatively speaking, the South dominated in agricultural production but fell behind in innovation growth and access to railway transportation. Notably, the educational achievements, measured by the fraction of students in academies, grammar schools, and universities/colleges, were similar between these two regions. We add these state-level characteristics as controls to Eq. (6); our results continue to hold, thus ruling out the potential confounding effects from these aspects. The results are reported in online Appendix Table A.7.

States with similar industry concentration and agricultural products A key difference between the free and slave states was industry concentration: The slave states had

[32] We do not include $\textit{Free state}_i$ separately in the model as it would be collinear with state fixed effects.

predominantly agricultural economies whereas the free states experienced early growth in manufacturing. To refine the comparison, we estimate Eq. (6) using states with similar industry concentration and agricultural products. First, we examine agriculture-dominating states, in which the output value ratio of agriculture to the sum of agriculture and manufacturing is above the sample median. While slave states were major agricultural producers, several free states are also included, such as Illinois, Indiana, and Vermont. Our results are robust. Second, agricultural production might differ depending on the major crops. Hence, we select states in which the proportional output value to agriculture of cotton, tobacco, corn, and wheat, respectively, is above the sample median. Once again, the results are qualitatively similar to those in Table 7. Particularly for wheat, the term *Free banking*$_{i,t}$ drops out of the regression because none of the slave states with free banking were major wheat producers. Results are similar when we restrict the sample to manufacturing-dominating states. The results are reported in online Appendix Table A.8.

Evidence against alternative interpretations There could be alternative interpretations of how the impact of finance on innovation manifested differently in the free and slave states. One argument could be that the weaker effect of free banking in the slave states is driven by the modest entry by free banks. To address this concern, instead of using a dummy variable which captures the extensive margin of free banking, we use free bank counts to capture the intensive margin and examine the differential effect in the two regions. If the results are caused by the more massive bank entry in the free states, then conditional on the same level of bank entry, we should not expect a greater effect in the free states. Instead, we find that, a same increase in free bank counts still enhanced innovation more significantly in free states than in slave states. The evidence confirms that our result is not solely driven by the different degrees of bank entry. The results are in online Appendix Table A.6.

Alternatively, the weaker effect of free banking in the slave states could be driven by the slave owners' disincentive toward producing innovations as that would reduce the value of their major assets. However, we argue that this concern is not slave-state specific and lacks a theoretical foundation. First, the same concern also applies to the free states. When artisans and blacksmith had ideas to automatize their work, they were also aware that the new machines might make their skill less valuable. Second, the inventors of innovation enjoyed monopoly profits. While labor-saving devices reduce marginal product of labor and impose negative externalities on others, it is not clear whether the cost would be large enough to exceed the monopoly benefits.

B Introducing Industry Classification

We have shown that free banking led to significantly more innovation in free states than in slave states, and the effect is not subsumed by economic conditions and industry composition. To further pin down the labor scarcity channel, we exploit differences in relative labor scarcity among free labor in the free states, free labor in the slave states, and slave labor in the slave states. In free states, the system of wage-earning labor was the outcome of labor scarcity, especially in the fast-growing manufacturing industry. In slave states, labor was less expensive in general; importantly, as we show in Section VI.A, the majority of the agricultural workforce consisted of slaves, who were considered to be more economical than their free counterparts. Therefore, we could rank the degree of labor scarcity within each state and industry bracket in the following ascending order: agriculture in slave states, manufacturing in slave states, agriculture in free states, and manufacturing in free states.

According to the rank of labor scarcity, we have the following conjectures: Upon free banking, (1) within slave states, innovation in agriculture could experience the lowest increase or even a decrease; (2) within agriculture, there was a greater increase in innovation in free states relative to slave states; (3) within slave states, there was a greater increase in innovation in manufacturing relative to agriculture; (4) the highest innovation increase was in manufacturing in the free states, where labor was the scarcest. We test these hypotheses using triple interactions between $\textit{Free banking}_{i,t}$, $\textit{Free state}_i$, and an indicator of industry classification.[33] The model is as follows:

$$\begin{aligned} Ln(Patents)_{i,j,t+s} =& \alpha + \beta_1 \textit{Free banking}_{i,t} + \beta_2 \textit{Free banking}_{i,t} \times \textit{Free state}_i \\ &+ \beta_3 \textit{Free banking}_{i,t} \times \textit{Manufacturing patent}_j \\ &+ \beta_4 \textit{Free banking}_{i,t} \times \textit{Free state}_i \times \textit{Manufacturing patent}_j \\ &+ \beta_5 \textit{Free state}_i \times \textit{Manufacturing patent}_j \\ &+ \beta_6 \textit{Manufacturing patent}_j + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,j,t}, \end{aligned} \tag{7}$$

where i indexes state, t indexes year, j indexes patent technology category, and s is equal

[33] The triple interaction regression model is similar to Chetty et al. (2009). We interact industry classification with $\textit{Free banking}_{i,t}$ and $\textit{Free state}_i$ instead of using subsamples because that would restrict the estimation to specific subsets of the data (either free states, slave states, agriculture, or manufacturing). A triple interaction is preferred because it uses all available data and all possible sources of variation in the data. This way, it allows us to compare outcomes across agriculture and manufacturing as well as across free and slave states.

Table 8. Labor Scarcity and Innovation: Patent Industry Classification

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking	-0.305**	-0.255**	-0.278**
	(0.117)	(0.112)	(0.126)
Free banking × *Free state*	0.787***	0.836***	0.921***
	(0.225)	(0.211)	(0.217)
Free banking × *Manufacturing patent*	0.300*	0.272**	0.282**
	(0.176)	(0.134)	(0.127)
Free banking × *Free state* × *Manufacturing patent*	0.325	0.328*	0.295*
	(0.222)	(0.185)	(0.172)
Manufacturing patent × *Free state*	0.444***	0.466***	0.492***
	(0.117)	(0.118)	(0.121)
Manufacturing patent	0.387***	0.402***	0.416***
	(0.068)	(0.068)	(0.070)
Ln(Population)	-0.006	0.039	0.090
	(0.061)	(0.062)	(0.065)
Urban ratio	2.749**	3.043**	3.254**
	(1.333)	(1.248)	(1.215)
White ratio	2.870**	2.921**	3.054**
	(1.335)	(1.344)	(1.394)
Observations	2,898	2,898	2,898
R-squared	0.792	0.793	0.797
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table presents regression coefficient estimates of Eq. (7). Dependent variables in columns (1)–(3) are the natural logarithm of one plus the total number of patents granted in year t+1, t+2, and t+3, respectively. Standard errors clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

to one, two, or three. The coefficient estimate β_1 captures the impact of free banking on agricultural innovation in slave states. The coefficient estimate β_2 is the "within agriculture" estimate of the impact of free banking on innovation, reflecting the effects of the free banking laws on agricultural innovation for free states (relative to slave states). The coefficient estimate β_3 is the "within slave states" estimate of free banking on innovation, measuring the effects of free banking on manufacturing innovation (relative to agricultural innovation) in slave states. The coefficient estimate β_4 measures the impact of free banking on manufacturing innovation (relative to agricultural innovation) in free states (relative to slave states). Under our hypotheses, we should expect a negative β_1, a positive β_2, a positive β_3, and a positive β_4.

We report the results in Table 8. In column (3), the coefficient estimate β_1 is negative and significant at 5% level, suggesting that slave states experienced a drop in agricultural innovation following the passage of free banking. This result contains an important insight which we will explore more in the next section. The coefficient estimate β_2 is positive and significant at 1% level, suggesting that free banking's effects on agricultural innovation were higher in free states than in slave states. The coefficient estimate β_3 is positive and significant at 5% level, suggesting that free banking's effects on manufacturing innovation were higher than agricultural innovation in slave states. The coefficient estimate β_4 is positive and significant at 10%, suggesting that the differential effects of the free banking laws on manufacturing innovation relative to agricultural innovation were higher in free states than in slave states. These findings are consistent with our conjecture that the free banking laws promoted innovation when labor was scarce. Particularly, the results suggest that free banking discouraged innovation where labor was plentiful and the marginal cost of labor was low—in agriculture of slave states.

C Changes in Labor Scarcity: Evidence from Wages

As predicted by our model, the impact of finance on innovation could be magnified by an increase in labor scarcity, but could be muted by a decrease in labor scarcity. In this section, we explore how labor scarcity changed in response to the free banking laws.

We conjecture that free banking intensified labor scarcity in the free states, and relaxed labor scarcity in the slave states. Presumably, the usage of finance could have been very different across regions: In the free states, greater access to finance prompted manufacturing expansions, which potentially caused a shortage of labor. In the slave states, opportunities in manufacturing were rather few; instead, slaves were considered a profitable investment.[34] Access to finance might have further expanded the slave population as banking made slave investment and trade more convenient. Banks' involvement with slave mortgaging occurred throughout the antebellum era and across the slave states. Many banks helped to underwrite the sale of slaves, using them as collateral.[35] While most direct historical records in early decades of the antebellum era concerned slave financing through traditionally-chartered

[34] As shown by Conrad and Meyer (1958), "slave capital" earned at least equal returns to those from other forms of capital investment, such as railroad bonds. The rate of return on slaves could be as high as 13%, compared to a yield of 6–8% on the railroads.

[35] Banks were willing to sell slaves as part of foreclosure proceedings on anyone who failed to fulfill a debt contract. See for example discussions in Martin (2010).

Table 9. Changes in Labor Scarcity: Evidence from Wages

	Laborer wage	Weighted wage	Slave population
	(1)	(2)	(3)
Free banking× *Free state*	0.063**	0.082***	
	(0.023)	(0.024)	
Free banking	-0.019	-0.046**	0.208*
	(0.016)	(0.022)	(0.106)
Ln(Population)	0.025*	0.029**	1.194***
	(0.013)	(0.012)	(0.128)
Urban ratio	0.671***	0.539**	
	(0.167)	(0.197)	
White ratio	-0.290	-1.168**	
	(0.292)	(0.500)	
Observations	1,023	840	716
R-squared	0.853	0.919	0.995
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table shows how free banking affected the labor scarcity conditions across the free states and the slave states. Column (1) uses the real *common laborer wage 1* as the dependent variable. Column (2) replaces the dependent variable with the weighted real wage. Specifically, the weighted wage is constructed as the weighted average of the real *common laborer wage 1* (weighted by the size of free population) and the real *slave hire price* (weighted by the size of slave population). To calculate the real wages and real slave hire prices, we deflate the nominal values using the CPI with 1860 as the base year. Column (3) uses the natural algorithm of one plus the slave population as the dependent variable, and the slave states as the sample. The dependent variables lead the independent variables by one year. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

banks (Murphy, 2017), the connectivity of the banking sector implies indirect relations between all southern banks and slavery. Alternatively, greater access to finance might have attracted more slaveholders to migrate, taking their slaves with them into states that passed the free banking laws (Fogel and Engerman, 1974).

As discussed in Rosenbloom (2018), with fluctuations in labor demand and supply, wages served as an indicator for labor costs and thus reflected the degree of labor scarcity. An increase in wage reflected a higher degree of labor scarcity. In Table 9, we analyze how wages responded differently to free banking in the free and the slave states. From column (1), we find that free banking led to a significantly higher increase in real daily wage for a common laborer in the free states relative to the slave states, whereas the response was insignificant in the slave states.[36] This result is in line with the findings about innovation in Table 7.

[36]We use *Common laborer wage 1* from Margo and Villaflor (1987) because it is the best in coverage over time and frequency (annual) among all the available wage data.

Column (2) replaces the dependent variable with the weighted real wage, constructed as the weighted average of the real *common laborer wage 1* (weighted by the size of free population) and the real *slave hire price* (weighted by the size of slave population).[37] We find that free banking had a significantly positive impact on wages in the free states, but a significantly negative impact on the weighted wages in the slave states. The results suggest that, the passage of the free banking laws led to an increase in labor costs in the adopting free states, and a decline in labor costs in the adopting slave states. In particular, the drop in labor costs in the slave states is likely driven by the drop in the cost of hiring slaves. Furthermore, in column (3) we find evidence consistent with a drop in the cost of slave hiring: Free banking indeed led to an increase in the slave population.

Taken together, our results show that free banking led to higher labor scarcity in free states, and lower labor scarcity in agriculture in the slave states. The results corroborate the earlier findings that finance promoted innovation in the free states but depressed agricultural innovation in the slave states.

D Exogenous Shock to Labor Scarcity: Immigrant Arrivals

Admittedly, labor scarcity is endogenous to the local economic conditions. To address the endogeneity concern, we exploit plausibly exogenous shocks to local labor scarcity—the influx of immigrants to the US ports. The arrival states of the immigrants were likely set by available sea lanes that were shaped by the distribution of land masses, geographical distances, and prevailing winds, rather than by the local economic conditions. Therefore, immigrant arrivals increased local labor supply and served as plausibly negative shocks to labor scarcity. Using novel data, we obtain the total number of passengers that arrived at each state in a given year. Waves of immigrants arrived at 19 states through long voyages in a staggered fashion. The magnitude was sizable: The immigrant arrivals in our sample period summed up to 0.85 million, about 75% of an average state population.

We estimate the following model:

$$\begin{aligned} Ln(Patents)_{i,t+s} =& \alpha + \beta_1 Free\ banking_{i,t} \times Immigrant\ shock_{i,t} + \beta_2 Free\ banking_{i,t} \\ &+ \beta_3 Immigrant\ shock_{i,t} + \gamma Z_{i,t} + State_i + Year_t + \epsilon_{i,t}, \end{aligned} \tag{8}$$

[37] Since the slave hire price is available for eight southern states, we use observations for the eight states to fill in their bordering states within the same economic census division. When a state has multiple bordering states (e.g., Alabama neighbors on both Mississippi and Tennessee in the East South Central division) we take the average across the neighbors.

Table 10. Exogenous Shock to Labor Scarcity: Immigration

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Free banking × *Immigrant shock*	-0.105**	-0.115***	-0.115**
	(0.040)	(0.041)	(0.044)
Free banking	0.395***	0.461***	0.469***
	(0.122)	(0.122)	(0.125)
Immigrant shock	0.040	0.045	0.030
	(0.027)	(0.029)	(0.035)
Ln(Population)	0.454***	0.518***	0.578***
	(0.091)	(0.094)	(0.097)
Urban ratio	1.549*	2.361**	3.046***
	(0.894)	(0.943)	(1.047)
White ratio	1.724	1.857	2.436
	(2.186)	(2.202)	(2.154)
Observations	1,449	1,449	1,449
R-squared	0.894	0.890	0.888
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table presents regression coefficient estimates of Eq. (8). Dependent variables in columns (1)–(3) are the natural logarithm of one plus the total number of patents granted in year t+1, t+2, and t+3, respectively. *Immigrant shock* is the natural logarithm of one plus the total number of immigrants that arrived in a state in a given year (standardized to a variable with mean zero and standard deviation one). Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

where i indexes state, t indexes time, and s is equal to one, two, or three. *Immigrant shock*$_{i,t}$ is the natural logarithm of one plus the total number of all immigrants that arrived at state i and year t. The coefficient estimate on the interaction term β_1 reflects the effects of the free banking laws on innovation when labor became less scarce. If a less pronounced degree of labor scarcity in production posed a weaker incentive to innovate, we should expect β_1 to be negative. As in Table 10, the coefficient estimates of *Free banking*$_{i,t}$ × *Immigrant shock*$_{i,t}$ are negative and significant. Based on the coefficient estimate reported in column (3), the free banking law generated a total of 11.5% fewer patents in the third year following the law's passage when the immigrants increased by one standard deviation. Overall, these findings confirm that access to finance had a larger causal impact on innovation under labor scarcity.

A reasonable concern is that immigration outcomes could be endogenous. Presumably, immigrants preferred to arrive at regions where labor was scarce, job prospects were strong, and economic opportunities were plentiful. However, such endogeneity would create a posi-

tive relation between immigrant arrivals and innovation, which would only bias against our result. The fact that we still find a significantly negative coefficient estimate of the interaction term *Free banking*$_{i,t} \times$ *Immigrant shock*$_{i,t}$ suggests that immigrant arrivals relaxed local labor scarcity and reduced incentives for innovation.

Another concern is that the immigrant arrivals data might be subject to measurement errors: some immigrants settled down whereas others possibly moved. For example, New York City was the major port of entry. Some immigrants entering from there might have moved west. For robustness, we drop the state of New York, and find the results still robust. In addition, Louisiana stood out as a large port in the South. Sitting at the mouth of the Mississippi River, New Orleans attracted immigrants who intended to travel up the river. We drop the state of Louisiana from our sample, and the results still hold.

VII Conclusion

In this paper, we present new evidence for the finance-growth nexus and establish labor scarcity as a novel economic mechanism. We examine antebellum America from 1812 to 1860. This period witnessed the staggered passage of free banking laws across 18 states, which provides us with a unique setting to identify shocks to access to finance. Furthermore, the documented differences in labor scarcity between slave and free states make antebellum America a unique setting in which to examine the labor scarcity mechanism.

We show that access to finance, as identified by the staggered passage of free banking laws, spurred innovation. However, improved access to finance alone was not sufficient to encourage innovation; importantly, the finance-growth nexus is more pronounced when one factor of production—i.e., labor—was scarce. We find that the impact of free banking on innovation was higher in free states, where producers faced higher labor costs and had stronger incentives to adopt labor-saving technologies. In contrast, slavery in the South led to a low marginal cost of slave labor, which discouraged technological innovation that aimed to substitute for slave labor. Our results thus suggest that finance promotes innovation when labor becomes scarcer and may impede innovation when labor scarcity gets relaxed.

Our paper sheds new light on factors driving technological innovation. The insights are useful today in explaining, for example, why some regions are more innovative than others, what the impacts would be for labor market policies such as minimum wages, and under what conditions additional financing resources are effective in spurring innovation.

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For Online Publication
Access to Finance and Technological Innovation: Evidence from Antebellum America*

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Abstract

In this Online Appendix we

1. present details of the variable definitions;
2. provide a brief legislative history of free banking laws' passage by state;
3. provide additional tables.

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Online Appendix A.1: Variable Definitions

Variable	Definitions
Innovation Measure	
Ln(Patents)	Natural logarithm of one plus a state's total number of patents granted in a given year.
Manufacturing patent	A variable that takes the value of one if the patent counts in a state are for manufacturing patents and zero if the patent counts in a state are for agricultural patents.
Free Banking Event	
Free banking	An indicator variable that takes the value of zero prior to the passage of free banking law and one otherwise. For Michigan, the variable reverts to zero in and after 1840, and before 1857. For the states that did not pass the free banking law, the variable takes the value of zero for the entire sample period.
$Before^{1^-}$	A variable that takes the value of one all years up to and including one year prior to the free banking law's passage and zero otherwise.
$Before^{2^-}$	A variable that takes the value of one all years up to and including two years prior to the free banking law's passage and zero otherwise.
$Before^{1}$	A variable that takes the value of one a year before the free banking law's passage and zero otherwise.
$After^{1}$	A variable that takes the value of one in the year following the free banking law's passage and zero otherwise.
$After^{2^+}$	A variable that takes the value of one, in two years or more after the free banking law's passage and zero otherwise.
Little free banking	An indicator variable that takes the value of one if *Free banking* equals one and the state had little free banking activities, and zero otherwise.
Large free banking	An indicator variable that takes the value of one if *Free banking* equals one and the state had significant free banking activities, and zero otherwise.
State Characteristics	
Ln(Population)	Natural logarithm of total number of people that resided at a state in a given year.
Urban ratio	Ratio of urban population to total population at a state in a given year.
White ratio	Ratio of white population to total population at a state in a given year.
Free state	An indicator variable that takes the value of one if a state was a free state and zero otherwise.

Wage and Labor Shocks	
Common laborer wage 1	Average nominal daily wage for common laborers at a state in a given year. The data is from Margo and Villaflor (1987), who construct wage measures based on the payroll records of civilian employees of the United States Army.
Common laborer wage 2	An alternative measure of average nominal daily wage for common laborers at a state in a given year. The source is the *Weeks Report* (1886). Based on the payroll records of 627 firms across the regions, Weeks and his staff computed the average daily wages for common laborers—the largest occupation. The data is available at the annual frequency starting from 1851 for six census regions.
Common laborer wage 3	An alternative measure of average nominal daily wage for common laborers: average wage for day laborer with board, collected from the decennial economic census (Haines, Michael and ICPSR, 2010).
Common laborer wage 4	An alternative measure of average nominal daily wage for common laborers: average wage for day laborer without board, collected from the decennial economic census (Haines, Michael and ICPSR, 2010).
Farm laborer wage	Average nominal daily wage for farm laborer at a state in a given year. The data is from Lebergott (1964) who provides estimate for average monthly earnings with board for farm laborers by geographic divisions.
Slave hire price	Average nominal daily hire price for a slave labor at a state in a given year, obtained from Fogel and Engerman (1976). We obtain data on slave hiring transactions that occurred during 1775–1865 in eight southern states: Virginia, Maryland, North Carolina, South Carolina, Louisiana, Tennessee, Georgia, and Mississippi. Variables document the location of the hiring transaction, together with the period and rate of hire.
Immigrant shock	The natural logarithm of one plus the total number of immigrants arrived at a state in a given year. The source is Immigrant Ships Transcribers Guild, which provides detailed records of immigrant ships, including detailed passenger lists with the dates and locations of departure and arrival.

Bank Data	
Ln(Bank counts)	The natural logarithm of one plus the total number of banks in operation at a state in a given year.
Ln(Assets)	The natural logarithm of one plus the total dollar value of bank assets at a state in a given year. The value is obtained by summing over the total assets on individual bank's balance sheets.
Ln(Loans)	The natural logarithm of one plus the total dollar value of bank loans and discounts at a state in a given year. The value is obtained by summing over the loans and discounts on individual bank's balance sheets.
Other State Characteristics	
Innovation growth	Average annual growth rate of innovation (the number of patents) in the past five years.
Political party	A variable that takes the value of one if the presiding party in a state was Whig party or Republican and zero 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 at a state in a given year, from decennial census.
Agricultural output	Value of total agricultural output at a state in a given year, from decennial census.
Manufacturing output	Value of total manufacturing output at a state in a given year, from decennial census.
Agricultural output ratio	The ratio of agricultural output value to the sum of agricultural and manufacturing output value, from decennial census.
Railway	The fraction of counties that had railway access at a state in a given year, from decennial census.
Education	The number of students in academies, grammar schools, and universities or colleges, scaled by the total population at a state in a given year, from 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 zero prior to the passage of the general incorporation statutes for manufacturing firms and the value of one otherwise. The variable resets to zero for states that repealed the laws and returns to one when the state reinstated the law. For states that did not pass the general incorporation laws, the variable takes the value of zero for the entire sample period. The chronology is from Hilt (2017).

Online Appendix A.2: Legislative History of Free Banking Laws

One concern about our identification strategy using the staggered passage of the free banking laws across states as a "shock" is that the timing was anticipated by the agents in our analysis or in response to market trends. Anticipation could lead to delayed or sped-up actions by inventors and manufacturers, confounding the parallel trends assumption. This section addresses this concern by describing the events leading up to the law's passage.

Records documenting the legislative history of early banking are rare. We reference the Annual Report of the Comptroller of the Currency (1876), Sumner (1896), as well as other historical studies (e.g., Bodenhorn, 2006; Du, 2010; Murphy, 2017; Gandhi, 2003) to provide background on those states where records are available. Evidence shows that the laws that were passed in the different states were often very contradictory, suggesting that the passage of the free banking laws was plausibly exogenous events.

New York (1838) In New York, the law's passage in 1838 was considered a serendipitous event by economic historians. It made its way against a great deal of opposition. The elimination of special charters and their replacement with general incorporation procedures was not a sudden post-1835 revelation for the proponents of free banking (Bodenhorn, 2006). In 1825 the New York state Senate considered a bill that would have repealed the restraining acts that forbade private banking in the state—a first step toward free banking (New York State Senate, 1825). The original 1829 bill that established New York's Safety Fund system included a provision that would have liberalized entry, though the provision was removed from the bill's final version (Hammond, 2006).

While several political leaders, e.g., political columnist William Leggett, Richard Hildreth, and William Marcy, had advocated the abandonment of special charter in the 1830s, the law's passage in 1838 was triggered by an unlikely event, the kidnapping of a man named William Morgan after he threatened to reveal the secrets of Freemasonry. Within a year of Morgan's disappearance, Freemasonry's critics called a series of conventions and a political movement formed. The Antimasonic Party was born, and, although its central philosophy remained anti-freemason, it attracted voters unhappy with the Regency's spoils and patronage. When the Regency lost support, the Whig Party (the Anti-Masons ultimately joined with the National Republicans to form the Whig Party) gained more power. Governor Marcy ultimately signed the Free Banking Act into law on April 18, 1838. In this regard, economist Bodenhorn calls it the "serendipitous nature of economic reform" (Bodenhorn, 2006, p. 21).

Illinois (1851) The law's passage in Illinois was a long and challenging process, and the specific timing of the Act was somewhat unexpected. In the constitutional convention of 1847, the banking issue became one focus of the delegates' attention. Whigs were considered as speaking on behalf of banks, and Democrats insisted on an anti-bank provision. In the convention, Democrats outnumbered Whigs ninety-one to seventy-one, and Democrats were dominant in political affairs (Cornelius, 1969). As a result, the new constitution still prohibited the establishment of banks. In 1848, a convention was held in Chicago, where representatives of the leading commercial and financial interests of the state drafted a memorandum to the legislature and the governor, urging them to abandon their attitude of hostility toward banks and to provide the state with a system of banking to supply some type of convenient and convertible circulating medium. Their appeal was successful, and a general banking law with the purpose of establishing a free banking system was passed in the legislature of 1848, to be submitted to the people at a general election.

The next general election would have taken place in 1852, but the legislature deprived all the county treasurers of their offices and provided that their successors should be elected in 1851 (Du, 2010, p. 6). This exception made it possible to pass the free banking law a year earlier.

Louisiana (1853) Free banking in Louisiana was rooted in the repercussions of the anti-banking philosophy (Murphy, 2017). Beginning in 1804, the state chartered several commercial banks; whereas these banks accommodated the commercial interests of merchants in New Orleans, restrictions on their lending practices meant that they failed to meet the needs of the land-and-slave-rich but cash-poor planters. Thus, beginning in 1828, Louisiana pioneered a new banking system known as plantation banks, which enabled the state's slaveholding class to tap into their vast landed and human wealth by securitizing plantations and slaves. When this system came crashing down after the Panics of 1837 and 1839, Louisianans turned against all banks, joining in an antibanking wave initiated by Andrew Jackson and hard-money Democrats. This culminated in the Louisiana Bank Act of 1842 which imposed restrictive measures on banking and the rewriting of the state constitution in 1845, which banned both new banks and the renewal of existing banking charters (Gandhi, 2003). The state economy suffered under this contractionary banking policy. By 1851, public opinion in Louisiana had also shifted decisively back in favor of banking. While the law's passage might be associated with a political economy story in some other states, this was not the case in Louisiana. Both Democrat and Whig parties alike were scrambling to keep up with

these shifts in public opinion, virtually erasing any differences in their political rhetoric with regards to banking.

During the constitutional convention of 1852, however, four of the eleven members of the Committee on General Provisions expressed their discontent with the proposed bill. The convention proceeded to debate and vote on these proposals and, in the end, the convention accepted the original language of the committee report, which would allow banking under both special acts of the legislature and general Incorporation. By mid-August, the new Constitution was complete; the convention overwhelmingly ratified the final document by a vote of 98-8. The last step was the approval of the voters of the state. However, quite unexpectedly, as the statewide vote on the new document approached, an apportionment clause became the central issue for the opposition. In November of 1852, the voters of Louisiana eventually voted to accept the new Constitution, which symbolized the enactment of the free banking law in 1853.

Massachusetts (1851) Antebellum Massachusetts possessed greater banking experience than other states; since a thriving banking system was already in place, the passage of the free banking law in 1851 had relatively little impact on the state.

The Massachusetts Bank of Boston was the earliest chartered bank in Massachusetts. Petitioners for this bank wanted to provide credit, a money supply and convenience for business transactions to the community (Gras, 1937). By the 1820s, motives for the petition for bank charters were more in the interest of a subset of the community, e.g. the mechanics or planters (Lamoreaux, 1996). By the 1830s, obtaining a charter to erect a new bank did not seem to be a prohibitive barrier to entry. Until the 1830s demand for credit was large and the banking sector expanded considerably from 1830 to 1837. The 1837 Panic hit the Massachusetts banks and caused bank suspensions. As banks resumed payments in specie in 1844, the sector increased in size steadily afterward. Therefore, when a free banking law was passed in Massachusetts in 1851, a thriving banking system was already in place and had been working for quite some time. The free banking law, known for easing barriers to entry, had little impact on the size of the Massachusetts banking sector as evidenced by the fact that only seven banks were founded under it (Gandhi, 2003).

Several features and bank regulations explained why the Massachusetts banking sector outperformed. A distinctive feature is the existence of a clearinghouse system called the Suffolk System. This System began in 1818 and facilitated note redemption by allowing member banks to share the cost of transporting and redeeming country banknotes. Moreover,

in response to the Panic of 1837, the state created a Board of Bank Commissioners in 1838 that annually conducted bank examinations. Lamoreaux (1996) proposes that the 1838 law also marked the beginning of a trend of Massachusetts's lawmakers attempting to protect bank stockholders relative to bank directors.

Ohio (1851) The timing of free banking law's passage in 1851 was somewhat unexpected for Ohio as that was the first year Democrats won the election after a long six-year control of the governorship by the Whigs. The constitutions adopted after that also made the experience of Ohio unique.

During the 1830s there was a great demand for credit; Ohio banks met this demand with a rapid increase of bank paper. Like other states, Ohio banks suspended payment in the Panic of 1837. The suspensions led to the Bank Commissioner Law in 1839, which restricted the maximum legal ratio of circulating notes to specie reserves and also established a committee to examine the state's banks regularly (Gandhi, 2003). Even though many bank charters were to expire by 1843, the Democrats passed the Latham Banking Act in 1842. This act created a special tax on circulation and capital, and made bankers personally liable for the banks' losses. While this act was not appealing to bankers, the public supported it and a Democrat won the election for governor in 1842 with an anti-bank campaign. The shortage of credit and currency due to bank closings provoked a split within the Democratic party: Those legislators allied with bankers passed the Wooster Bank Bill in 1844, which extended the charter of five banks. The cleavage among Democrats allowed Whigs to regain the governorship in 1844 and to pass the Kelley Bank Act of 1845. This act created a state bank and a safety fund system. Many independent banks were organized under this act. The public's perception of the new banking system was positive, and the banking system remained unchanged for six years (Huntington, 1915).

On March 21, 1851, Ohio passed the free banking law despite some opposition. However, a new constitution was adopted in June, 1851, which contained an article prohibiting the organization of additional banks, without the approval by the people at the next succeeding general election of the law authorizing the same (OCC, 1876). Moreover, the legislature passed a tax law in 1852, which levied upon the banks double, and in some instances triple, the rate imposed upon any other property. Most banks organized under the free banking law were ultimately obliged to go into liquidation because of the oppressive taxation (OCC, 1876).

Tennessee (1852) In Tennessee, a small, primarily state-controlled banking system dominated the state from 1830 until 1852, when the free banking law was passed.

In response to the Panic of 1819 but despite protest, the charter for the State Bank of Tennessee in Nashville was granted in 1820. However, by the end of the decade, anti-bank forces occupied the state congress and ordered the banks to be discontinued. The legislature also passed a law in 1827 that mandated that any firm wishing to carry on banking activities must obtain a charter. Later, this contraction would worsen the pressure on the community, causing popular demand for a new bank. The legislature satiated this demand by chartering the Union Bank in 1832 and the Planters' Bank in 1833. In 1839, the Democrats, who had just regained the governorship, attempted to have the banks surrender their charters. Fortunately for the banks, this never occurred because some Democratic legislators crossed party lines to vote against it. Not only did these banks survive the Panic but also the suspension actually incited the legislature to found another state bank in 1839 (Gandhi, 2003).

Little bank entry occurred during the antebellum period until 1853. In 1852, Tennessee passed a free banking law, authorizing the organization of banks upon a deposit of bonds of the State equal to the amount of their capital (OCC, 1876). The free banking law was rectified in 1856 with market valuation restriction.

Connecticut (1852) The free banking law was passed in 1852, after a hard two-year struggle. A special stress was laid upon the provision that every bank must be one of discount and deposit, and not simply of circulation. The free banking law, however, was so modified in 1855 as to be in effect repealed, by converting all the free banks into joint-stock banks under a general law. The notes were to be surrendered and the securities taken up. Circulation was limited under the new law to one hundred and fifty percent of the capital. In case of failure, the note-holders "shall have a lien on all the estate of said corporation of every description." By June 26, 1855, all the banks under the free banking law were compelled to accept subscriptions of charitable and educational societies, according to the Connecticut custom (Sumner, 1896).

New Jersey (1850) The Constitution of 1844 required a three-fifths vote in each House for granting or renewing bank charters, which were also to be limited to twenty years' duration. In 1855, the bank circulation was made a preferred debt, for which, according to each charter, all the assets were pledged; also, each stockholder was liable for double his stock, and the

directors were individually liable without limit. It was reported, in 1857, that all the banks under the free banking law of February 27, 1850, were trying to get special charters. The free bank system had fallen into disfavor in New Jersey and was being abandoned (Sumner, 1896).

Alabama (1849) The tax collectors of Alabama appear to have been speculating on the depreciation of the currency, for an act was passed February 4, 1846, to prevent them from doing so. It was enacted March 4, 1848, that no foreign corporation should do discount banking in Alabama, unless it did so using gold and silver or of notes issued under the authority of the State. Notes discounted contrary to this law were to be void. The Southern Bank of Alabama was chartered February 12, 1850. On the same day, a free banking law was adopted. The lowest note was set at $5, which was changed in 1852 to $2. At that time, also, the Southern Bank was authorized to make its circulation thrice its capital. Then, the Northern Bank of Alabama was also chartered, similarly as the Southern Bank (Sumner, 1896).

Indiana (1852) The State Bank of Indiana was incorporated in 1834. In November 1851, the new constitution prohibited the organization of banks except under a general law (OCC, 1876), which, if passed, must provide for registry of notes by a State officer, with ample security, in the custody of a State officer. On May 28, 1852, the free banking law was passed and provided that United States stocks or stocks of the several States, including those of Indiana, should be deposited with the auditor as security for circulating notes, the stocks to be made equal to one bearing six percent interest. The law did not require a board of directors, nor that the stockholders should be citizens of the State. In October 1854, there were eighty-three free banks (Sumner, 1896).

Wisconsin (1853) In the 1830s and 1840s, few banks were chartered by the Territorial Legislature. An act creating a State Bank of Wisconsin at Prairie du Chien was disallowed on June 12, 1838, but the Wisconsin Marine and Fire Insurance Company of Milwaukee was chartered in 1839. In the Constitution of 1848, the Legislature was forbidden to create any bank in any way, unless the question of bank or no bank should have been decided at a general election in favor of banks. Then it might create banks by general or special law, but every such law must be ratified by a majority at a general election before it should be valid. A free banking law was passed in 1853. In this state also the possibilities of mischief in this

free banking system were amply manifested (Sumner, 1896).

Iowa (1858) The Miners' Bank, of Dubuque, chartered by the Territory of Wisconsin, was the only bank in Iowa in 1840. It suspended in March 1841; resumed July 1, 1842; and its charter was repealed in 1844, by virtue of a power reserved to the Legislature to do so. While a number of Whigs did join with the Democrats in the various attempts to repeal the bank's charter, the struggle did have an ultimate political impact. The sorry showing of the Miners' Bank strengthened the hand of the anti-bank wing of the Iowa Democratic Party so that in the Constitutional Convention of 1846 they controlled the party and were able to pass a constitutional prohibition of all banks of issue in Iowa—a prohibition that lasted until 1857 (Erickson, 1969). The free banking law of 1858 forbade the payment of interest on deposits, required a specie reserve of 25 percent of deposits, prescribed that the stocks deposited for circulation must pay six percent or more, and that the circulation issued should not exceed 90 percent of the value of the bonds (Sumner, 1896).

Online Appendix A.3: Additional Tables

- Table A.1 lists the states in our sample.
- Table A.2 reports the results from Cox proportional hazards model analyzing the hazard of a state passing the free banking law.
- Table A.3 reports how free banking affected innovation based on the intensity of free bank entry.
- Table A.4 reports how innovation outcomes related to the entry of free banks at both the state and county level.
- Table A.5 presents robustness checks of the baseline results.
- Table A.6 reports how innovation outcomes related to the free bank counts differently in the free states and the slave states.
- Table A.7 presents robustness checks for the labor scarcity mechanism by controlling for economic conditions and industry composition.
- Table A.8 presents robustness checks for the labor scarcity mechanism by performing subsamples tests with similar industry concentration and agricultural products.

Table A.1. List of States

State	Being a slave or free state	Year of territory/statehood
Alabama	Slave State	1819
Arkansas	Slave State	1819
California	Free State	1850
Connecticut	Free State	1788
District of Columbia	Slave State	1790
Delaware	Slave State	1787
Florida	Slave State	1822
Georgia	Slave State	1788
Iowa	Free State	1838
Illinois	Free State	1809
Indiana	Free State	1800
Kansas	Free State	1854
Kentucky	Slave State	1792
Louisiana	Slave State	1804
Massachusetts	Free State	1788
Maryland	Slave State	1788
Maine	Free State	1788
Michigan	Free State	1805
Minnesota	Free State	1849
Missouri	Slave State	1812
Mississippi	Slave State	1798
North Carolina	Slave State	1789
Nebraska	Free State	1854
New Hampshire	Free State	1788
New Jersey	Free State	1787
New Mexico	Slave State	1850
New York	Free State	1788
Ohio	Free State	1803
Oregon	Free State	1848
Pennsylvania	Free State	1787
Rhode Island	Free State	1790
South Carolina	Slave State	1788
Tennessee	Slave State	1796
Texas	Slave State	1846
Utah	Slave State	1850
Virginia	Slave State	1788
Vermont	Free State	1791
Washington	Free State	1853
Wisconsin	Free State	1836

Notes: This table lists the states, their slave/free category, and the year of territory/statehood.

Table A.2. Determinants of the Free Banking Laws' Passage

	Duration model for the time until the law's passage				
	(1)	(2)	(3)	(4)	(5)
Ln(Population)	0.290	0.211	0.077	0.162	0.413
	(0.201)	(0.208)	(0.252)	(0.688)	(0.592)
Urban ratio	-0.334	-0.563	-1.082	-0.626	-0.263
	(0.390)	(0.573)	(0.893)	(1.386)	(1.475)
White ratio	0.572	0.483	0.265	1.238	0.674
	(0.382)	(0.384)	(0.480)	(0.899)	(0.978)
Innovation growth		0.043	0.202	-0.104	-0.101
		(0.044)	(0.147)	(0.182)	(0.202)
Bank counts		0.244	0.235	-0.375	-0.653
		(0.316)	(0.430)	(0.584)	(0.897)
Political party			0.330	0.534	0.509
			(0.310)	(0.679)	(0.654)
Agricultural labor ratio			-0.584	-0.249	-0.365
			(0.399)	(0.677)	(0.770)
Common laborer wage 1			0.059	-0.338	0.086
			(0.333)	(0.842)	(1.032)
Agricultural output				-0.067	-0.282
				(1.236)	(1.350)
Manufacturing output				0.318	0.320
				(1.027)	(1.199)
Railway					0.342
					(1.076)
Education					-1.267
					(1.116)
Observations	1,256	1,252	564	137	137
Year FE	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.086	0.087	0.056	0.102	0.117

Notes: This table reports the results from Cox proportional hazards model analyzing the hazard of a state passing the free banking law. A "failure event" is the passage of the free banking law in a state, and states are excluded from the sample once they passed the free banking laws. The dependent variable is the log expected time to the law's passage. *Common laborer wage 1*, *Agricultural output*, and *Manufacturing output* are deflated to real values using the CPI with 1860 as the base year. All independent variables, except for dummy variables, are standardized to have a mean of zero and a standard deviation of one. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.3. Little Free Banking and Large Free Banking

	Ln(Patents)					
	t+1	t+2	t+3	t+1	t+2	t+3
	(1)	(2)	(3)	(4)	(5)	(6)
Little free banking	0.081	0.161	0.158			
	(0.135)	(0.150)	(0.168)			
Large free banking				0.442***	0.473***	0.483***
				(0.147)	(0.150)	(0.157)
Ln(Population)	0.476***	0.545***	0.605***	0.441***	0.506***	0.566***
	(0.102)	(0.106)	(0.110)	(0.094)	(0.098)	(0.101)
Urban ratio	1.666	2.528**	3.185**	1.286	2.099**	2.750**
	(1.053)	(1.131)	(1.220)	(0.922)	(1.004)	(1.087)
White ratio	1.537	1.684	2.206	1.499	1.594	2.118
	(2.357)	(2.372)	(2.334)	(2.161)	(2.213)	(2.192)
Observations	1,449	1,449	1,449	1,449	1,449	1,449
R-squared	0.890	0.885	0.883	0.893	0.889	0.887
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports how free banking affected innovation based on the intensity of free bank entry. Columns (1)–(3) show how *Little free banking* affected innovation, and columns (4)–(6) show how *Large free banking* affected innovation. Dependent variables are the natural logarithm of one plus the aggregate patent counts of a state in year t+1, t+2, and t+3, respectively. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.4. Free Banks and Innovation: State and County-Level Results

	Ln(Patents)					
	State level			County level		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Free bank counts)	0.134***			0.401***		
	(0.066)			(0.032)		
Ln(Free bank assets)		0.025**			0.032***	
		(0.011)			(0.003)	
Ln(Free bank loans)			0.026**			0.034***
			(0.011)			(0.003)
Ln(Population)	0.573***	0.584***	0.586***	0.077***	0.078***	0.081***
	(0.095)	(0.098)	(0.099)	(0.015)	(0.015)	(0.015)
Urban ratio	2.679**	2.901**	2.860**	1.901***	1.923***	1.929***
	(1.088)	(1.095)	(1.090)	(0.243)	(0.245)	(0.245)
White ratio	2.195	2.246	2.314	0.827***	0.864***	0.869***
	(2.225)	(2.207)	(2.224)	(0.120)	(0.126)	(0.127)
Observations	1,449	1,449	1,449	51,585	51,585	51,585
R-squared	0.886	0.886	0.885	0.666	0.661	0.662
State FE	Yes	Yes	Yes	No	No	No
County FE	No	No	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports how innovation outcomes were associated with the expansion of free banks. Columns (1)–(3) report results at the state level, and columns (4)–(6) report results at the county level. Dependent variables are the natural logarithm of one plus the aggregate patent counts of a state in year t+3. Standard errors are clustered at the state level for columns (1)–(3) and at the county level for columns (4)–(6). ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.5. Robustness of the Free Banking-Innovation Result

	Ln(Patents)					
	Non-zero patents	Year>1836	Year>1849	No "wildcat"	Usury law	Incorporation law
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking	0.282**	0.252*	0.531***	0.358***	0.423***	0.501***
	(0.105)	(0.125)	(0.180)	(0.121)	(0.126)	(0.150)
Ln(Population)	0.754***	0.659***	0.484	0.580***	0.722***	0.602***
	(0.124)	(0.199)	(0.309)	(0.140)	(0.120)	(0.098)
Urban ratio	2.977***	4.916***	6.287	2.721***	3.140***	2.660**
	(0.993)	(1.418)	(4.217)	(0.950)	(1.030)	(1.020)
White ratio	0.844	-0.238	-1.178	2.930	3.320	2.686
	(1.869)	(2.718)	(4.588)	(1.785)	(2.111)	(2.056)
Max rate					-0.252	
					(0.525)	
Incorporation law						-0.210
						(0.138)
Observations	1,234	783	399	1,221	1,392	1,449
R-squared	0.889	0.912	0.920	0.894	0.887	0.888
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports the robustness checks of the baseline results. Dependent variables are the natural logarithm of one plus the aggregate patent counts of a state in year t+3. Columns (1)–(4) test for subsamples. Column (1) includes only the state-year observations with non-zero patents. Column (2) restricts the sample period to 1837–1860. Column (3) restricts the sample period to 1850–1860. Column (4) excludes the "wildcat banking" states, i.e., Michigan, Indiana, Illinois, Wisconsin, Minnesota, and New Jersey, as listed in Rockoff (1974). Columns (5)–(6) control for contemporaneous laws and regulation changes. Column (5) controls for the maximum interest rate limit imposed by the usury laws. Column (6) controls for the general incorporation statutes for manufacturing firms. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.6. Free Bank Counts and Innovation

	Ln(Patents)		
	t+1	t+2	t+3
	(1)	(2)	(3)
Ln(Free bank counts) × Free state	0.204**	0.264***	0.277***
	(0.078)	(0.080)	(0.085)
Ln(Free bank counts)	0.012	-0.028	-0.023
	(0.081)	(0.083)	(0.086)
Ln(Population)	0.426***	0.484***	0.540***
	(0.092)	(0.094)	(0.095)
Urban ratio	0.916	1.600	2.205**
	(0.927)	(0.972)	(1.030)
White ratio	1.435	1.535	2.053
	(2.165)	(2.182)	(2.134)
Observations	1,449	1,449	1,449
R-squared	0.895	0.891	0.890
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: This table reports how innovation outcomes related to the free bank counts differently in the free states and the slave states. Dependent variables in columns (1)–(3) are the natural logarithm of one plus the total number of patents granted in year t+1, t+2, and t+3, respectively. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.7. Labor Scarcity and Innovation: Robustness

Panel A: Differences in Economic Conditions

	P25	P50	Mean	P75	SD	N
Free states						
Agricultural output ratio	0.287	0.399	0.424	0.620	0.209	201
Education	0.005	0.010	0.011	0.016	0.008	351
Innovation growth	0	0.063	0.078	0.169	0.171	735
Railway	0.107	0.585	0.478	0.782	0.325	201
Slave states						
Agricultural output ratio	0.558	0.782	0.693	0.856	0.217	198
Education	0.007	0.009	0.011	0.011	0.008	348
Innovation growth	-0.027	0	0.046	0.139	0.175	741
Railway	0.037	0.176	0.233	0.314	0.249	198

Panel B: Controlling for Economic Conditions and Industry Composition

	Ln(Patents)				
	(1)	(2)	(3)	(4)	(5)
Free banking × Free state	0.565***	0.612***	0.582***	0.572***	0.537***
	(0.199)	(0.176)	(0.161)	(0.208)	(0.192)
Free banking	0.140	-0.142	0.054	0.118	0.065
	(0.111)	(0.140)	(0.137)	(0.119)	(0.137)
Agricultural output ratio	1.769				2.974
	(2.320)				(2.641)
Education		3.030			28.753
		(8.512)			(17.225)
Innovation growth			0.293**		0.072
			(0.121)		(0.281)
Railway				-0.076	-0.286
				(0.430)	(0.466)
Ln(Population)	0.250	0.573***	0.561***	0.438	0.136
	(0.424)	(0.205)	(0.093)	(0.321)	(0.513)
Urban ratio	5.999	4.611**	2.088**	5.967	8.319**
	(4.114)	(1.987)	(0.899)	(4.258)	(3.441)
White ratio	-1.044	-0.298	2.692	-1.286	0.655
	(4.187)	(2.840)	(2.187)	(5.064)	(5.217)
Observations	399	699	1,445	399	396
R-squared	0.922	0.918	0.891	0.921	0.924
State FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents robustness checks in estimating Eq. (7). Panel A compares the economic conditions between the free and slave states, in terms of industry concentration, educational achievement, innovation growth, and access to railway transportation. Panel B adds these state-level characteristics as controls to the estimation of Eq. (7). Dependent variables for all columns are the natural logarithm of one plus the total number of patents granted in year t+3. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

Table A.8. Subsamples with Similar Industry Concentration and Agricultural Products

	Ln(Patents)					
	Agriculture	Cotton	Tobacco	Corn	Wheat	Manufacturing
	(1)	(2)	(3)	(4)	(5)	(6)
Free banking × *Free state*	0.894***	0.907***	0.754**	0.827***	0.449**	0.285**
	(0.173)	(0.270)	(0.267)	(0.185)	(0.170)	(0.116)
Free banking	0.199	0.244*	0.118	0.296		
	(0.130)	(0.140)	(0.239)	(0.200)		
Ln(Population)	0.468***	0.555***	0.687***	0.710***	0.669***	0.523***
	(0.090)	(0.108)	(0.105)	(0.109)	(0.168)	(0.077)
Urban ratio	12.116***	7.263***	6.283*	5.296**	3.563	-1.406
	(3.450)	(2.313)	(3.459)	(2.058)	(2.600)	(0.910)
White ratio	1.999	1.603	1.936	1.318	-7.593**	-6.265*
	(1.922)	(1.889)	(3.328)	(2.869)	(3.237)	(3.047)
Observations	706	697	716	714	713	743
R-squared	0.829	0.818	0.906	0.858	0.913	0.928
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table conducts subsample tests by using states with similar industry concentration and agricultural products. Dependent variables for all columns are the natural logarithm of one plus the total number of patents granted in year t+3. Column (1) restricts the sample to agriculture dominating states, in which the ratio of agriculture output value to the sum of agriculture and manufacturing output value is above the sample median. Columns (2)–(5) restrict the sample to states in which the proportional output value of, cotton, tobacco, corn, and wheat, respectively, to agriculture is above the sample median. Column (6) restricts the sample to manufacturing dominating states, in which the ratio of agriculture output value to the sum of agriculture and manufacturing output value is below the sample median. Standard errors are clustered at the state level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Definitions of the variables are in online Appendix A.1.

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